# INFLUENCE OF STORAGE STRUCTURE ON SEED LONGEVITY IN RICE (*Oryza sativa* L.)

**By**

**JYOTHISH BABU E.**

**(2018-11-156)**

**DEPARTMENT SEED SCIENCE AND TECHNOLOGY**

**COLLEGE OF HORTICULTURE**

**VELLANIKKARA, THRISSUR -680 656**

**KERALA, INDIA**

**2020**

# INFLUENCE OF STORAGE STRUCTURE ON SEED LONGEVITY IN RICE (*Oryza sativa* L.)

**By**

**JYOTHISH BABU E.**

**(2018-11-156)**

**THESIS**

**Submitted in partial fulfilment of the requirement for the degree of**

**Master of Science in Agriculture**

**Faculty of Agriculture**
**Kerala Agricultural University**

**DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY**
**COLLEGE OF HORTICULTURE**
**VELLANIKKARA, THRISSUR -680656**
**KERALA, INDIA**

**2020**

## DECLARATION

I, hereby declare that the thesis entitled **'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),'** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

11/1/2021

**Vellanikkara**

**Date:** 11/01/2021

**Jyothish Babu E.**

**(2018-11-156)**

**CERTIFICATE**

Certified that the thesis entitled **'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),'** is a record of research work done independently by **Jyothish Babu E. (2018-11-156)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to his.

Vellanikkara
11/01/2021

**Dr. Rose Mary Francies**
(Chairman)
Professor (Pl. Br. & Gen.) and Head
Department of Seed Science and Technology
College of Horticulture
Vellanikkara

## CERTIFICATE

We, the undersigned members of the advisory committee of **Jyothish Babu E. (2018-11-156)** a candidate for the degree of **Master of Science in Agriculture**, with major field in Seed Science and Technology, agree that the thesis entitled **'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),'** may be submitted by **Jyothish Babu E. (2018-11-156)**, in partial fulfilment of the requirement for the degree.

11/01/2021

**Dr. Rose Mary Francies**
(Chairman)
Professor (Pl. Br. & Gen.) and Head
Dept. of Seed Science and Technology
College of Horticulture, Vellanikkara

**Dr. Dijee Bastian**
Professor (Pl. Br. & Gen.)
Dept. of Seed Science and Technology
College of Horticulture, Vellanikkara

**Dr. K. P. Sudheer**
Professor and Head
Department of Agricultural Engineering
Associate Director of Research (Agrl. Engg.)
College of Horticulture, Vellanikkara

**Dr. B. Ajithkumar**
Assistant Professor and Head
Department of Agricultural Meteorology
College of Horticulture, Vellanikkara

# *ACKNOWLEDGEMENT*

*First and foremost, I would like to thank God Almighty for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible.*

*It is with great pleasure I express my deep sense of gratitude and sincere thanks to* **Dr. Rose Mary Francies***, Professor and Head, Department of Seed Science and Technology, College of Horticulture, vellanikkara, chairperson of my advisory committee for her valuable guidance, inspiring advices, critical comments, constant supervision, keen interest, support and encouragement from the very early stage of my research work till the end. This work would not have been possible without her unfailing support in the preparation of the manuscript.*

*I am ineffable in expressing my deep sense of gratitude to* **Dr. Dijee Bastian***, Professor (Plant Breeding), Department of Seed Science and Technology, College of Horticulture, vellanikkara, member of my Advisory Committee for her critical comments, constant supervision, support and encouragement throughout the course of my research work.*

*My sincere thanks to* **Dr. K. P. Sudheer***, Professor and Head, Department of Agricultural Engineering, Associate Director of Research (Agril. Engg.),College of Horticulture, vellanikkara, member of Advisory Committee for the valuable guidance, timely suggestions and help rendered in the conduct of the experiment.*

*I wish to extend my wholehearted gratitude to* **Dr. B. Ajithkumar***, Assistant Professor and Head, Department of Agricultural Meteorology, College of Horticulture, Vellanikkara, member of my advisory committee for his timely help, constant support and valuable guidance for the successful completion of the research work.*

*I am respectfully thankful to* **Dr. Ayoob***, Assistant professor, and* **Mr. Vishnu** *Department of Agricultural Statistics, College of Horticulture, Vellanikkara, for his advice and help rendered in the statistical analysis of the data and subsequent interpretation.*

*I owe special thanks to the Library and **Dr. A. T. Francies**, Librarian, College of Horticulture, Vellanikkara who guided me in several ways, which immensely helped for collection of literature for writing my thesis.*

*I express my deep sense of gratitude to **Kerala Agricultural University** for the financial and technical support for persuation of my study and research work.*

*I greatfully thank **Aravind chettan**, Computer club, COH, Thrissur for their technical assistance in the preparation of the manuscript.*

*I wish to express my sincere thanks to all non-teaching staff members **Smitha chechi, Jeena chichi, Indira chechi, Naveen chettan, Abhilash chettan, Uthaman chettan, Sajeesh chettan, Omana chechi, Raki chechi, Kamala chechi, Kunjumol chechi, Omana chichi and Bilha for** their kind cooperation and help during the conduct of the research work.*

*It's my fortune to gratefully acknowledge the infinite affection, warm concern, constant encouragement and moral support of my friends **Rin Rose Antony, Riya, Milu, Harshapradha, Abinsha, Vinu, K. S, Akhil K.P, Nidhin Raj, Shinu, Saleesh, Asif Ali P, Nibin, Pavithrakumar, Pooja, Abhaya, Rashi, Neha, Harya, Harithalekshmi, Aswathy, Lakshmi, Reshma.** They were always besides me during the happy and hard moments of my life to push and motivate me. I wish to express my sincere gratitude to my seniors **Bennet chettan,, Agina chechi , Athulya chechi, Gayathri chechi, Roshna chechi, Nayana chechi,** and my junior friends **Vyshak, Vyshnavi, Sneha and Oliviya***

*I am forever beholden to my beloved parents **Mr. Babu Skaria** and **Mrs. Shiji Babu** and my brother **Jobish Babu** for their unfathomable love, boundless affection, personal sacrifice, incessant inspiration and constant prayers, which supported me to stay at tough tracks and helped me for the successful completion of this programme.*

*A word of apology to those I have not mentioned in person and a note of thanks to one and all who worked for the successful completion of this endeavour.*

*Jyothish Babu E*

# CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF PLATES

## LIST OF APPENDICES

# List of abbreviation

| | |
|---|---|
| C.D | - Critical Difference |
| cm | - Centimetre |
| ºC | - Degree Celsius |
| EC | - Electrical conductivity |
| g | - Gram |
| KAU | - Kerala Agricultural University |
| m | - Metre |
| MAS | - Months after storage |
| mg | - milligram |
| $\mu Sm^{-1}$ | - micro Siemens per metre |
| mm | - Millimetre |
| % | - Per cent |
| $SE_{(m)}$ | - Standard Error Mean |
| VI-I | - Seedling vigour index- I |
| VI-II | - Seedling vigour index- I |
| MT | - Matta Triveni |
| MR | - Manuratna |
| RH | - Relative humiity |
| THI | - Temperature Humidity Index |

# Introduction

# 1. INTRODUCTION

Seed is a critical input in agriculture and its quality is vital in determining crop yield and productivity. Traditionally, farmers store seeds in earthen pots, or in pits or in a granary. Sometimes, they store seeds as bulk, either in modern storage structures or in reasonably sophisticated storages. Irrespective of the storage structure, the primary concern during seed storage is deterioration of quality. The environment under which the seed is stored often influences the quality and longevity of seeds. Poor storage conditions have been reported to cause 10 per cent loss in seed quality in tropics (Genchev, 1997).

Rapid loss of viability and quality during storage in a high volume low value crop like rice is very common in tropical countries like India. Post-harvest losses of rice in India are estimated to be around 10 per cent, of which, the losses during storage alone are estimated to be 6.58 per cent (FAO, 2017). High relative humidity of storage environment leads to an increase in moisture content. This, in combination with high ambient temperature, result in rapid decline in seed vigour and ultimate loss of seed viability in humid tropic conditions (Kapoor *et al*., 2011). Unlike the rest of the country, the steep decline in quality is more evident in Kerala, owing to the predominance of hot and humid tropical to subtropical climate with great variation in temperature. For instance, during the study period *i.e.,* May, 2019 to Jan 2020, the mean temperature varied between 19.9 °C in Aug, 2019 and 35.20 °C in May 2019, with the mean relative humidity fluctuating between 73 per cent (Dec, 2019) to 96 per cent (Aug, 2019). The total rainfall received between the months of May, 2019 and January, 2020 amounted to 3042.9 mm, whereas, the neighboring state of Tamil Nadu received 907 mm of rain during the corresponding period, with the mean temperature ranging between 37 °C (May, 2019) and 28.8 °C (Jan, 2020) and the mean relative humidity varying from 57 per cent (June, 2019) to 78 per cent (Nov, 2019).

Seed longevity, though an inherited trait, is greatly influenced by the relative humidity (RH) and temperature during storage. Inter-dependence of these two factors during the storage seeds of orthodox species like rice, and their subsequent effect on seed moisture was recognized by Harrington in 1973. He proposed the three rules of thumbs' regarding optimal seed storage environment. The first one states that each one per cent reduction of seed moisture doubles the storage life of the seeds; the second one states that for each $10^0$F ($5.6^0$C) decrease in seed storage temperature, storage life of seed is doubled; and the third one states that arithmetic sum of relative humidity and storage temperature (in $^0$C) should not exceed 100 or 120 for safe seed storage (Harrington, 1973; Bewley and Black, 1985; Copeland and McDonald, 1999).

According to Jian *et al.* (1998), between the two crucial factors the RH and temperature discussed above, relative humidity which is directly proportional to the seed moisture content, is reported to have a greater influence on seed longevity than temperature. The variation in temperature and relative humidity during storage affects not only the viability but also the vigour during germination. Seed aging process leads to deterioration in seed quality and aged seed show decreased vigour leading to weak seedlings which cannot withstand the rigours of weather when introduced to field conditions (Rokich *et al*., 2000).

Coolbear (1995) reported that low seed moisture content and storage temperature slows down the rate of aging. The environment within a warehouse fluctuates depending on the season of the year, and therefore, seeds in such storage are exposed to low temperature and humidity during winter, moderate temperature and humidity during spring and autumn, and elevated temperature and humidity during summer. Under such conditions, seeds kept in cloths or paper bags easily exchange moisture with environmental air of defined relative humidity and temperature depending on species (Copeland and McDonald, 1999). If moisture equilibration between seeds and environmental air result in an increase in seed moisture, deteriorative process increases concomitantly with temperature, consequently leading to germination and vigour decrease (Volenik *et al*., 2006).

Most farm buildings in which the seeds are stored are usually not insulated against the heat and may have asbestos or tin sheets or reinforced concrete (R.C.C.) roofing. The temperature inside such storage structures may exceed the outer temperature by several degrees during the summer season due to absorption and transmission of solar energy by roof to the interior. Many a times, the absence of ventilation prevent airflow within the godown make lowering of temperature near impossible. In addition, poor ventilation causing poor airflow also influences the RH within the storage environment. Hence, ventilation within the seed store becomes a critical factor in controlling the storage environment and eventually the quality of the seed during storage and at the time of planting.

Considering the above, the present study 'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.)' was envisaged with the following objectives.

- To deduce the influence of temperature and relative humidity on longevity of rice seeds stored in godowns with asbestos or R.C.C. roofing, with provision or no provision for ventilation.

- To elucidate the quality of rice seeds during storage under the above storage structures.

# Review of literature

# 2. REVIEW OF LITERATURE

Seed being a living entity, is subjected to various environmental stresses, which affect its quality (Doijode, 1988). During storage, the viability and vigour of the seeds not only vary from genera to genera and variety to variety, but, it is also regulated by many physico-chemical factors like moisture content, atmospheric relative humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials, etc. Metabolic activities during storage deteriorate the seed quality parameters. This deterioration may lead to delayed germination, low viability, slow growth of seedling and increased susceptibility to environmental stress (diseases and pest).

Rajjou and Debeaujon (2008) opined that seed longevity is influenced by several factors such as temperature, oxygen, relative air humidity and seed moisture content. Poor storage conditions have been reported to cause 10 per cent loss in seed quality in tropics (Genchev, 1997).

Considering the above, the present study was formulated to elucidate the influence of different storage structures on seed longevity in rice. The literature related to the study is detailed below in brief under the following headings.

**2.1 Storage environment and seed longevity**

**2.2 Storage structures and seed storability**

**2.3 Effect of storage conditions on seed quality parameters**

**2.3.1 Germination**

**2.3.2 Seedling vigour indices**

**2.3.3 Seed moisture content**

**2.3.4 Electrical conductivity**

**2.3.5 Seed health**

## 2.1 Storage environment and seed longevity

Temperature and relative humidity are the two most important factors that influence the lifespan of seeds during storage. Each $5^0$C reduction in seed temperature doubles the life of the seeds. Low temperatures and dry conditions are adequate for the storage of all orthodox seeds, but not for intermediate recalcitrant seeds (Harrington, 1972). Harrington, (1973) reported that high temperature and relative humidity leads to seed deterioration and loss of germination rapidly. The 'Rule of Thumb' clearly indicates that temperature is the crucial factor in determining viability since, these conditions provide suitable environment for increased metabolic activity both within and outside the seed, leading to rapid deterioration of seed quality.

Tango *et al*. (1977) reported that 35 per cent storage RH together with $15^0$ C resulted in a minimum loss in viability and ensured satisfactory storage up to 36 months, while, with 50-70 per cent storage RH, the longevity of soybean seeds was reduced to nine months.

Depending upon the species, most seeds stored with a moisture content of 3-7 per cent under -18ºC survive for 50 to 100 years without loss of much of seed viability and genetic integrity (IBPGR, 1989). Storage of seeds at low temperature is the main *ex-situ* conservation method employed in gene banks.

Roberts and Ellis (1989) suggested that, moisture content in equilibrium with about 10-11 per cent RH is optimum to maximize the longevity in wheat seeds. However, Vertucci and Roos (1990) reported that moisture content in equilibrium with 19-27 per cent RH is optimal for the longevity of orthodox seeds in storage.

Ellis *et al*. (1990) reported that seed deterioration leads to a reduction in viability and vigour pre-disposing seed to the deteriorative process, eventually leading to death of seed. Seed moisture and storage temperature are the two most important environmental factors, which influence seed germination. The seed deteriorates rapidly when these factors are high. The relationship between seed moisture content and relative humidity is positive, but not linear.

Storing seeds in viable state for planting during the next cropping season is integral for sustenance of farming. According to Hong *et al*. (1996) of the 2,50,000 known species, information on seed storage behaviour is available only for about 7,000 species from 251 families of plants. The seed storage behaviour includes details on the longevity of seed and viability under various storage conditions. The knowledge of seed storage behaviour is essential and critical to preserving the seeds under the best suitable conditions possible, while keeping the costs minimal (FAO/IBPGR, 1992).

Temperature and relative humidity of the storage environment are the two most important factors influencing seed viability and longevity during the storage. Most farm buildings in which the seeds are stored are usually not insulated against the heat and may have asbestos or tin sheets or reinforced concrete (R.C.C.) roofing. The inside temperature and relative humidity exceeds the outer environmental conditions by several degrees during the different season which result in loss of seed quality parameters (Sawant, 1994).

Hendry *et al*. (1994) revealed that the rates of ageing and potential life spans of seeds vary among species. Even within species, various accessions often exhibit differences in their storage properties. Hence, elucidating the difference in seed longevity among species and their accessions is vital for the effective management of seed conservation.

Jian *et al*. (1998) proposed different models representing seed moisture content as a function of relative humidity and temperature. All models indicated that seed moisture content increases with increase in relative humidity.

Heatherly and Elmore (2004) reported that irrespective of the initial seed quality, unfavourable storage conditions, particularly the air temperature and relative humidity, contribute to accelerating seed deterioration.

Miah *et al*. (2006) assessed the effect of storage relative humidity (*viz,* 50%, 60%, 70%, and 80%) on longevity of wheat seed. The germination in all the varieties decreased with increase in RH. Longevity of seeds stored at 70 per cent and 80 per cent RH was six months and two months respectively, while it was the longest in seeds stored at 50 per cent RH.

Sharma *et al*. (2007) reported that seed longevity was greatly influenced by storage conditions, such as relative humidity and temperature and lowering of these parameters significantly increases the storage life of seeds.

Simic *et al*. (2007) revealed that the longevity of seeds in storage was affected by the factors like genotype, initial seed quality, storage conditions, and moisture content among others. Among the same plant species, different varieties may exhibit different storing abilities either from genetic variations or from other external factors.

Sun *et al*. (2007) reported that higher viability and vigour of seeds during room temperature storage are mainly due to the storage conditions and seed quality at the beginning of storage. Genetics, the environment in which the seeds were produced and the conditions of the storage environment are the three main factors that influence seed longevity.

Rajjou and Debeaujon (2008) suggested that seed longevity in rice was influenced by several factors such as temperature, oxygen, relative air humidity and seed moisture content.

Tatipata (2009) reported that seed moisture content, temperature, relative humidity, initial viability, stage of maturity at harvest, storage gas and initial moisture content of seeds are the different factors that influence seed longevity during storage.

Nagel and Borner (2010) studied the response of crops (18 species) that were stored at 20.3 $^{o}$C $\pm$ 2.3$^{o}$C and 50.5 $\pm$ 6.3 per cent RH for 26 years. Pea, common bean and maize seeds retained their viability over the longest period (23, 21 and 19 years, respectively). In contrast, chive seeds survived for only five years and lettuce for seven years.

Oyekale *et al*. (2012) suggested that long-term storage of orthodox seeds require storage conditions with low temperature and humidity. Storage of cereal seeds requires low seed moisture content and need to be free from fungal infestation.

Assefa and Sreenivasan (2016) studied the effect of different storage temperature and relative humidity on two varieties each of sorghum and lentil. They reported that, between the two sorghum varieties, significant reduction in germination was observed in cultivar CSV-15 at 75 per cent RH and 35°C temperature after 30, 60 and 90 days of storage. In lentil, both the varieties registered a significant decrease in germination when stored at these conditions. Storage at 95 per cent RH and 35°C for 20 days resulted in a drastic fall in the germinability of both the varieties of sorghum as well as lentil. In sorghum, CSV-15 performed better, maintaining 82 per cent germination after 20 days of storage, while, CSV-216R was poorer with viability dropping to 50 per cent.

Wang *et al*. (2018) reported that storage of primed seeds under high RH condition beyond 15 days is deteriorative for germination and growth of rice. However, if primed seeds were stored at vacuum or low RH or low-temperature conditions, there will be no negative effect on seed viability within 60 days of storage.

Bakhtavar *et al*. (2019) reported that hermetic super bag could maintain minimum seed moisture content (SMC) up to 70 per cent RH. At a higher level of RH, moisture contents increased to some extent (1–2%) in super bags, whereas, this increase was much higher in conventional packaging materials.  Seeds stored in Super Bag at 14 per cent initial SMC, rapidly lost their viability as they were unable to lose their moisture due to barrier layer of the Super Bag. The high moisture content proved lethal for the seed germination.

Solberg *et al.* (2020) found that the half-life of orthodox seeds stored under optimal ambient conditions amounted to 5 to 10 years, whereas, it ranged between 40 and 60 years when stored at low humidity and low temperature conditions.

## 2.2 Storage structures and seed storability

Sawant (1994) compared godown storage and silo storage with respect to functional, structural and financial aspects, and concluded the superiority of silo system in reducing storage losses. Comparison was also given between metal silos and RCC silos. He found galvanized iron corrugated (GIC) silos were advantageous over metal and RCC silos for reducing the storage loss.

Dejene et al. (2004) conducted a study on the impact of grain storage methods on the storage environment and grain quality in sorghum at Harare, Ethiopia. The farmers stored their sorghum grain in underground pits for a period of 24 months. Temperature and moisture content was higher in the soil pits than in the bins, cement and dung pits. The bins maintained the lowest temperature and grain moisture content. Regression analysis of percent germination on grain storage period showed that germination of samples from soil pits decreased by six per cent per storage month.

Thilakarathna *et al*. (2006) elucidated the quality change and mass loss of rice seeds during airtight storage in a Ferro-cement bin in Sri Lanka. Germination per cent decreased from 85 to 0 in the airtight bin, whereas, it was still 38 per cent in the control after 10 months of storage. High relative humidity and temperature caused high moisture content in seeds and resulted in low germination after one year of storage (McCormack, 2004).

Tekrony *et al*. (2005) studied the effects of storage of maize on germination and vigour in an ‘uncontrolled’ warehouse and in a controlled environment where the temperature and humidity were monitored. Their results indicated that all seed lots had high germination (87–99%) before storage, but a range in seed vigour as measured by the accelerated ageing test (ISTA, 2006). After eight months of storage in the ‘uncontrolled’ warehouse, the germination and vigour declined to 50–80 per cent.

One of the problems with airtight storage is the reduction of grain germination rate. Anaerobic conditions may cause decreased levels of rice germination (Adhikarinayake *et al*., 2006).

Studies conducted by Rickman and Aquino (2007) at IRRI, Philippines, revealed that, seed stored for 12 months under hermetic storage conditions had the same level of germination as those stored in an air-conditioned store. Both systems had 82 per cent germination at the end of 12 months of storage while seeds stored in the traditional bag system had germination levels of 65 per cent after nine months and only 26 per cent after 12 months.

Alam *et al*. (2009) studied the performance of alternate storage devices on seed quality of boro rice. The different storage devices used in this study were Organic Cocoon, Rexin Cocoon, Polythene bag, Poly + Gunny bag, and Gunny bag. He found that germination per cent of Boro seeds stored in organic cocoon was significantly high (91%) compared to that of rexin cocoon (87%), polythene bag (80%), polythene + gunny bag (79.67) and Gunny bag (68%). Seeds stored in the 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 a higher proportion of dead insects (97%) caused by reduced oxygen.

In air tight storage method, initially relative humidity of wheat grains was higher and it gradually decreased with the advance in storage period , while, in godown storage method, relative humidity of grains increased with the advancement of storage (Sawant *et al.,* 2012).

Seed of barley were stored at cold temperatures (4ºC) in different packaging structures by Hedimbi (2012). After 16 months of storage, viability and germination remained high in seeds stored using plastic packaging (around 80 %) compared with those stored in cement structures (<20%) and containers made of wood (60% viability).

Guenha *et al*. (2014 opined that use of hermetic storage led to a safe, pesticide-free, and sustainable storage method, suitable for rice seeds.

Prasantha *et al*. (2014) compared the paddy storage in hermetic IRRI bags and common woven polyethene bags stored at room temperature for 9 months. They found that hermetic storage of dry paddy could significantly improve overall paddy quality.

Bakhtavar *et al*. (2019) reported that the type of packaging materials significantly affected seed germination of all crops under study. Highest germination (85%) was recorded in maize seed s stored in hermetic Super Bags.

**2.2 Effect of storage conditions on seed quality parameters**

**2.2.1 Germination**

Vanangamudi *et al*. (1986) reported that germination of field bean seeds packed in polyethylene 700 gauge pouches (85%) was significantly higher than that stored in cloth bag (62%) due to its moisture impervious nature.

Prabhakar and Mukherjee (1977) reported that seeds stored at low temperature (10°C to 15°C) at an optimum seed moisture of 10 per cent, would retain high germination potential for nine months. Room temperature (26°C) or high temperature (32°C or 35°C), accelerated the decline in germination potential.

Devereau *et al*. (2000) reported that storing wheat seeds at room temperature tend to decrease the viability and vigour of seeds faster than storage at low temperatures. Environmental conditions surrounding the storage will affect the quality of seeds during the storage period.

Under ambient conditions of storage, rice seeds stored in polythene bags and aluminium pouch had extended storage life by five to seven months respectively as compared to seeds stored in cloth bags, which retained germinability up to 14 months (Padma and Reddy, 2000).

Fukai *et al*. (2003) and Rehman (2006) reported that in low-temperature storage, it is possible to store rice seeds for the long term without deterioration in quality.

Meints and Smith (2003) found that germination of kenaf under ideal conditions remained high in seeds stored up to 4 years at 10 ºC. There were no appreciable differences in field emergence or performance throughout the growing season.

Bailly (2004) reported the major reason for the reduction of wheat seed germination in conventional packaging materials could be the high seed moisture content that lead to the production of reactive oxygen species causing oxidative damage and seed deterioration

Rickman and Aquino (2007) reported that germination for seed stored in hermetic systems was 90 per cent after six months and 63 per cent after 12 months. In comparison, seed stored in the traditional systems registered germination levels of 51 per cent and eight per cent respectively.

Kumar (2009) reported that all the physiological parameters like seed germination (%), vigour index, root length, shoot length and speed of germination in rice seeds were adversely affected by high relative humidity (75 %) conditions.

Sterlec *et al*. (2010) reported that highest changes in quality parameters were observed for wheat seeds kept at 40°C and RH of 45 per cent, followed by seeds stored at 25°C and RH of 45 per cent.

Lower temperature and humidity result in delayed seed deteriorative process and thereby leading to prolonged viability of soybean seeds (Mohammadi *et al*., 2011).

Walters *et al*. (2010) reported that deterioration can occur in seed in a few days or years but, it becomes evident as germination per cent reduces and they produce weak seedlings, leading ultimately to its death. However, its rate depends on several factors including, seed moisture, storage temperature, and genetic factors.

Throughout the storage period, Mbofung (2012) observed that, sorghum seeds stored at low temperatures registered higher germination than those stored at high temperatures. He opined that storing seeds under high temperatures increase the respiration rate and enzyme activity, resulting in the overhaul of food reserves before the seeds germinate. This resulted in decreased vigour and physical quality of seed.

Rani *et al.* (2013) found a negative correlation between wheat seed germination per cent and high temperature and moisture during storage.

Akter *et al.* (2014) studied the effect of three storage containers (tin container, polythene bag and cloth bag) and five storage periods (0, 15, 30, 45, and 60 days) on the seed quality of soybean. Seeds packed in tin container retained seed viability for longer time than in cloth bags. Initial germination was 83.00 per cent for all containers at 0-day storage. Both germination per cent (GP) and germination index (GI) decreased with the increase in storage period. The highest GP and GI were recorded for seeds in tin container, whereas the low values were recorded in cloth bag at 15, 30, 45 and 60 DAS, respectively, which were statistically identical to polythene bag at 15 DAS.

Ali *et al.* (2014) suggested that soybean seed dried to eight per cent seed moisture content and packed in polythene bag could be stored for at least six months under a range of relative humidity (50 to 60 %) and retain above 80 per cent germination.

Kishore *et al.* (2014) revealed that, field bean seeds stored in polyethylene 700 gauge was able to retain maximum germination per cent at three, six and nine months after storage, compared to those packed in other materials.

Hussain *et al.* (2015) reported that germination percent and growth attributes of primed rice seedlings were significantly reduced when stored at 25°C, while, no significant decrease was found when primed seeds were store at −4 °C.

Mondal *et al.* (2017) reported that seeds packaged in cheese cloth and polythene had significantly higher germination for rice variety BW 196. Significantly, lower germination was observed in seeds of variety Basmati 370 compared to BW 196.

### 2.2.2 Seedling vigour indices

Abba and Lovato (1999) reported that proper and safe storage conditions are defined as those that maintain seed quality without loss of vigour for three years.

Mettananda *et al*. (2001) stated that in orthodox seeds, vigour decreases with increasing water content, especially in high-temperature environments and high relative humidity.

Seed vigour is defined by the International Seed Testing Association (ISTA) as 'the sum total of those properties of the seed that determine the level of activity and performance of the seed during germination and seedling emergence' (ISTA, 2006).

Copeland and McDonald (2001), Tekrony (2003) and ISTA, (2006) reported that germination and vigour tests show a progressive decline during the storage period. This can be used to make informed decisions regarding the value of different seed lots.

Agha *et al*. (2004) revealed that in soybean seed packaged in moisture-proof containers, the relative humidity of the air around the seed remains low due to which the seed equilibrium moisture remains low, and the seed maintains its viability and vigour for a longer time.

Seeds packed in polythene bags maintained high viability with time due to minimized moisture fluctuation and consequently produced more vigorous seedlings compared with those from seeds stored in jute or cloth bags which had little protection against moisture fluctuation (Karim *et al*., 2005).

In soybean seeds during storage, Miah *et al*. (2006) found that the vigour index decreased with an increase in storage relative humidity.

Sterlec *et al*. (2010) studied the influence of storage temperature and relative humidity on grain moisture, germination and vigour of different wheat cultivars during storage. They reported that decrease in the grain moisture content by 4, 2.5 and 1 per cent occurred at relative humidity of 45 per cent and temperature of 40 °C, 25 °C and 4 °C, respectively, occurred during first ninety days of seed storage. Seed germination and vigour were significantly reduced during storage only at elevated temperatures.

Naguib *et al*. (2011) reported that wheat seeds packed in aluminium bags and stored for 18 months had registered low electrical conductivity value (33.5 $dSm^{-1}$) and high germination values (beginning and end germination: 68.3% and 88.0% respectively). The seeds recorded high values for seed viability and vigour parameters until 12 months of storage, producing strong and tall seedling with heavier seedling dry weights.

Monira *et al*. (2012) reported that the moisture content in soybean increased with the advancement of storage period. However, the rate of moisture absorbance was higher in cloth bag than polythene bag. The rate of decrease in germination and the increase in rate of deterioration was higher in seeds stored in cloth bag compared to polyethylene bag. At the end of storage period, the shoot and root length of seedling, and seedling vigour was the least in cloth compared to that in polyethylene bag.

Mbofung *et al*. (2013) studied the effect of soybean seeds stored in three storage environments differing in temperature and relative humidity: a cold storage (CS) (10°C), a warm storage (WS) (25°C), and a warehouse (WH). Seed viability and vigor were evaluated at $4^{th}$ and $20^{th}$ month after storage using standard germination and accelerated aging tests. Viability and vigour remained high throughout the study for seeds stored in CS (>92%) and moderate in the WS (>78%), but decreased to almost 0 per cent after 20 months in the WH.

Bortey *et al*. (2016) studied the effect of storage material (polyethylene bag, cotton bag and glass container) on four cowpea genotypes and found that the seeds stored in glass containers had the highest vigour (63.7%), followed by seeds stored in polyethylene bags which had vigour per cent of 63. Seeds stored in cotton bags (57%) recorded the least seed vigour.

### 2.2.3 Seed moisture content

Harrington (1972) proposed that each $5^0$C reduction in seed temperature doubles the life of the seeds or 1 per cent reduction in moisture level.

Survival of seeds in dry storage depends more on its moisture content than on any other factor (Justice and Bass, 1978). Deteriorative reactions frequently proceed in the seed more readily if the moisture content is higher and consequently, the moisture condition would constitute a threat to the longevity of survival.

Cromarty *et al.* (1985) and Priestley (1986) reported that the moisture level of seeds is an important determinant of the seed longevity that is influenced by both RH and temperature.

Ellis *et al.* (1990) studied the relationship between seed moisture and longevity in beans *(Phaselous vulgaris)* and established a negative logarithmic relation between moisture content and longevity.

Many researchers have commented on the superiority of decreased moisture content of grains in storage and the storability of rice as influenced by moisture content of rice (Moreno-Martinez et al., 1998; Al-Yahya, 2001).

Copeland and McDonald (1999) and Volenik *et al.* (2006) reported that moisture equilibrium between seeds and environmental air, result in an increase in seed moisture. The deteriorative process increases within seeds and speeds up with concomitant increase in temperature, consequently leading to germination and vigour decrease.

Dillahunty *et al.* (2000) reported that the respiration rate of rice decreases with decreasing moisture content and the growth of microorganisms is inhibited at low water activity.

If seed could be packaged in moisture proof containers such that the relative humidity of the air around the seed remains low, then the seed equilibrium moisture remains low and the seed maintains its viability and vigour for a longer time (Poonam *et al*., 2001; Agha *et al*., 2004).

Miah *et al*. (2006) reported that after one month of storage, wheat seed moisture content (SMC) increased with increase in storage RH. At 50 per cent storage RH, the SMC was seven to eight per cent, while, it was 15-16 per cent at 80 per cent storage RH.

Rickman and Aquino (2007) reported that grain moisture levels in the traditional open storage systems fluctuated between 2 and 3 per cent over a 12-month storage period. Using a hermetic system reduced the variation to less than 1.5 per cent, while the moisture level in grain stored in the air-conditioned room decreased by more than two moisture level over a 12-month period.

Khaldun and Haque (2009) reported that in cucumber, the decline in germinability with high moisture content is related to high temperature and relative humidity of the surrounding air.

Sisman and Albut (2010) recommended that the moisture content of wheat for safe storage should not exceed 8-14 per cent.

Eluid *et al*. (2010) reported that germination per cent of bean seeds declined below the accepted level of 80 moisture level after storage of two months and to zero after nine months, while the electrical conductivity shot above the critical level after two months.

Jyoti and Malik (2013) reported that soybean seeds stored at high moisture content manifested increased respiration, heating, and fungal invasion resulting in reduced seed vigour and viability.

Ali *et al*. (2014) suggested that soybean seed could be stored with above 80 per cent germination for at least six months under a range of relative humidity (50 to 60%) if stored in a polythene bag after drying to 8 per cent initial seed moisture content.

Bakhtavar *et al*. (2019) reported that seed germination was highly linked with the initial seed moisture content and storage conditions. Highest germination (85%) of maize seed was recorded when it was stored in Super Bag at eight moisture level initial seed moisture contents (SMC). Even in Super Bag, maize seed lost its germination completely when it was stored at 14 per cent initial SMC.

### 2.2.4 Electrical conductivity

Mathew and Brandnock (1967) and Mathew and Whitburead (1968) reported that the electrical conductivity (EC) test is based on the concentration of solutes, namely sugar, amino acids possessing electrical charges that have leached out of the seed and can be detected by measurement of the EC of a solution in which the seeds were soaked overnight. The low leakage would mean low conductivity, which is associated with seeds that emerged well with high vigour compared to those with high leakage of electrolyte, resulting in increased EC, which is expressed in lowered seed-vigour with poor emergence.

Abdul-Baki and Anderson (1973) reported that seed deterioration is associated with ageing phenomenon, which is defined as an irreversible degradation, and change in the quality of a seed after it has reached that stage of its maximum quality level. Seed deterioration starts on the plant itself, immediately after attaining physiological maturity. Seed viability during storage declines due to various physiological and biochemical changes resulting in deterioration.

Bewley and Black (1985) reported that the EC is based on the fact that seeds, when soaked in water, exude ions, sugars and other metabolites, from the starting of the soaking period, due to changes in the integrity of the cell membranes, as a function of water amount and the level of seed deterioration. In deteriorated seeds, the repair mechanism is absent or inefficient, or the membranes are completely damaged thus permitting leaching of larger electrolyte amounts.

Among the seed vigour tests, the measurement of electric conductivity (EC) of the seed leachates has been frequently used to evaluate the physiological quality of soybean seeds (AOSA, 1983, Vieira *et al.,* 2004, ISTA, 1993).

Hampton and Tekrony (1995) reported that Conductivity test is a valuable seed vigour test for many crops and it is the recommended ISTA vigour test for large-seeded legumes.

Vieira *et al*. (1999) and Tajbakhsh (2000) revealed that all germination parameters in wheat crop were inversely proportional to electrical conductivity or vice- versa as storage period increases.

Thobunluepop *et al*. (2009) revealed that seeds of rice kept in storage for 12 months under ambient conditions showed increased seed moisture content and seed water activity which affected germination rate, seedling vigour, seedling dry weight, shoot and root length. Loss in viability was due to disturbances in the cell membrane and the loss of enzymes like alpha-amylase.

Rice stored under high temperature ($45^0$C) and humidity (~100%) for 15 days showed a decrease in per cent germination and concentration of protein and starch. However, it resulted in an increase in conductivity of leachate and content of sugar (Smruti *et al*., 2010).

Assefa and Sreenivasan (2016) reported that an increase in the EC value was recorded with a decrease in the seed quality expressed in terms of germination and vigour index of sorghum seeds.

Bijanzadeh *et al*. (2016) found that in seeds of rice cultivars, the initial electrical conductivity ranged from 50-67 $\mu Scm^{-1}mg^{-1}$. After 120 hours of ageing, various cultivars exhibited E.C. in the range of 272 $\mu Scm^{-1}mg^{-1}$ to 493 $\mu Scm^{-1}mg^{-1}$.

Khidrapure *et al*. (2016) revealed that hybrid corn seeds when stored in cloth bag for one month recorded an electrical conductivity of 0.253 $dSm^{-1}$, whereas, the same seed lot when subjected to one day of accelerated ageing measured 0.279 $dSm^{-1}$.

Govindaraj *et al*. (2017) reported that irrespective of the treatment and varieties, the least electrical conductivity was observed in fresh seeds (60.1 $\mu Sm^{-1}$) and increased gradually with increase in the duration of accelerated ageing and reached the maximum at 20 days of ageing (143.7 $\mu Sm^{-1}$).

**2.2.5 Seed health**

Seed pathogens are responsible for both pre and post-emergence death of grains, affect seedling vigour, and thus cause some reduction in germination and variation in plant morphology. Several studies reported the involvement of fungal infection in seed ageing. Fungal infected seeds deteriorate faster than uninfected seeds in storage was reported by Christensen and Kaufman (1969), Christensen (1967, 1972 and 1973), and Neergard (1977).

Seed-borne fungi are one of the most important biotic constrains in seed production worldwide. Of the 16 per cent annual crop losses due to plant diseases, at least 10 per cent loss occurs due to seed-borne diseases (Fakir, 1983). The quality of planted seeds has a critical influence on the ability of crops to become established and to realize their full potential of yield and value (McGee, 1995).

The respiration rate of rice decreases with decreasing moisture content (Dillahunty *et al.,* 2000) and the growth of microorganisms is inhibited at a low water activity (Abdullah *et al.,* 2000).

Elevated moisture content in dried seeds enables the growth of both microorganisms associated with spoilage and insects that damage stored commodities (Fontana, 2007; Murdock *et al*., 2012; Roberts, 1972).

On examination of 25 seed samples of rice in Vietnam, Trung *et al*. (2001) reported that the most common micro-organism were fungi belonging to the genus *Aspergillus*, *Fusarium* and *Penicillium.*

Javaid *et al*. (2002) and Gopalakrishnan (2010) reported that more than 100 species of fungi have been identified on rice seeds so far. However, their severity depends on the time of sampling, location and varieties.

Reddy *et al*. (2004) conducted a study on stored rice for more than a year from 18 different ecosystems in India. They reported that *Aspergillus* is the most important fungal contamination on rice seeds.

Rahman *et al*. (2008) reported that seed health is a well-recognized factor in modern agricultural science to establish the desired plant population and realize a good harvest. Seed borne pathogens are a continuing problem and may even be responsible for the re-emergence of diseases of the past as well as the introduction of diseases into new areas and it is a serious threat to seedling establishment.

Karami *et al*. (2012) studied the effect of *Fusarium* spp. and brown spot (*Bipolaris oryzae*) on seed germination of high yield rice varieties and they found that germination percentage and seedling growth on studied cultivars declined due to fungal contamination.

Ahmead *et al*. (2013) identified nine species of seed-borne fungi in their study on rice seed contamination including *Fusarium oxysporum*, *Fusarium moniliforme*, *Bipolaris oryzae*, *Alternaria padwickii*, *Curvularia lunata*, *Aspergillus flavus*, *Aspergillus niger*, *Penicillium sp*. and *Nigrospora oryzae*.

Monajjem *et al*. (2014) reported that among seed-borne fungi, *Aspergillus niger* and *Aspergillus flavus* had the most severity rate compared to other fungi during rice seed storage.

Barret *et al*. (2015) reported that seeds carrying pathogens such as fungi, bacteria, nematodes and viruses responsible for transmitting seed-borne diseases, which often cause partial or total crop losses.

Seed microflora infection per cent increased over the period of storage and the highest incidence of fungus that were observed in storage are *Aspergillus flavus* and *Aspergillus niger* (Navya, 2016; Sandhya, 2016; Shobha, 2016; Antony, 2016, Nagendra, 2017, Nishidha, 2018).

# Materials and methods

# 3. MATERIALS AND METHODS

Temperature and relative humidity of the storage environment are two most important factors influencing seed viability and longevity during storage. Considering the importance of storage structure and environment, the present investigation 'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),' was formulated to deduce the influence of temperature and relative humidity on longevity of rice seeds stored under different godown structures. The details of experiments, materials used and methods followed in the study are described hereunder.

## 3.1 Location

The experiment was conducted between May, 2019 and January, 2020, in the Department of Seed Science and Technology, College of Horticulture (COH), Kerala Agricultural University, (KAU), Vellanikkara, Thrissur, located 40 m above MSL between 10°54' North latitude and 76°28' East longitude.

## 3.2 Climatic conditions

The experimental location experiences a hot humid tropical climate. During the study period, relative humidity (RH) varied between 73 per cent (December, 2019) and 96 per cent (August, 2019). Total rainfall received during the study period was 3042.9 mm, ranging between 4.4 mm (Dec, 2019) and 977.5 mm (Aug, 2019). The monthly mean maximum temperatures ranged from 29.50 °C in August 2019 to 35.20 °C in May 2019, while, the mean minimum temperature varied between 19.9 °C in August 2019 and 22.4°C in January 2020. The month-wise details of RH, and temperature during the study period are given in Fig. 1 and Fig 2 respectively.

## 3.3 Experiment materials

The study material comprised of seeds of four short duration and four medium duration rice varieties procured from three different sources. The seeds harvested in March, 2019, was procured, dried, processed and the experiment initiated in May, 2019. The details are catalogued in Table 1.

**Fig 1.**

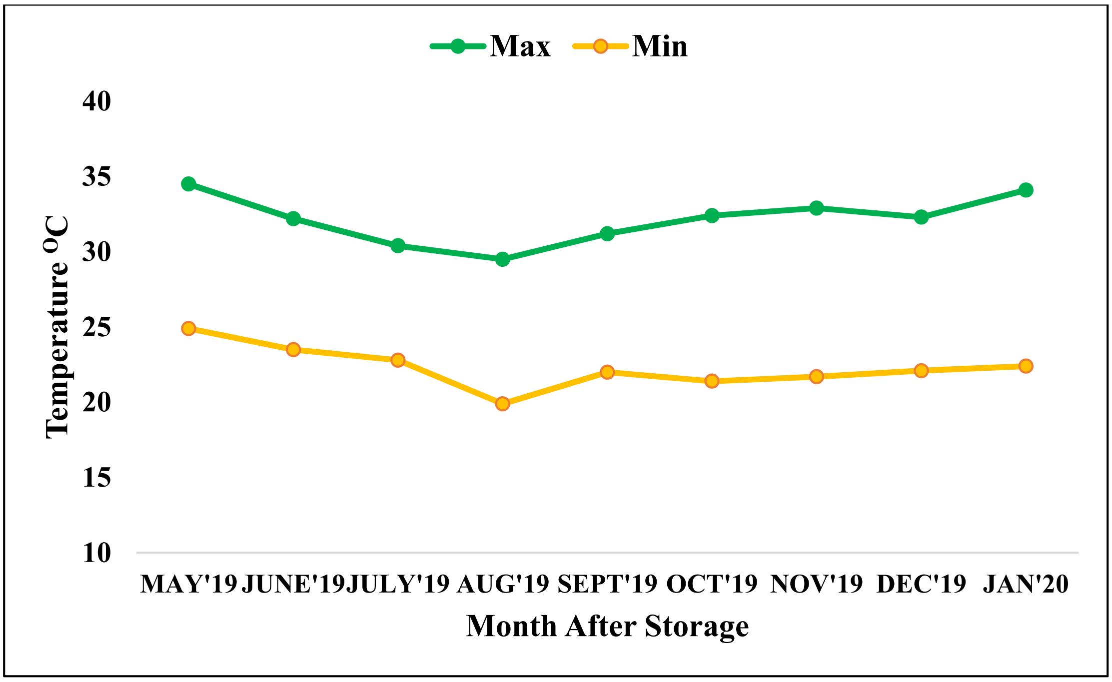



Fig. 1: Mean temperature ($^{O}C$) during the study period (May, 2019 to Jan, 2020).

**Fig 2.**

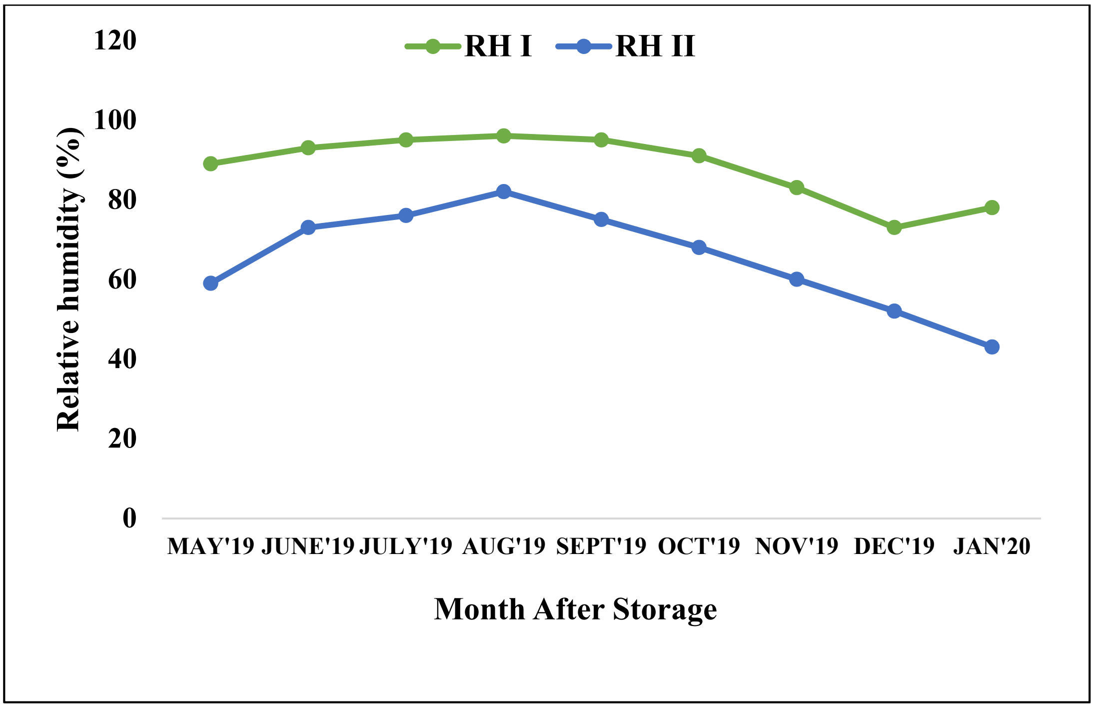



Fig. 2: Relative humidity (%) [Fore noon (RH I) and Afternoon (RH II)] during the study period (May, 2019 to Jan, 2020).

**Table 1: Details of seed material used in the study**

| **Sl. No.** | **Variety** | **Seed source** | **Date of harvest** | **Remarks** |
|---|---|---|---|---|
| A. Short duration varieties | | | | |
| 1 | Manuratna | Department of Seed Science and Technology, COH, Vellanikkara | 17/03/19 | Released from ARS, Mannuthy, KAU (2018). Duration -100-105 days. Red kernelled variety suitable for normal wetlands of kerala. |
| 2 | Matta Triveni | Regional Agricultural Research Station (RARS), KAU, Pattambi | 21/03/19 | Released from RARS, Pattambi, KAU (1990) Duration-100-105 days. Red kernelled variety suitable for 1st and 3rd crop season. |
| 3 | Harsha | Regional Agricultural Research Station (RARS), KAU, Pattambi | 13/03/19 | Released from RARS, Pattambi, KAU (2001) Duration-105-110 days. Red kernelled variety suitable for rainfed lowlands. |
| 4 | Kanchana | State Seed Farm, Nadavarmbu, Thrissur | 10/03/19 | Released from RARS, Pattambi, KAU (1993) Duration-105-110 days. Red kernelled variety suitable for Kole and Kuttanad regions. |
| B. Medium duration varieties | | | | |

| | | | | |
|---|---|---|---|---|
| 1 | Aiswarya | Regional Agricultural Research Station (RARS), KAU, Pattambi | 27/03/19 | Released from RARS, Pattambi, KAU (1993)<br>Duration -120-125 days. Red kernelled variety suited for 1st and 2nd crop season. |
| 2 | Sreyas | Regional Agricultural Research Station (RARS), KAU, Pattambi | 17/03/19 | Released from RRS, Moncompu, KAU (2015)<br>Duration-115-120 days. Red kernelled variety suited to three seasons of Kuttanad. |
| 3 | Jyothi | Department of Seed Science and Technology, COH, Vellanikkara | 18/03/19 | Released from RARS, Pattambi, KAU (1974)<br>Duration-110-125 days. Red kernelled variety suitable for direct seeding, transplanting and special systems of Kole and Kuttanad. |
| 4 | Uma | Department of Seed Science and Technology, COH, Vellanikkara | 20/03/19 | Released from RRS, Moncompu, KAU (1998)<br>Duration-120-135 days. Red kernelled variety suited to three seasons especially to additional Virippu crop season of Kuttanad. |

### 3.4 Experiment details

The seeds were dried to ≤12 per cent moisture content and packed in jute bags of 30 kg capacity before storage. The experimental details are enumerated below.

#### 3.4.1 Experiment 1: Impact of storage structure on seed longevity of short duration rice varieties.

The experiment was conducted in a Completely Randomized Design (CRD) with four short duration varieties (Table 1) and three replications. The seeds were stored under five different storage conditions (Treatments: S1 to S5) each varying from the other with respect to the type of roofing and provision of ventilation. The different storage conditions are catalogued in Table 2.

**Table 2. Nature of environment for seed storage**

| Treatments | Storage structure | | Designation |
|---|---|---|---|
| | Type | Ventilation | |
| SC1 | Gabled asbestos roofing | Provision for natural air flow | Asbestos + ventilation |
| SC2 | Gabled asbestos roofing | No provision for natural air flow | Asbestos + without ventilation |
| SC3 | Flat R.C.C roofing | Provision for natural air flow | R.C.C. + ventilation |
| SC4 | Flat R.C.C roofing | No provision for natural air flow | R.C.C. + without ventilation |
| SC5 | Gabled asbestos roofing | Provision of electrically operated exhaust fans of 0.5 Hp motor. | Asbestos + forced ventilation |

The flat R.C.C roofed storage godown was of size 5m (L) x 3m (B) x 3m (H). The storage structures had windows (6 Nos.) of size 1.5m (L) x 0.5m (B) positioned 1m above floor level and a door of size 2m (L) x 1m (B). The windows were positioned opposite to each other to aid cross-ventilation. The storage godown with asbestos roofing was of size 10m (L) x 6m (B) with gabled in the centre at 7.5m (H) and had a height of 5m at the sides. The opposite walls of the gabled roofed structures had a set of two windows at different levels above floor level, one of size 1.5m (L) x 0.5m (B) at 1m (lower vent) and another of size 1m (L) x 0.5m (B) at 3m (upper vent), in addition to a door of size of size 2m (L) x 0.75m (B).

In case of treatments S2, S4 and S5, the windows and doors were kept tightly shut during the period of study, while in case of S1 and S3, the windows were left open to aid natural air flow in and out of the structure. In case of S5, it was ensured that the exhaust fans were operated throughout the storage period.

### 3.4.2 Experiment 2: Impact of storage structure on seed longevity of medium duration rice varieties.

The experiment was conducted in Completely Randomized Design (CRD) with four medium duration varieties (Table 1) with three replications under five storage conditions (Treatments). The details of storage structure and recording of observation is as enumerated under 3.4.1

### 3.5 Observations recorded

The seeds required for quality assessment were drawn randomly from each replication of a treatment. The quality parameters were evaluated at the start and subsequently at monthly intervals, during the storage period until the germination of seed fell below the minimum standards for seed certification (MSCS <80%). Seed quality parameters assessed were germination per cent, root and shoot length of the seedling, seedling dry weight and electrical conductivity (E.C.), seed moisture content (%) and field establishment (%). However, seed microflora infections were assessed at the start and end of storage.

Throughout the storage period, observations on storage environment *i.e.*, storage temperature (°C) and relative humidity (%) were recorded at weekly intervals. The procedure followed with respect to recording of various observations is enumerated below.

### 3.5.1 Seed quality parameters

#### 3.5.1.1 Germination (%)

Germination test was conducted by adopting the top paper method as per ISTA (1965). Moist filter paper was used as the substratum. Seeds were placed on a layer of moist filter paper placed in petriplates. These petriplates were covered with lid and placed inside the germination cabinet at a temperature of 25±2°C and RH 90±3%. The number of normal seedlings was counted on the 5$^{th}$ and 14$^{th}$day and the total number expressed in per cent. Germination percentage was worked out using the following formula:

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

#### 3.5.1.2 Seedling shoot length (cm)

Ten normal seedlings were randomly selected from each replication of the treatments at the end of germination test (14$^{th}$ day), for recording the shoot length. The length between collar region and tip of the shoot was measured and the average expressed in centimetre.

#### 3.5.1.3 Seedling root length (cm)

The same seedlings used for measuring shoot length were used to measure the root length. The length between tip of the root and the collar region was measured and the average expressed in centimetre.

#### 3.5.1.4 Seedling dry weight (mg)

The seedling dry weight estimation was done with the same ten seedlings used for the measurement of shoot and root length. They were taken in properly labelled butter paper bags and kept in hot air oven maintained at 80°C temperature for 24 h. The butter paper bags were then transferred to a desiccator to cool for 30 minutes. The weight of ten seedlings was recorded using a digital weighing balance and the average expressed in milligram (mg).

**3.5.1.5 Vigour index**

It is a secondary trait computed using the data recorded on germination (%) and seedling dry weight (mg) or shoot length (cm).

**3.5.5.1 Vigour index- I** (VI-I)

Seedling vigour index-I was calculated as per the formula given by Abdul Baki and Anderson (1973).

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

**3.5.5.2 Vigour index- II** (VI-II)

Seedling vigour index II was calculated as per the formula given by Bewly and Black, (1994).

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

**3.5.1.6 Field establishment (%)**

The substratum serves as moisture reservoir and provides a surface or medium in which the seeds can germinate and the seedlings grow. To record field establishment, sand was used as the substratum. Care was taken to ensure that the sand particles was not be too large or too small. The sand particles that passed through a 0.80 mm sieve and retained by a 0.05mm sieve was taken in germination trays of size 22.5 cm x 22.5 cm x 4.0 cm. Seeds were planted in a uniform layer of moist sand and then covered to a depth of 1 to 2 cm with sand. Equal spacing was provided on all sides to facilitate normal growth of seedling and to avoid entangling of seed and spread of disease. The sand was moistened to 50 per cent of its water holding capacity unlike for large seeded legumes and maize in which case it is to be moistened to 60 per cent water holding capacity.

Three replicates of 100 seeds each, drawn from each replication of a treatment sown and the field emergence of each variety were recorded on the $14^{th}$ day.

$$\text{Field establishment (\%)} = \frac{\text{Number of seeds emerged}}{\text{Total number of seeds kept for field emergence}} \times 100$$

### 3.5.1.7 Electrical conductivity of seed leachate (µS $cm^{-1}$)

This test is based on the leakage of solutes that occurs through the cell membrane from all the seeds into deionized distilled water. The amount of electrolyte leakage can be assessed by measuring the electrical conductivity of the seed soaked water, with a conductivity meter.

Three replicates of 25 seeds from each treatment were pre-washed thrice with the distilled water to remove the adhering chemicals before soaking in 25 ml of distilled water for 24 hours. The soaked seeds were maintained at room temperature and occasionally stirred. The beakers were covered in order to reduce evaporation and other contaminants. The seed leachate was collected in 50 ml beaker from which EC was measured and expressed in microSeimens per meter (µ$Sm^{-1}$) (Jackson, 1973).

### 3.5.1.8 Seed moisture content (%)

Moisture content (MC) of the seed was measured during the storage period by using the low constant temperature procedure advocated by ISTA (1985). Five gram seeds from each replication of each treatment was drawn from the sample and evenly distributed over the surface of the container made of non-corrosive glass of approximately 0.5 mm thickness. Both the container and its cover were weighed before and after filling. It was then placed in a hot-air oven maintained at 103±2 °C and dried for 17±1 h. The drying period was considered to have begun from the time when oven reaches 103 °C. At the completion of the prescribed time, the container was removed from the oven and placed in a desiccator to cool for 30-45 minutes. After cooling, the container along with its cover was weighed and the seed moisture content (%) was calculated using the following formula:

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

Where,

M1: weight of container with lid

M2: weight of container with lid + seeds before drying

M3: weight of container with lid + seeds after drying

**3.5.1. 9 Seed infection**

Seed health test was conducted by adopting both the blotter paper method and agar plate method as recommended by ISTA (1999).

**3.5.1. 9.1 Blotter paper method**

The detection of seed microflora was carried out by adopting ISTA's standard blotter test described by Neergaard (1979). Three layers of sterilized blotter papers were kept in sterilized petri plates. Sterilized water was added in the plates to soak the filter paper and the excess water was removed. Twenty-five seeds of rice were kept on the blotter paper equidistantly under aseptic conditions maintained by laminar air flow. After plating the seeds, the petridishes were incubated at 25±1°C under 12/12 hrs light and darkness cycle for 7 days. On the eighth day, the plates were observed for the presence of seed microflora under stereo binocular microscope. The number of infected seeds were counted and recorded in per cent. The fungal bodies were also identified based on the morphological characters of the conidia, conidiophores and fruiting bodies by making slides of the same.

**3.5.1. 9.2 Agar plate method**

The agar plate method for detection of seed microflora requires surface sterilization. Potato Dextrose Agar (20 mL) was poured into sterilized petri plates in aseptic conditions. The seeds were surface sterilized with 0.1% sodium hypochlorite and subsequently washed with sterile distilled water thrice. The washed seeds were then placed on sterile filter paper to remove the excessive water on its surface. After the media had set, the seeds were kept equidistantly in PDA plate. The petri plates were incubated under bell jar for six days. After incubation, the number of infected seeds were observed and recorded as per cent. The identification of the infection causing pathogen was also done by preparation of slide.

**3.5.2 Storage environment**

**3.5.2.1 Relative humidity (%)**

Relative humidity can be measured by an instrument called a hygrometer. The simplest hygrometer - a whirling psychrometer consists of two thermometers mounted together with a handle attached on a chain. One thermometer is an ordinary dry-bulb one while, the other has a cloth wick over its bulb and is called a wet-bulb thermometer. When a reading is to be taken, the wick was first dipped in water and then the instrument was whirled around over the seed lot. During the whirling, the water evaporates from the wick, cooling the wet-bulb thermometer. Then the temperatures of both thermometers were read. The principle of operation is that if the surrounding air is dry, more moisture evaporates from the wick, cooling the wet-bulb thermometer more so there is a greater difference between the temperatures of the two thermometers. If the surrounding air is holding as much moisture as possible - if the relative humidity is 100% - there will be no difference between the two temperatures. Meteorologists have worked out charts of these differences for each degree of temperature such that the observer can find relative humidity easily.

### 3.5.2.2 Temperature

The dry bulb temperature, usually referred to as 'air temperature', is the air property that is most commonly used. When people refer to the temperature of the air, they are normally referring to the dry bulb temperature. In Dry bulb thermometer, the air temperature indicated is not affected by the moisture of the air. Dry-bulb temperature - $T_{db}$, can be measured using a normal Dry-bulb thermometer freely exposed to the air but shielded from radiation and moisture. By using whirling psychrometer both dry bulb and wet bulb reading can be noted. The dry bulb reading indicates the temperature of the storage environment.

### 3.5.2.3 Temperature - Humidity Index (THI)

The combined effect of temperature and relative humidity were analyzed by using Temperature - Humidity Index (THI). THI is a single value representing the combination of air temperature and relative humidity at place over the period of study. Temperature - Humidity Index was calculated using the following formula:

$$THI = (1.8 \times T_{db}+32)-[(0.55-0.0055 \times RH) \times (1.8 \times T_{db}-26.8) \qquad \text{[NRC, 1971]}$$

Where,

$T_{db}$ = Dry-bulb temperature

RH = Relative humidity

## 3.6 Statistical analysis

### 3.6.1 Analysis of data

Statistical analysis of the data on various seed quality parameters was performed following the factorial completely randomized design (CRD) with three replications, four different varieties (Factor A), five storage conditions (Factor B) and period of storage (Factor C), as per Fisher's method of analysis of variance (Gomez and Gomez 1976). Square root transformation of data was done wherever applicable (Snedecor and Cochran, 1967).

#### 3.6.1.1 ANOVA for Factorial design

The data recorded in each of the experiment was analyzed using three factorial ANOVA (CRD) so as to estimate the effect of varieties, storage condition and period of storage on dependent variables. In case of seed infection two factorial analysis to deduce the impact of varieties and storage condition was employed. It helps us to distinguish whether there are interactions between the different factors considered. The mean squares due to different sources of variation were worked out using the following analysis of variance for two and three factors (Gomez and Gomez, 1976).

**Table.3 Analysis of variance model for three and factorial experiments**

| Source | df | Mean square | Expected mean squares |
|---|---|---|---|
| Replication | (r-1) | $M_r$ | $M_r/M_e$ |
| Main effect (A) | (a-1) | $M_A$ | $M_A/ M_e$ |
| Main effect (B) | (b-1) | $M_B$ | $M_B/ M_e$ |
| Factor (AB) | (a-1) (b-1) | $M_{AB}$ | $M_{AB}/ M_e$ |
| Main effect (C) | (c-1) | $M_C$ | $M_B/ M_e$ |
| Factor (AC) | (a-1) (c-1) | $M_{AC}$ | $M_{AC}/ M_e$ |
| Factor (BC) | (b-1) (c-1) | $M_{BC}$ | $M_{BC}/ M_e$ |
| Factor (ABC) | (a-1)(b-1) (c-1) | $M_{ABC}$ | $M_{ABC}/ M_e$ |
| Error | ab (r-1) | $M_e$ | |

| Source | df | Mean square | Expected mean squares |
|---|---|---|---|
| Replication | (r-1) | $M_r$ | $M_r/M_e$ |
| Treatment | $(2^n-1)$ | $M_t$ | $M_t$ / $M_e$ |
| Main effect (A) | 1 | $M_A$ | $M_A/M_e$ |
| Main effect (B) | 1 | $M_B$ | $M_B/M_e$ |
| Factor (AB) | 1 | $M_{AB}$ | $M_{AB}/M_e$ |
| Error | (r-1) $(2^n-1)$ | $M_e$ | |

The treatments were compared using the critical difference (C.D) estimate at P = 0.05.

**3.6.1.2 Correlation analysis**

To study the influence of weekly storage temperature and RH on seed quality parameters during the storage period (38 weeks), correlation analysis was carried out. Storage temperature and RH during each week after storage were correlated with important seed quality parameters such as reduction in germination and seed moisture content. The combined effect of temperature and relative humidity were analyzed by using Temperature Humidity Index (THI). Correlation analysis was done by using SPSS package.

**SC1 (Asbestos + ventilation)**

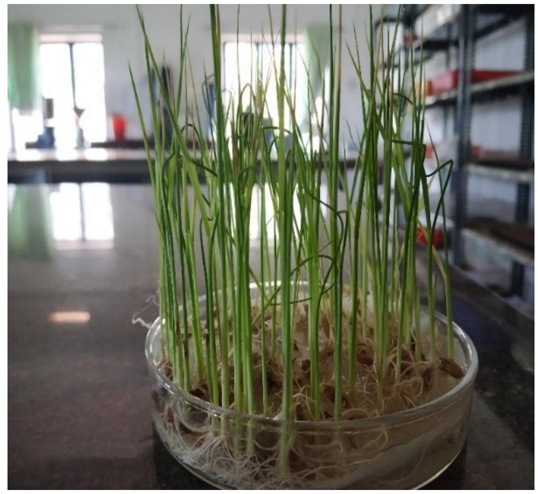
**SC2 (Asbestos + without ventilation)**

**SC3 (R.C.C + ventilation)**

**SC4 (R.C.C + without ventilation)**

**SC1 (Asbestos + forced ventilation)**

**Plate 1. Different storage conditions**

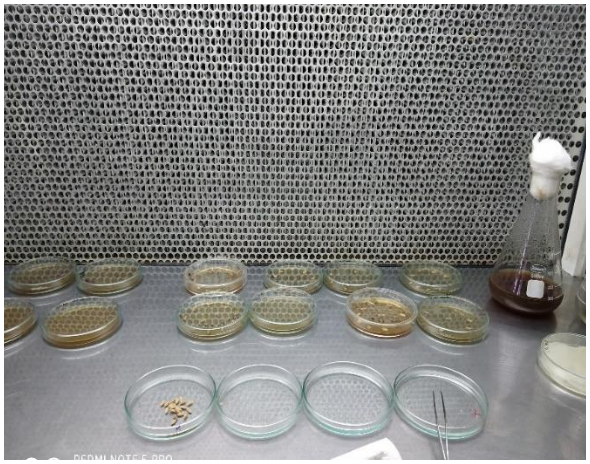


**Germination test**

**Field Establishment**

**Test for Electrical conductivity of seed leachate**

**Plate 2. Observations recorded**



**Seed microflora analysis**


**Seed sampling** **Whirling psychrometer**

**Plate 3. Observations recorded**

# Results

# 4. RESULTS

The present investigation, 'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),' was carried out in the Department of Seed Science and Technology, College of Horticulture, Vellanikkara, Kerala Agricultural University (KAU), Thrissur, during the year 2019 - 2020. The results obtained from the study are furnished below.

## 4.1 Experiment 1: Impact of storage structure on seed longevity of short duration rice varieties.

### 4.1.1 Seed quality before storage

The quality parameters of the seeds of various short-duration varieties were recorded before storage (Table 4).

Germination before storage, ranged from 96.00 per cent (Kanchana) to 100.00 per cent (Harsha, Matta Triveni and Manuratna). Shoot length varied between 8.90 cm (Harsha and Manuratna) and 10.10 cm (Matta Triveni), while, the length of root in seedlings, ranged between 9.90 cm (Manuratna) and 11.10 cm (Kanchana). Seedling dry weight was high in variety Matta Triveni (0.218 g) and the least in Manuratna (0.171 g). Vigour index - I varied between 1880.00 (Manuratna) and 2110.00 (Matta Triveni), while, Vigour index - II (VI-I) ranged from 1710.00 (Manuratna) to 2333.00 (Kanchana). Moisture content in seeds before storage was the least in Kanchana (10.1%), while it was 10.8 per cent in the other varieties. The electrical conductivity (EC) of seed leachate ranged from 39.02 $\mu Sm^{-1}$ (Kanchana) to 102.20 $\mu Sm^{-1}$ (Manuratna). In case of field establishment, the trend was the same as observed in germination. Field establishment varied between 96.00 per cent in variety Kanchana and 100.00 per cent in varieties Harsha, Matta Triveni and Manuratna.

### 4.1.2 Seed quality during storage

Analysis of variance for various traits studied indicated existence of wide variability in the impact of varieties, storage conditions, storage period and their interaction on most of the seed indices studied. The results obtained are enumerated henceforth.

**Table 4. Seed quality parameters of short duration rice varieties before storage**

| Parameters | Varieties | | | |
|---|---|---|---|---|
| | **Harsha** | **Matta Triveni** | **Manurathna** | **Kanchana** |
| **Germination (%)** | 100.00 | 100.00 | 100.00 | 96.00 |
| **Seedling shoot length (cm)** | 8.90 | 10.10 | 8.90 | 9.90 |
| **Seedling root length (cm)** | 10.90 | 11.00 | 9.90 | 11.10 |
| **Seedling dry weight (g)** | 0.194 | 0.218 | 0.171 | 0.243 |
| **Vigour index I** | 1930.00 | 2110.00 | 1880.00 | 2006.00 |
| **Vigour index II** | 1980.00 | 2170.00 | 1710.00 | 2333.00 |
| **Seed moisture content (%)** | 10.80 | 10.80 | 10.80 | 10.10 |
| **Electrical conductivity (EC) of seed leachate ($\mu Sm^{-1}$)** | 40.60 | 58.72 | 102.20 | 39.02 |
| **Field establishment (%)** | 100.00 | 100.00 | 100.00 | 96.00 |

### 4.1.2.1 GERMINATION (%)

The results on per cent germination as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are enumerated in Tables 5, 6, 7 and 8.

#### 4.1.2.1.1 Effect of varieties (VAR)

Irrespective of the period of storage and the storage conditions, germination was found to vary significantly between the varieties during the storage period (Table 5).

Germination in Matta Triveni (91.39%) was significantly superior to other varieties. Germination in Harsha (90.27%) differed significantly from Manurathna (89.69%). Manurathna in turn differed significantly from variety Kanchana (86.82%) that exhibited the least estimate.

#### 4.1.2.1.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, germination was found to vary significantly during the storage period (Table 5).

Germination was found to be lower and significantly different from that of the preceding month throughout the storage period. It was found to be above 90.00 per cent up to 5 MAS (91.88%) and later, a drastic decline in germination was observed. Germination fell below IMSCS at 8 MAS (79.19%).

#### 4.1.2.1.3 Effect of storage condition (SC)

Irrespective of varieties and the period of storage, storage condition exerted significant influence on germination (Table 6).

Germination in seeds stored under treatments SC3 (R.C.C. + ventilation: 90.32%) and SC1 (Asbestos + ventilation: 90.24%), were found to be on par with each other and significantly superior to all other treatments. Germination in SC5 (Asbestos + forced ventilation: 89.94%) was found to be the next best and significantly superior to that in SC2 (Asbestos + without ventilation: 89.53%). Germination was found to be the least in SC4 (R.C.C. + without ventilation: 87.67%).

#### 4.1.2.1.4 Effect to interaction

##### 4.1.2.1.4.1 Varieties × Storage period (VAR × MAS)

Irrespective of the storage conditions, germination was significantly influenced by the interaction between different varieties and storage period (Table 5).

Germination of all the varieties declined progressively with an increase in the storage period. Variety MT had registered the highest germination per cent throughout the storage period. Germination in varieties Harsha and MT was observed to be above IMSCS up to 8 MAS, while germination in variety Manuratna (83.10 %) and variety Kanchana (83.00%) fell below MSCS at 7 MAS. Germination of this variety was retained above 90.00 per cent only up to 3 MAS (92.8%), while, it was retained above 90.00 for 6 MAS in all other varieties (Harsha: 90.53%, Matta Triveni: 91.86% and Manuratna: 90.66% at 6 MAS).

#### 4.1.2.1.4.2 Storage condition × Storage period (SC × MAS)

Irrespective of the varieties, the interaction between storage condition and storage period significantly influenced germination (Table 6).

Germination in seeds stored under SC1 (Asbestos + ventilation), SC3 (R.C.C. + ventilation) and SC5 (Asbestos + forced ventilation) was observed to be above IMSCS up to 8 MAS. These were also found to be significantly superior to the other storage conditions. At 7 MAS, germination under storage condition SC2 (Asbestos + without ventilation: 85.08%) and SC4 (R.C.C. + without ventilation: 82.83), fell below IMSCS.

Germination in storage condition, SC1 (90%), SC3 (90.41) and SC5 (90.16%) was retained above 90.00 per cent up to 6 MAS, while it was for 5 MAS in SC2 (92.5%) and only up to 4 MAS in SC4 (91.48%).

#### 4.1.2.1.4.3 Varieties × Storage condition (VAR × SC)

Irrespective of storage period, significant difference in germination was observed due to the interaction of varieties and storage condition (Table 7).

With the exception of SC4 (R.C.C. + without ventilation), germination in varieties Harsha (88.44%) and MT (89.96%) stored under various storage conditions were observed to be above 90.00 per cent, while, in variety Manuratna it was observed to be so only in SC1 (Asbestos + ventilation: 90.37 %) and SC3 (R.C.C. + ventilation: 90.48 %). Variety Kanchana stored under various storage conditions registered germination below 90 per cent.

#### 4.1.2.1.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)

Germination was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 8).

Germination in varieties Harsha and MT was retained above IMSCS for 8 MAS under SC1 (81.33% each), SC3 (Harsha: 81.33%; MT: 81.00%) and SC5 (Harsha: 80.33%; MT: 81.00%) in all ventilated storage structures. In comparison, germination in Manurathna and Kanchana was retained above IMSCS only for a shorter period (7 MAS), *i.e.*, the varieties differed in their longevity under ventilated storage. At 8 MAS, germination in Harsha and MT was significantly superior to that of Manurathna and

Kanchana. Germination in SC1 and SC3 was comparatively higher than under SC5 in the corresponding period of storage.

Germination in all the varieties stored under SC2 (Harsha: 86.33%; MT: 81.00%; Manuratna: 82.67%; Kanchana: 83.67%) and SC4 (Harsha: 85.00%; MT: 85.33%; Manuratna: 81.00%; Kanchana: 80.00%), as well as varieties Manuratna and Kanchana stored under SC1 (Manuratna: 84.33%; Kanchana: 83.67%), SC3 (84.00% each) and SC5 (83.67% each) were retained above, IMSCS for 7 MAS. Varieties Harsha and MT however, were found to be on par with each other as well as significantly superior to other varieties under both these storage environments.

**Table 5. Impact of varieties, storage period and their interactions on germination of short duration rice varieties.**

| VAR | Germination (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean VAR** |
| **Harsha** | 100.00 (10) $^{a}$ | 97.53 (92)$^{b}$ | 95.53 (9.82)$^{d}$ | 94.13 (9.75)$^{d}$ | 92.73 (9.68)$^{e}$ | 90.53 (9.56)$^{g}$ | 86.60 (9.35)$^{j}$ | 80.06 (8.97)$^{m}$ | 75.26 (8.73)$^{o}$ | **90.27 (9.54)$^{b}$** |
| **Matta Triveni** | 100.00 (10) $^{a}$ | 98.20 (9.96) $^{b}$ | 97.46 (9.92)$^{c}$ | 96.53 (9.87)$^{c}$ | 94.46 (9.77)$^{d}$ | 91.86 (9.63)$^{f}$ | 87.80 (9.42)$^{i}$ | 80.26 (8.99)$^{m}$ | 75.86 (8.76)$^{o}$ | **91.39 (9.60)$^{a}$** |
| **Manuratna** | 100.00 (10) $^{a}$ | 97.73 (9.93)$^{b}$ | 96.20 (9.85)$^{d}$ | 94.26 (9.76)$^{d}$ | 92.53 (9.67)$^{ef}$ | 90.66 (9.57)$^{g}$ | 83.10 (9.17)$^{l}$ | 78.40 (8.91)$^{n}$ | 74.26 (8.67)$^{p}$ | **89.69 (9.51)$^{c}$** |
| **Kanchana** | 96.00 (9.84) $^{c}$ | 94.46 (9.77)$^{d}$ | 92.80 (9.68)$^{h}$ | 89.60 (9.51)$^{h}$ | 87.80 (9.42) $^{i}$ | 85.73 (9.31)$^{k}$ | 83.00 (9.16)$^{l}$ | 77.93 (8.88)$^{n}$ | 74.00 (8.65)$^{p}$ | **86.82 (9.36)$^{d}$** |
| **Mean MAS** | **99.00 (9.95)$^{a}$** | **96.98 (9.89)$^{b}$** | **95.50 (9.82)$^{c}$** | **93.63 (9.72)$^{d}$** | **91.88 (9.63)$^{e}$** | **89.70 (9.52)$^{f}$** | **85.13 (9.28)$^{g}$** | **79.17 (8.95)$^{h}$** | **74.85 (8.70)$^{i}$** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.13 | 0.066 | 0.047 |
| VAR x MAS | 0.391 | 0.199 | 0.141 |

**Table 6. Impact of storage condition, storage period and their interactions on germination of short duration rice varieties**.

| **Storage condition** | **Germination (%)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1 MAS** | **2 MAS** | **3 MAS** | **4 MAS** | **5 MAS** | **6 MAS** | **7MAS** | **8 MAS** | **9 MAS** | **Mean SC** |
| **SC 1** | 99.00 (9.95)[a] | 97.41 (9.92)[b] | 96.00 (9.84)[d] | 94.58 (9.77)[d] | 92.25 (9.65)[fg] | 90.00 (9.53)[h] | 86.00 (9.32)[j] | 80.25 (9.01)[m] | 76.60 (8.81)[o] | **90.24 (9.54)[a]** |
| **SC 2** | 99.00 (9.95)[a] | 96.83 (9.89)[b] | 95.16 (9.80)[d] | 93.91 (9.74)[d] | 92.5 (9.66)[fg] | 89.83 (9.52)[h] | 85.08 (9.27)[k] | 78.75 (8.93)[n] | 74.60 (8.69)[q] | **89.53 (9.50)[c]** |
| **SC 3** | 99.00 (9.95)[a] | 97.75 (9.93)[b] | 96.33 (9.86)[d] | 94.08 (9.75)[d] | 92.91 (9.69)[ef] | 90.41 (9.56)[h] | 86.16 (9.33)[j] | 80.41 (9.02)[m] | 75.83 (8.76)[op] | **90.32 (9.54)[a]** |
| **SC 4** | 99.00 (9.95)[a] | 95.75 (9.83)[c] | 94.08 (9.75)[d] | 91.83 (9.63)[g] | 89.66 (9.52)[h] | 88.08 (9.43)[i] | 82.83 (9.15)[l] | 76.33 (8.79)[op] | 71.41 (8.50)[r] | **87.67 (9.40)[d]** |
| **SC 5** | 99.00 (9.95)[a] | 97.16 (9.90)[b] | 95.91 (9.84)[d] | 93.75 (9.73)[de] | 92.08 (9.64)[fg] | 90.16 (9.54)[h] | 85.58 (9.30)[jk] | 80.08 (8.99)[m] | 75.66 (8.75)[p] | **89.94 (9.52)[b]** |
| **Mean MAS** | **99.00 (9.95)[a]** | **96.98 (9.89)[b]** | **95.50 (9.82)[c]** | **93.63 (9.72)[d]** | **91.88 (9.63)[e]** | **89.70 (9.52)[f]** | **85.13 (9.28)[g]** | **79.17 (8.95)[h]** | **74.85 (8.70)[i]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.146 | 0.074 | 0.052 |
| SC x MAS | 0.437 | 0.222 | 0.157 |

**Table 7. Impact of varieties, storage condition and their interactions on germination of short duration rice varieties.**

| VAR | Germination (%) | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| **Harsha** | 91.11 (9.59)$^{b}$ | 90.33 (9.54)$^{cde}$ | 91.00 (9.58)$^{bc}$ | 88.44 (9.44)$^{g}$ | 90.44 (9.55)$^{cde}$ | **90.27 (9.54)$^{b}$** |
| **Matta Triveni** | 91.92 (9.63)$^{a}$ | 91.14 (9.59)$^{b}$ | 92.03 (9.63)$^{a}$ | 89.96 (9.52)$^{def}$ | 91.85 (9.62)$^{a}$ | **91.39 (9.60)$^{a}$** |
| **Manuratna** | 90.48 (9.55)$^{cd}$ | 89.77 (9.51)$^{f}$ | 90.37 (9.54)$^{def}$ | 87.85 (9.41)$^{h}$ | 89.96 (9.52)$^{ef}$ | **89.69 (9.51)$^{c}$** |
| **Kanchana** | 87.44 (9.39)$^{h}$ | 86.85 (9.36)$^{i}$ | 87.88 (9.42)$^{h}$ | 84.40 (9.23)$^{j}$ | 87.48 (9.40)$^{hi}$ | **86.82 (9.36)$^{d}$** |
| **Mean SC** | **90.24 (9.54)$^{a}$** | **89.53 (9.50)$^{c}$** | **90.32 (9.54)$^{a}$** | **87.67 (9.40)$^{d}$** | **89.94 (9.52)$^{b}$** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.13 | 0.066 | 0.047 |
| SC | 0.146 | 0.074 | 0.052 |
| VAR x SC | 0.291 | 0.148 | 0.105 |

**Table 8. Impact of varieties, storage conditions, storage periods and their interactions on germination (%) of short duration rice varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 100.00 | 100.00 | 100.00 | 96.00 | 100.00 | 100.00 | 100.00 | 96.00 | 100.00 | 100.00 | 100.00 | 96.00 |
| **2MAS** | 98.00 | 98.67 | 98.00 | 95.00 | 97.33 | 98.00 | 97.67 | 94.33 | 98.33 | 99.00 | 98.00 | 95.67 |
| **3MAS** | 96.33 | 98.00 | 96.67 | 93.00 | 95.67 | 97.00 | 95.67 | 92.33 | 96.67 | 98.00 | 97.00 | 93.67 |
| **4MAS** | 95.33 | 96.67 | 95.67 | 90.67 | 95.00 | 96.00 | 94.67 | 90.00 | 94.33 | 97.33 | 94.33 | 90.33 |
| **5MAS** | 93.33 | 94.33 | 93.33 | 88.00 | 93.33 | 94.67 | 93.67 | 88.33 | 93.67 | 95.67 | 93.00 | 89.33 |
| **6MAS** | 90.67 | 92.00 | 91.33 | 86.00 | 90.67 | 92.00 | 91.00 | 85.67 | 91.33 | 92.00 | 91.67 | 86.67 |
| **7MAS** | 87.33 | 88.67 | 84.33 | 83.67 | 86.33 | 87.67 | 82.67 | 83.67 | 87.67 | 89.00 | 84.00 | 84.00 |
| **8MAS** | 81.33 | 81.33 | 79.33 | 79.00 | 79.33 | 79.67 | 78.33 | 77.67 | 81.33 | 81.00 | 79.67 | 79.67 |
| **9MAS** | 77.67 | 77.67 | 75.67 | 75.67 | 75.33 | 75.33 | 74.33 | 73.67 | 75.67 | 76.33 | 75.67 | 75.67 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 100.00 | 100.00 | 100.00 | 96.00 | 100.00 | 100.00 | 100.00 | 96.00 |
| **2MAS** | 96.33 | 97.00 | 97.00 | 92.67 | 97.67 | 98.33 | 98.00 | 94.67 |
| **3MAS** | 93.33 | 96.33 | 95.33 | 91.33 | 95.67 | 98.00 | 96.33 | 93.67 |
| **4MAS** | 92.33 | 95.67 | 92.33 | 87.00 | 93.67 | 97.00 | 94.33 | 90.00 |
| **5MAS** | 90.33 | 93.00 | 90.33 | 85.00 | 93.00 | 94.67 | 92.33 | 88.33 |
| **6MAS** | 89.33 | 90.33 | 88.33 | 84.33 | 90.67 | 93.00 | 91.00 | 86.00 |
| **7MAS** | 85.00 | 85.33 | 81.00 | 80.00 | 86.67 | 88.33 | 83.67 | 83.67 |
| **8MAS** | 78.00 | 78.33 | 75.33 | 73.67 | 80.33 | 81.00 | 79.33 | 79.67 |
| **9MAS** | 71.33 | 73.67 | 71.00 | 69.67 | 76.33 | 76.33 | 74.67 | 75.33 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | 0.874 | 0.444 | 0.314 |

#### 4.1.2.1.5 Influence of storage environment on germination (%)

##### 4.1.2.1.5.1 Comparison between ambient environment within and outside the storage structures

The average weekly temperature and RH (%) in various storage environments and the parameters recorded outside the storage environment is detailed in Table 9, (Appendix) and Fig.3 and 4.

The temperature inside SC3 (R.C.C. + ventilation) varied between 26.0 $^{O}$C and 31.5 $^{O}$C, while in SC1 (Asbestos + ventilation) it ranged between 26.5 $^{O}$C and 31.5 $^{O}$C. In SC5 (Asbestos + forced ventilation), it ranged between 27.0 $^{O}$C and 32.0$^{O}$C, respectively. The temperature inside SC4 (R.C.C. + ventilation) varied between 28.0 $^{O}$C and 33.0 $^{O}$C, while in SC2 (Asbestos + ventilation) it varied from 27.0 $^{O}$C to 31.5 $^{O}$C.

The relative humidity inside SC5 (Asbestos + forced ventilation: 64.0% to 87.0%) was relatively lower than that in SC1 (Asbestos + ventilation: 66.0% to 88.0%) and SC3 (R.C.C. + ventilation: 69.5% to 90.0%). Throughout the storage period, higher RH was observed in SC4 (R.C.C. + without ventilation: 74.0% to 96.0%) and SC2 (Asbestos + without ventilation: 72.0% to 92.0%).

##### 4.1.2.1.5.2 Impact of storage temperature (T) on germination (%)

The correlation between weekly storage temperatures recorded during the 38 weeks of storage period and reduction in germination per cent of different short duration varieties stored various different storage condition was analyzed. The results are presented in Table 10 and Appendix.

Temperature within the storage environment during 1$^{st}$, 10$^{th}$, 11$^{th}$ and 13$^{th}$ weeks registered a significant positive correlation with reduction in germination in all varieties, the correlation being highly significant in case of variety Kanchana in the 13$^{th}$ week of storage (r = 0.880**).

Storage temperature during the 1$^{st}$ week (4$^{th}$ to 11$^{th}$ May, 2019), was 28.4 $^{O}$C in SC1, 29 $^{O}$C in SC2, 28.3 $^{O}$C in SC3, 29.5 $^{O}$C in SC4 and 28.2 $^{O}$C in SC5.

**Table 9. Average weekly temperature and RH (%) under ambient and different storage condition.**

| Weeks | Ambient | | SC1 | | SC2 | | SC3 | | SC4 | | SC5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp | RH | Temp | RH | Temp | RH | Temp | RH | Temp | RH | Temp | RH |
| W1 | 35.3 | 89.0 | 28.4 | 79.8 | 29.0 | 80.0 | 28.3 | 81.3 | 29.5 | 84.0 | 28.2 | 81.0 |
| W2 | 34.0 | 87.0 | 27.5 | 80.0 | 28.4 | 80.5 | 28.0 | 84.0 | 28.9 | 86.0 | 27.6 | 80.0 |
| W3 | 34.8 | 87.0 | 27.7 | 81.0 | 28.8 | 83.0 | 28.3 | 86.5 | 29.4 | 89.0 | 27.7 | 79.0 |
| W4 | 33.4 | 89.0 | 28.0 | 86.5 | 29.4 | 86.5 | 28.0 | 88.7 | 29.1 | 90.5 | 28.0 | 85.0 |
| W5 | 34.4 | 83.0 | 28.4 | 87.0 | 29.8 | 87.6 | 27.9 | 89.8 | 29.0 | 92.3 | 28.1 | 86.0 |
| W6 | 30.5 | 87.0 | 29.0 | 88.0 | 30.0 | 90.0 | 28.0 | 88.0 | 29.5 | 93.0 | 29.0 | 87.0 |
| W7 | 29.4 | 86.0 | 30.0 | 71.0 | 30.0 | 86.0 | 29.0 | 78.0 | 31.0 | 88.5 | 30.0 | 66.0 |
| W8 | 31.8 | 97.0 | 30.5 | 68.5 | 30.5 | 75.0 | 29.5 | 81.5 | 31.5 | 86.5 | 29.5 | 64.7 |
| W9 | 31.1 | 95.0 | 30.5 | 72.0 | 30.7 | 75.6 | 29.4 | 80.6 | 31.9 | 82.0 | 29.2 | 64.5 |
| W10 | 32.3 | 92.0 | 29.6 | 76.5 | 30.2 | 79.5 | 29.0 | 83.2 | 31.2 | 84.5 | 29.0 | 69.1 |
| W11 | 27.7 | 98.0 | 26.5 | 88.0 | 27.0 | 88.0 | 26.0 | 92.0 | 28.0 | 96.0 | 27.0 | 81.0 |
| W12 | 28.9 | 92.0 | 26.7 | 86.0 | 27.0 | 86.0 | 26.0 | 82.0 | 28.0 | 90.5 | 27.5 | 81.0 |
| W13 | 31.0 | 98.0 | 27.8 | 85.1 | 28.1 | 85.5 | 27.1 | 90.5 | 28.8 | 91.6 | 27.9 | 80.6 |
| W14 | 25.0 | 97.0 | 28.5 | 84.7 | 28.8 | 84.8 | 27.5 | 90.3 | 29.5 | 90.7 | 28.1 | 80.5 |
| W15 | 29.6 | 92.0 | 26.5 | 78.0 | 29.5 | 77.5 | 30.0 | 74.5 | 29.5 | 78.0 | 30.0 | 74.5 |
| W16 | 29.0 | 99.0 | 26.7 | 77.5 | 29.0 | 77.2 | 29.2 | 77.7 | 29.5 | 81.5 | 29.0 | 76.0 |
| W17 | 29.4 | 98.0 | 27.8 | 81.0 | 28.6 | 80.8 | 28.8 | 80.1 | 29.1 | 83.8 | 28.6 | 79.6 |
| W18 | 30.5 | 91.0 | 28.5 | 81.7 | 28.1 | 82.6 | 28.2 | 82.1 | 28.6 | 86.8 | 28.0 | 79.4 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W19 | 32.1 | 90.0 | 30.0 | 75.0 | 30.5 | 78.0 | 30.5 | 69.5 | 31.0 | 79.0 | 30.0 | 74.5 |
| W20 | 31.9 | 98.0 | 29.2 | 81.5 | 29.5 | 83.2 | 29.7 | 75.5 | 30.2 | 82.0 | 29.2 | 79.2 |
| W21 | 33.1 | 98.0 | 29.0 | 82.5 | 29.3 | 82.6 | 29.5 | 78.6 | 30.1 | 83.0 | 29.1 | 81.8 |
| W22 | 32.5 | 96.0 | 30.0 | 78.6 | 30.5 | 78.7 | 29.6 | 78.6 | 30.3 | 82.0 | 30.6 | 76.8 |
| W23 | 34.2 | 93.0 | 31.0 | 66.0 | 31.0 | 72.0 | 29.0 | 71.0 | 30.0 | 78.0 | 32.0 | 66.0 |
| W24 | 33.7 | 94.0 | 30.5 | 72.0 | 31.0 | 75.5 | 30.2 | 74.5 | 31.0 | 78.5 | 31.5 | 72.5 |
| W25 | 32.7 | 95.0 | 30.6 | 72.0 | 31.3 | 74.6 | 29.8 | 75.6 | 30.6 | 80.6 | 32.0 | 68.6 |
| W26 | 33.1 | 90.0 | 30.7 | 72.0 | 31.5 | 74.2 | 29.3 | 76.0 | 30.2 | 81.7 | 32.5 | 64.2 |
| W27 | 31.9 | 93.0 | 29.0 | 78.0 | 28.5 | 80.0 | 28.5 | 78.0 | 29.0 | 80.0 | 30.0 | 71.0 |
| W28 | 33.6 | 95.0 | 28.9 | 76.5 | 28.6 | 79.0 | 28.4 | 79.0 | 28.8 | 81.0 | 29.7 | 72.5 |
| W29 | 32.0 | 95.0 | 29.1 | 73.6 | 29.1 | 76.3 | 28.2 | 76.0 | 28.5 | 84.6 | 29.8 | 68.0 |
| W30 | 32.1 | 81.0 | 29.3 | 71.5 | 29.4 | 73.5 | 28.4 | 73.0 | 28.7 | 82.1 | 28.8 | 66.5 |
| W31 | 31.5 | 70.0 | 29.8 | 68.0 | 31.0 | 70.0 | 30.0 | 70.0 | 31.3 | 74.0 | 30.5 | 70.0 |
| W32 | 33.0 | 74.0 | 31.2 | 69.0 | 30.5 | 72.0 | 30.2 | 70.5 | 30.2 | 76.0 | 30.2 | 72.5 |
| W33 | 32.3 | 69.0 | 30.8 | 70.6 | 30.2 | 73.6 | 30.5 | 73.8 | 30.3 | 78.3 | 30.0 | 72.0 |
| W34 | 33.0 | 70.0 | 30.3 | 73.2 | 29.9 | 77.2 | 29.9 | 76.6 | 30.0 | 82.7 | 29.8 | 74.7 |
| W35 | 34.6 | 77.0 | 29.8 | 74.0 | 30.0 | 77.0 | 30.5 | 75.0 | 31.0 | 83.0 | 29.6 | 71.0 |
| W36 | 33.0 | 78.0 | 30.0 | 70.0 | 31.5 | 74.0 | 30.0 | 71.0 | 30.5 | 78.0 | 30.0 | 75.0 |
| W37 | 34.0 | 79.0 | 31.0 | 68.0 | 31.0 | 70.0 | 30.5 | 70.0 | 30.0 | 74.0 | 30.5 | 70.0 |
| W38 | 34.5 | 72.0 | 31.5 | 70.0 | 31.5 | 71.0 | 31.5 | 72.0 | 31.0 | 78.0 | 31.0 | 64.0 |
| Avg | 32.0 | 88.5 | 29.2 | 76.6 | 29.7 | 78.9 | 29.0 | 77.8 | 29.8 | 83.4 | 29.4 | 74.6 |

During the 10th week (5th to 12th July, 2019) it varied between 29.0$^{O}$C in SC3 and SC5, and 31.2$^{O}$C in SC4 (SC1: 29.7$^{O}$C, SC2: 30.2 $^{O}$C, SC3: 29.0$^{O}$C, SC4: 31.2$^{O}$C and SC5: 29.0$^{O}$C).

It was 26.5 $^{O}$C in SC1, 27.0 $^{O}$C in SC2, 26.0 $^{O}$C in SC3, 28.0 $^{O}$C in SC4 and 27.0 $^{O}$C in SC5 during the 11th week (12th to 19th July, 2019) and 27.8 $^{O}$C in SC1, 28.1 $^{O}$C in SC2, 27.1 $^{O}$C in SC3, 28.8 $^{O}$C in SC4 and 27.9 $^{O}$C in SC5 during 13th week (26th July to 3rd Aug, 2019).

**Table 10. Correlation between storage temperature and reduction in germination (%) of short duration varieties.**

| **Storage temperature (Weeks)** | **Varieties** | | | |
|---|---|---|---|---|
| | **Harsha** | **Matta Triveni** | **Manuratna** | **Kanchana** |
| **1** | 0.915* | 0.875* | 0.887* | 0.951* |
| **10** | 0.897* | 0.788* | 0.878* | 0.938* |
| **11** | 0.946* | 0.810* | 0.942* | 0.900* |
| **13** | 0.908* | 0.733* | 0.898* | 0.880** |

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

### 4.1.2.1.5.3 Impact of relative humidity (RH) on germination (%)

The correlation between weekly relative humidity recorded during the 38 weeks of storage period and reduction in germination per cent of different short duration varieties stored in different storage condition was analyzed. The results are presented in Table 11 and Appendix.

**Table 11. Influence of relative humidity (%) and reduction in germination (%) of short duration varieties.**

| Relative humidity (Weeks) | Varieties | | | |
|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana |
| **24** | 0.880* | 0.954* | 0.864* | 0.917* |
| **31** | 0.931* | 0.954* | 0.943* | 0.921* |
| **32** | 0.949* | 0.943* | 0.951* | 0.900* |
| **33** | 0.893* | 0.953* | 0.895* | 0.917* |
| **34** | 0.920* | 0.967* | 0.917* | 0.942* |
| **36** | 0.914* | 0.889* | 0.911* | 0.842* |
| **37** | 0.931* | 0.954* | 0.943* | 0.921* |

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Relative humidity showed a significant positive correlation with reduction in germination during 24$^{th}$, 31$^{st}$, 32$^{nd}$, 33$^{rd}$, 34$^{th}$, and 36$^{th}$ weeks in all the varieties.

Relative humidity during the 24$^{th}$ week (11$^{th}$ to 18$^{th}$ Oct, 2019), was 72.0 per cent in SC1, 75.5 per cent in SC2, 74.5 per cent in SC3, 78.5 per cent in SC4 and 72.5 per cent in SC5.

During the 31$^{st}$ week (29$^{th}$ Nov to 6$^{th}$ Dec, 2019) it varied between 68.0 per cent in SC1 and 74.0 per cent in SC4 (SC1: 68%, SC2: 72.0%, SC3: 70.0%, SC4: 74% and SC5: 70.0%).

It was 69.0 per cent in SC1, 72.0 per cent in SC2, 70.5 per cent in SC3, 76.0 per cent in SC4 and 72.5 per cent in SC5 during the 32$^{nd}$ week (6$^{th}$ to 13$^{th}$ Dec, 2019) and 70.65 per cent in SC1, 73.6 per cent in SC2, 73.8 per cent in SC3, 78.30 per cent in SC4 and 72.0 per cent in SC5 during 33$^{rd}$ week (13$^{th}$ to 20$^{th}$ Dec, 2019).

During the 34th week (20th to 27th Dec) it varied between 73.2 per cent in SC1 and 82.7 per cent in SC4 (SC1: 73.2%, SC2: 77.2%, SC3: 76.6%, SC4: 82.7% and SC5: 74.7%). It was 74.0 per cent in SC1, 77.0 per cent in SC2, 75.0 per cent in SC3, 83.0 per cent in SC4 and 71.0 per cent in SC5 during the 36th week (3rd to 10th Jan, 2020) and 70.6 per cent in SC1, 73.6 per cent in SC2, 73.8 per cent in SC3, 78.3 per cent in SC4 and 72.0 per cent in SC5 during 37th week (10th to 17th Jan, 2020).

#### 4.1.2.1.5.4 Impact of Temperature Humidity Index (THI) on germination (%)

The correlation between combined effect of weekly storage temperature and relative humidity recorded during the 38 weeks of storage period and reduction in germination per cent of different short duration varieties stored in different storage condition was analyzed. The results are presented in Table 12 and Appendix.

**Table 12. Influence of Temperature Humidity Index (THI) on reduction in germination (%) of short duration varieties.**

| Temperature Humidity Index (Weeks) | Varieties | | | |
|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana |
| 1 | 0.957* | 0.924* | 0.942* | 0.987* |
| 2 | 0.855* | 0.935* | 0.844* | 0.899* |
| 11 | 0.982* | 0.887* | 0.982* | 0.994* |
| 13 | 0.952* | 0.850* | 0.954* | 0.984* |
| 14 | 0.892* | 0.782* | 0.881* | 0.942* |
| 19 | 0.908* | 0.823* | 0.884* | 0.944** |
| 20 | 0.931* | 0.883** | 0.916* | 0.973* |
| 21 | 0.971** | 0.935* | 0.975* | 0.989* |

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Temperature-Humidity Index (THI) showed a significant positive correlation with reduction in germination during 1st, 2nd, 11th, 13th, 14th, 19th, 20th and 21st weeks, the correlation being highly significant in case of variety Harsha, Matta Triveni, and Kanchana during 21st (r = 0.971**), 20th (r = 0.883**), and 19th (r = 0.944**) week of storage, respectively.

THI during the 1st week (4th to 11th May, 2019), was 80.38 in SC1, 81.41 in SC2, 80.46 in SC3, 82.79 in SC4 and 80.26 in SC5.

During the 2nd week (11th to 18th May, 2019) it varied between 79 in SC1 and 82.08 in SC4 (SC1: 79, SC2: 80.51, SC3: 80.32, SC4: 82.08 and SC5: 79.16).

It was 81.97 in SC1, 83.28 in SC2, 81.89 in SC3, 85.77 in SC4 and 79.92 in SC5 during the 11th week (5th to 12th July, 2019) and 80.19 in SC1, 80.73 in SC2, 79.68 in SC3, 82.79 in SC4 and 79.78 in SC5 during 13th week (19th to 26th July, 2019).

During the 14th week (26th July to 3rd Aug, 2019) it varied between 81.28 in SC1 and 84.92 in SC4 (SC1: 81.28, SC2: 81.85, SC3: 82.19, SC4: 84.92 and SC5: 82.12). It was 82.71 in SC1, 83.50 in SC2, 82.19 in SC3, 84.45 in SC4 and 82.19 in SC5 during the 19th week (6th to 13th Sept, 2020) and 82.80 in SC1, 83.62 in SC2, 82.20 in SC3, 83.91 in SC4 and 83.51 in SC5 during 20th week (13th to 20th Sept, 2020). It was 82.38 in SC1, 83.33 in SC2, 80.15 in SC3, 82.71 in SC4 and 81.84 in SC5 during the 21st week.

#### 4.1.2.3 VIGOUR INDEX – I

The results on vigour index - I as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are presented in Tables 13, 14, 15 and 16.

#### 4.1.2.5.1 Effect of varieties (VAR)

Irrespective of storage period and the storage conditions, vigour index - I varied significantly between the varieties (Table 13).

Variety Matta Triveni (1816.00) registered the highest vigour index - I estimate followed by Kanchana (1731.00). MT and Kanchana were found to be on par with each other. Varieties Harsha (1682.00) and Manuratna (1673.00) with vigour index - I of 1682.00and 1673.00 respectively with were on par with each other as well as Kanchana.

**4.1.2.5.2 Effect of period of storage (MAS)**

Irrespective of varieties and the storage conditions, vigour index – I was found to significantly influenced by storage duration (Table 13).

Vigour index – I declined progressively over the storage period from 1987.00 during 1 MAS to 1305.00 at 9 MAS. VI-I towards the end of storage period differed significantly (8MAS: 1438.00; 9 MAS: 1305.00) from estimates in the initial months.

**4.1.2.5.3 Effect of storage condition (SC)**

Irrespective of varieties and the storage period, vigour index – I was found to be significantly influenced by storage condition (Table 14).

VI-I varied between 1695.00 (SC4: R.C.C. + without ventilation) and 1759.00 (SC3: R.C.C. + ventilation). SC3 was found to be significantly superior vigour index -I over all other storage conditions. SC1 (Asbestos + ventilation: 1735.00) and SC5 (Asbestos + forced ventilation: 1733.00) which were found to on par with each other and next best to SC3. Vigour index-I in SC2 (Asbestos + without ventilation: 1706.00) followed by SC4 (R.C.C. + without ventilation: 1695.00) and was significantly lower than other conditions and also differed significantly from each other.

**4.1.2.5.4 Effect to interaction**

**4.1.2.5.4.1 Varieties × Storage period (VAR x MAS)**

The interaction between varieties and storage period, did not significantly influence vigour index - I (Table 13).

**4.1.2.5.4.2 Storage condition × Storage period (SC x MAS)**

The interaction between different storage conditions and storage period, did not significantly influence vigour index - I (Table 14).

#### 4.1.2.5.4.3 Varieties × Storage condition (VAR x SC)

The interaction between varieties and storage conditions, did not significantly influence vigour index - I (Table 15).

#### 4.1.2.5.4.4 Varieties × Storage condition × Storage period (VAR x SC x MAS)

The interaction between varieties, storage conditions and period of storage, did not significantly influence vigour index - I (Table 16).

**Table 13. Impact of varieties, storage period and their interactions on vigour index-I of short duration varieties.**

| VAR | Vigour index –I | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8MAS** | **9MAS** | **Mean VAR** |
| **Harsha** | 1940.00 | 1867.00 | 1821.00 | 1815.00 | 1717.00 | 1654.00 | 1534.00 | 1497.00 | 1286.00 | **1682.00[b]** |
| **Matta triveni** | 2110.00 | 2063.00 | 2024.00 | 1942.00 | 1874.00 | 1784.00 | 1673.00 | 1496.00 | 1378.00 | **1816.00[a]** |
| **Manuratna** | 1880.00 | 1835.00 | 1817.00 | 1800.00 | 1731.00 | 1681.00 | 1807.00 | 1308.00 | 1192.00 | **1673.00[b]** |
| **Kanchana** | 2016.00 | 1953.00 | 1932.00 | 1831.00 | 1769.00 | 1681.00 | 1583.00 | 1450.00 | 1363.00 | **1731.00[ab]** |
| **Mean MAS** | **1987.00[a]** | **1929.00[ab]** | **1898.00[abc]** | **1847.00[bc]** | **1773.00[cd]** | **1700.00[d]** | **1649.00[d]** | **1438.00[e]** | **1305.00[e]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 58.45 | 29.72 | 21.02 |
| MAS | 87.67 | 44.58 | 31.52 |
| VAR x MAS | N/A | 89.16 | 63.05 |

**Table 14. Impact of storage condition, storage period and their interactions on vigour index-I of short duration varieties.**

| Storage condition (SC) | Vigour index –I | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8MAS** | **9MAS** | **Mean SC** |
| **SC 1** | 1987.00 | 1951.00 | 1916.00 | 1875.00 | 1787.00 | 1707.00 | 1577.00 | 1460.00 | 1349.00 | **1735.00**$^{b}$ |
| **SC 2** | 1987.00 | 1902.00 | 1877.00 | 1858.00 | 1780.00 | 1690.00 | 1542.00 | 1419.00 | 1295.00 | **1706.00**$^{c}$ |
| **SC 3** | 1987.00 | 1993.00 | 1947.00 | 1880.00 | 1823.00 | 1748.00 | 1612.00 | 1490.00 | 1345.00 | **1759.00**$^{a}$ |
| **SC 4** | 1987.00 | 1860.00 | 1832.00 | 1757.00 | 1681.00 | 1626.00 | 1945.00 | 1355.00 | 1207.00 | **1695.00**$^{d}$ |
| **SC 5** | 1987.00 | 1941.00 | 1920.00 | 1863.00 | 1793.00 | 1729.00 | 1570.00 | 1465.00 | 1328.00 | **1733.00**$^{b}$ |
| **Mean MAS** | **1987.00**$^{a}$ | **1929.00**$^{ab}$ | **1898.00**$^{abc}$ | **1847.00**$^{bc}$ | **1773.32**$^{cd}$ | **1700.00**$^{d}$ | **1649.00**$^{d}$ | **1438.00**$^{e}$ | **1305.00**$^{e}$ | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 54.82 | 33.23 | 23.50 |
| MAS | 87.67 | 44.58 | 31.52 |
| SC x MAS | N/A | 99.68 | 70.49 |

**Table 15. Impact of varieties, storage condition and their interactions on vigour index-I of short duration varieties.**

| VAR | Vigour index –I | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| **Harsha** | 1694.00 | 1677.00 | 1727.00 | 1610.00 | 1697.00 | **1682.00$^{b}$** |
| **Matta Triveni** | 1839.00 | 1801.00 | 1856.00 | 1749.00 | 1835.00 | **1816.00$^{a}$** |
| **Manuratna** | 1647.00 | 1620.00 | 1676.00 | 1771.00 | 1647.00 | **1673.00$^{b}$** |
| **Kanchana** | 1756.00 | 1724.00 | 1775.00 | 1648.00 | 1752.00 | **1731.00$^{ab}$** |
| **Mean SC** | **1735.00$^{b}$** | **1706.00$^{c}$** | **1759.00$^{a}$** | **1695.00$^{d}$** | **1733.00$^{b}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 58.45 | 29.72 | 21.02 |
| SC | 54.82 | 33.23 | 23.50 |
| VAR x SC | N/A | 66.46 | 46.99 |

**Table 16. Impact of varieties, storage conditions, storage periods and their interactions on vigour index-I of short duration varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 1940.00 | 2110.00 | 1880.00 | 2016.00 | 1940.00 | 2110.00 | 1880.00 | 2016.00 | 1940.00 | 2110.00 | 1880.00 | 2016.00 |
| **2MAS** | 1885.00 | 2082.00 | 1849.00 | 1989.00 | 1840.00 | 2038.00 | 1804.00 | 1928.00 | 1941.00 | 2125.00 | 1888.00 | 2022.00 |
| **3MAS** | 1843.00 | 2055.00 | 1817.00 | 1949.00 | 1808.00 | 1998.00 | 1786.00 | 1919.00 | 1872.00 | 2058.00 | 1888.00 | 1972.00 |
| **4MAS** | 1840.00 | 1975.00 | 1827.00 | 1859.00 | 1840.00 | 1939.00 | 1821.00 | 1836.00 | 1849.00 | 1976.00 | 1830.00 | 1867.00 |
| **5MAS** | 1727.00 | 1899.00 | 1742.00 | 1783.00 | 1733.00 | 1868.00 | 1742.00 | 1778.00 | 1751.00 | 1936.00 | 1780.00 | 1825.00 |
| **6MAS** | 1644.00 | 1797.00 | 1702.00 | 1688.00 | 1653.00 | 1766.00 | 1665.00 | 1676.00 | 1708.00 | 1849.00 | 1739.00 | 1699.00 |
| **7MAS** | 1555.00 | 1691.00 | 1459.00 | 1606.00 | 1514.00 | 1660.00 | 1408.00 | 1587.00 | 1593.00 | 1718.00 | 1492.00 | 1649.00 |
| **8MAS** | 1499.00 | 1521.00 | 1325.00 | 1496.00 | 1488.00 | 1469.00 | 1293.00 | 1429.00 | 1560.00 | 1534.00 | 1354.00 | 1514.00 |
| **9MAS** | 1320.00 | 1429.00 | 1228.00 | 1420.00 | 1286.00 | 1361.00 | 1187.00 | 1348.00 | 1329.00 | 1405.00 | 1233.00 | 1415.00 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 1940.00 | 2110.00 | 1880.00 | 2016.00 | 1940.00 | 2110.00 | 1880.00 | 2016.00 |
| **2MAS** | 1792.00 | 1989.00 | 1785.00 | 1875.00 | 1878.00 | 2081.00 | 1852.00 | 1953.00 |
| **3MAS** | 1739.00 | 1959.00 | 1761.00 | 1871.00 | 1843.00 | 2055.00 | 1834.00 | 1951.00 |
| **4MAS** | 1720.00 | 1872.00 | 1705.00 | 1734.00 | 1827.00 | 1950.00 | 1818.00 | 1860.00 |
| **5MAS** | 1638.00 | 1786.00 | 1635.00 | 1669.00 | 1739.00 | 1884.00 | 1760.00 | 1790.00 |
| **6MAS** | 1578.00 | 1704.00 | 1599.00 | 1625.00 | 1689.00 | 1807.00 | 1702.00 | 1720.00 |
| **7MAS** | 1468.00 | 1599.00 | 3243.00 | 1472.00 | 1543.00 | 1699.00 | 1436.00 | 1604.00 |
| **8MAS** | 1434.00 | 1431.00 | 1230.00 | 1328.00 | 1508.00 | 1528.00 | 1338.00 | 1487.00 |
| **9MAS** | 1187.00 | 1297.00 | 1103.00 | 1245.00 | 1313.00 | 1402.00 | 1210.00 | 1391.00 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | N/A | 199.37 | 140.97 |

### 4.1.2.3 VIGOUR INDEX – II

The results on vigour index - II as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are enumerated in Tables 17, 18, 19 and 20.

#### 4.1.2.3.1 Effect of varieties (VAR)

Irrespective of the period of storage and storage condition, vigour index - II was found to vary significantly between the varieties (Table 17).

Variety Kanchana (2058.00) registered significant superior vigour index - II over all other varieties, while Manurathna registered the least (1557.00). Matta Triveni (1870.00) followed by Harsha (1669.00) were next best to Kanchana. Matta Triveni and Harsha had also differed significantly from each other.

#### 4.1.2.3.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, vigour index - II was found to be significantly influenced by period of storage (Table 17).

Vigour index – II declined progressively and significantly over the storage period *i.e.,* from 2053.00 at 1 MAS to 1443.00 at 9 MAS. .VI-I at 1 MAS was significantly superior over other months, while the estimates from 2 MAS (1959.00) to 4 MAS (1878.00) were on par with each other. The VI-II towards the end of storage *i.e.,* 8 MAS (1536.00) and 9 MAS (1443.00), were on par with each other.

#### 4.1.2.3.3 Effect of storage condition (SC)

Irrespective of varieties and the storage period, vigour index - II was found to be significantly influenced by the different storage conditions (Table 18).

Vigour Index-II of seeds stored in SC3 (R.C.C. + ventilation: 1827.00), SC1 (Asbestos + ventilation: 1815.00) and SC5 (Asbestos + forced ventilation: 1813.00) were found to on par with each other and were significantly superior over those stored in SC 2

(Asbestos + without ventilation: 1761.00) and SC4 (R.C.C. + without ventilation: 1689.00). SC2 and SC4 were found to differ significantly from each other.

**4.1.2.3.4 Effect to interaction**

**4.1.2.3.4.1 Varieties × Storage period (VAR × MAS)**

Irrespective of the storage conditions, vigour index -II was found to be significantly influenced by the interaction between varieties and storage period (Table 17).

All the varieties showed a progressive decline in vigour index - II was recorded over the storage period. Vigour index -II of variety Kanchana was significantly superior throughout the storage period and varied between 2332.00 (1 MAS) to 1638.00 (9 MAS), whereas Manuratna had registered the least estimate for most part of storage ranging between 1710.00 (1 MAS) to 1470.00 (9 MAS). Matta Triveni was next best to Kanchana.

**4.1.2.3.4.2 Storage condition × Storage period (SC × MAS)**

Irrespective of the varieties, vigour index -II was found to be significantly influenced by the interaction between different storage conditions and the period of storage (Table 18).

Vigour Index-II during 1 MAS was 2053.00 under all storage conditions and subsequently, at 9 MAS, it declined to 1434.00, 1699.00, 1430.00, 1252.00 and 1402.00 in SCI (Asbestos + ventilation), SC2 (Asbestos + without ventilation), SC3 (R.C.C. + ventilation), SC4 (R.C.C. + without ventilation) and SC5 (Asbestos + forced ventilation), respectively.

**4.1.2.3.4.3 Varieties × Storage condition (VAR × SC)**

Irrespective of the storage period, the interaction between varieties and storage conditions did not significantly influence vigour index -II (Table 19).

**4.1.2.3.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

The interaction between varieties, storage conditions and storage period on vigour index -II was found to be non-significant (Table 20).

**Table 17. Impact of varieties, storage period and their interactions on vigour index - II of short duration varieties.**

| VAR | Vigour index – II | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean VAR |
| **Harsha** | 1990.00 | 1841.00 | 1,805.17 | 1761.00 | 1693.00 | 1641.00 | 1558.00 | 1491.00 | 1243.00 | **1669.00[c]** |
| **Matta Triveni** | 2180.00 | 2021.00 | 2011.48 | 2023.00 | 1942.00 | 1922.00 | 1762.00 | 1545.00 | 1422.00 | **1870.00[b]** |
| **Manuratna** | 1710.00 | 1694.00 | 1634.95 | 1592.00 | 1586.00 | 1574.00 | 1438.00 | 1318.00 | 1470.00 | **1557.00[d]** |
| **Kanchana** | 2332.00 | 2282.00 | 2233.67 | 2139.00 | 2088.00 | 2035.00 | 1994.00 | 1784.00 | 1638.00 | **2058.00[a]** |
| **Mean MAS** | **2053.00[a]** | **1959.00[b]** | **1921.00[b]** | **1879.00[bc]** | **1827.00[c]** | **1793.00[c]** | **1688.00[d]** | **1535.00[e]** | **1443.00[e]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 38.898 | 19.778 | 13.985 |
| MAS | 58.347 | 29.668 | 20.978 |
| VAR x MAS | 116.695 | 59.335 | 41.956 |

**Table 18. Impact of storage condition, storage period and their interactions on vigour index – II of short duration varieties.**

| Storage condition (SC) | Vigour index – II | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean SC |
| SC 1 | 2053.00 | 2017.00 | 1964.00 | 1928.00 | 1858.00 | 1802.00 | 1711.00 | 1567.00 | 1434.00 | **1815.00[a]** |
| SC 2 | 2053.00 | 1911.00 | 1879.00 | 1867.00 | 1810.00 | 1775.00 | 1671.00 | 1541.00 | 1699.00 | **1761.00[b]** |
| SC 3 | 2053.00 | 1995.00 | 1978.00 | 1918.00 | 1893.00 | 1822.00 | 1754.00 | 1593.00 | 1430.00 | **1827.00 [a]** |
| SC 4 | 2053.00 | 1884.00 | 1845.00 | 1778.00 | 1708.00 | 1675.00 | 1589.00 | 1412.00 | 1252.00 | **1689.00[c]** |
| SC 5 | 2053.00 | 1989.00 | 1941.00 | 1903.00 | 1866.00 | 1889.00 | 1712.00 | 1557.00 | 1402.00 | **1813.00 [a]** |
| **Mean MAS** | **2053.00[a]** | **1959.00[b]** | **1921.00[b]** | **1879.00[bc]** | **1827.00[c]** | **1793.00[c]** | **1688.00[d]** | **1535.00[e]** | **1443.00[e]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 43.489 | 22.113 | 15.636 |
| MAS | 58.347 | 29.668 | 20.978 |
| SC x MAS | 130.468 | 66.339 | 46.909 |

**Table 19. Impact of varieties, storage condition and their interactions on vigour index - II of short duration varieties.**

| VAR | Vigour index – II | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| **Harsha** | 1690.00 | 1653.00 | 1715.00 | 1602.00 | 1688.00 | **1669.00[c]** |
| **Matta triveni** | 1919.00 | 1847.00 | 1912.00 | 1738.00 | 1932.00 | **1870.00[b]** |
| **Manuratna** | 1555.00 | 1653.00 | 1573.00 | 1459.00 | 1546.00 | **1557.00[d]** |
| **Kanchana** | 2096.00 | 2051.00 | 2105.00 | 1956.00 | 2085.00 | **2058.00[a]** |
| **Mean SC** | **1815.00 [a]** | **1761.00[b]** | **1827.00 [a]** | **1688.62[c]** | **1813.00 [a]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 38.898 | 19.778 | 13.985 |
| SC | 43.489 | 22.113 | 15.636 |
| VAR x SC | N/A | 44.226 | 31.273 |

**Table 20. Impact of varieties, storage conditions, storage periods and their interactions on vigour index - II of short duration varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 1990.00 | 2180.00 | 1710.00 | 2332.00 | 1990.00 | 2180.00 | 1710.00 | 2332.00 | 1990.00 | 2180.00 | 1710.00 | 2332.00 |
| **2MAS** | 1898.00 | 2118.00 | 1735.00 | 2318.00 | 1794.00 | 1924.00 | 1651.00 | 2273.00 | 1901.00 | 2043.00 | 1748.00 | 2287.00 |
| **3MAS** | 1827.00 | 2114.00 | 1640.00 | 2275.00 | 1763.00 | 1937.00 | 1604.00 | 2210.00 | 1879.00 | 2042.00 | 1701.00 | 2292.00 |
| **4MAS** | 1783.00 | 2111.00 | 1617.00 | 2203.00 | 1783.00 | 1949.00 | 1603.00 | 2133.00 | 1786.00 | 2089.00 | 1616.00 | 2180.00 |
| **5MAS** | 1668.00 | 2044.00 | 1574.00 | 2147.00 | 1652.00 | 1903.00 | 1623.00 | 2064.00 | 1783.00 | 1990.00 | 1649.00 | 2153.00 |
| **6MAS** | 1641.00 | 1886.00 | 1592.00 | 2090.00 | 1620.00 | 1865.00 | 1580.00 | 2036.00 | 1696.00 | 1926.00 | 1589.00 | 2080.00 |
| **7MAS** | 1569.00 | 1744.00 | 1507.00 | 2028.00 | 1531.00 | 1768.00 | 1392.00 | 1997.00 | 1628.00 | 1863.00 | 1476.00 | 2052.00 |
| **8MAS** | 1523.00 | 1597.00 | 1354.00 | 1796.00 | 1508.00 | 1604.00 | 1298.00 | 1758.00 | 1508.00 | 1604.00 | 1386.00 | 1877.00 |
| **9MAS** | 1307.00 | 1481.00 | 1269.00 | 1677.00 | 1236.00 | 1492.00 | 2418.00 | 1653.00 | 1266.00 | 1476.00 | 1284.00 | 1695.00 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 1990.00 | 2180.00 | 1710.00 | 2332.00 | 1990.00 | 2180.00 | 1710.00 | 2332.00 |
| **2MAS** | 1769.00 | 1934.00 | 1633.00 | 2202.00 | 1843.00 | 2085.00 | 1702.00 | 2329.00 |
| **3MAS** | 1745.00 | 1898.00 | 1592.00 | 2143.00 | 1811.00 | 2068.00 | 1638.00 | 2248.00 |
| **4MAS** | 1690.00 | 1875.00 | 1520.00 | 2027.00 | 1767.00 | 2089.00 | 1604.00 | 2154.00 |
| **5MAS** | 1617.00 | 1786.00 | 1482.00 | 1949.00 | 1745.00 | 1988.00 | 1604.00 | 2129.00 |
| **6MAS** | 1566.00 | 1698.00 | 1517.00 | 1923.00 | 1683.00 | 2235.00 | 1589.00 | 2050.00 |
| **7MAS** | 1502.00 | 1630.00 | 1345.00 | 1880.00 | 1560.00 | 1805.00 | 1470.00 | 2014.00 |
| **8MAS** | 1405.00 | 1392.00 | 1203.00 | 1650.00 | 1511.00 | 1531.00 | 1349.00 | 1838.00 |
| **9MAS** | 1130.00 | 1250.00 | 1134.00 | 1493.00 | 1277.00 | 1412.00 | 1247.00 | 1670.00 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | N/A | 132.678 | 93.818 |

### 4.1.2.4 SEED MOISTURE CONTENT (%)

The results on per cent seed moisture content as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are enumerated in Table 21, 22, 23 and 24.

#### 4.1.2.4.1 Effect of varieties (VAR)

Irrespective of the period of storage and storage condition, seed moisture content was found to vary significantly between the varieties during storage (Table 21).

Seeds of variety Kanchana (12.72%) had registered significant low moisture (%) than the other varieties. The moisture content in seeds of variety Harsha (12.92%) differed significantly from Matta Triveni (12.99%). Variety Manuratna had registered significant high seed moisture estimate (13.37%).

#### 4.1.2.4.2 Effect of period of storage (MAS)

Irrespective of the varieties and storage condition, seed moisture content was found to vary significantly during storage (Table 21).

Seed moisture content increased progressively, differing significantly with increase in the storage period. It varied between 10.63 per cent (1 MAS) and 15.06 per cent (9 MAS). The moisture content of stored seeds was found to be below 13 per cent up to 4 MAS (12.35 %).

#### 4.1.2.4.3 Effect of storage condition (SC)

Irrespective of varieties and the period of storage, storage condition exerted significant influence on seed moisture content (Table 22).

The average moisture content in seeds stored under storage condition SC4 (R.C.C. + without ventilation: 13.79%) was significantly high compared to all other environments. Seed moisture in SC2 (Asbestos + without ventilation: 13.18%) was significantly higher than in SC5 (Asbestos + forced ventilation: 12.82%) and SC3 (R.C.C. + ventilation: 12.

78%). SC5 and SC3 were found to be on par with each other. Seeds stored in SC1 (Asbestos + ventilation: 12.42%) registered the least moisture estimate. It was observed to be significantly lower than in the others.

**4.1.2.3.4 Effect to interaction**

**4.1.2.3.4.1 Varieties × Storage period (VAR x MAS)**

Irrespective of the storage condition, seed moisture content was significantly influenced by the interaction between varieties and storage period (Table 21).

Seed moisture in all the varieties increased gradually with an increase in the storage period. At 9 MAS, Manurathna (15.51) registered significantly high seed moisture followed by Harsha (15.09). Varieties Matta Triveni (14.90) and Kanchana (14.72), were found to on par with each other and registered lower seed moisture at 9 MAS. Moisture in seeds of varieties Harsha, Matta Triveni and Kanchana reached above 13.00 per cent at 6 MAS, while in Manurathna it reached 13.44 per cent at 4 MAS.

**4.1.2.3.4.2 Storage condition × Storage period (SC x MAS)**

Irrespective of the varieties, seed moisture content was significantly influenced by the interaction between different storage condition and storage period (Table 22).

Initially, the moisture content of seeds in all storage conditions was 10.62 per cent (1 MAS). However, as storage period increased, significant variations in moisture content was observed. Seed moisture was found to be the high under SC4 (R.C.C. + without ventilation) throughout the storage period (2 MAS: 12.30%; 9 MAS: 15.86%) and the least under SC1 (Asbestos + ventilation- 2 MAS: 11.69%; 9 MAS: 14.36%).

At 9 MAS, the moisture content in seeds stored under treatments SC4 (R.C.C. + without ventilation: 15.86) and SC2 (Asbestos + without ventilation: 15.26%) was significantly higher than that observed in SC5 (Asbestos + forced ventilation (14.97%), SC3 (R.C.C. + ventilation: 14.81%) and SC1 (Asbestos + ventilation: 14.36%). The moisture in seeds in SC1 (13.53%), SC2 (13.25%), SC3 (13.19%), SC4 (13.27%) and SC5

(13.55%), reached above 13.00 per cent at 7 MAS, 5 MAS, 6 MAS, 4 MAS and 6 MAS, respectively.

**4.1.2.3.4.3 Varieties × Storage condition (VAR x SC)**

Irrespective of storage period, significant difference in seed moisture content was observed due to the interaction of varieties and storage condition (Table 23).

Seed moisture in variety Manuratna was found to be significantly high (SC1:12.88%; SC2:13.33%; SC3:13.19%; SC4:14.04%; and SC5: 13.19%) under all storage environment, while, it was found to be the least in variety Kanchana under SC1:11.99; SC2:12.67 and SC3:12.61). Moisture content in seeds of variety Kanchana was on par with that of variety Harsha, under SC4: (Kanchana: 13.66%; Harsha: 13.56%) and SC5 (Kanchana: 12.63%; Harsha: 12.61%). Seed moisture in Kanchana was also found to be on par with variety Matta Triveni in SC3 (12.58%).

**4.1.2.3.4.4 Varieties × Storage condition × Storage period (VAR x SC x MAS)**

Seed moisture content was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 24).

At 8 MAS, seeds of varieties stored under SC2 (Harsha: 14.90%; Matta Triveni: 14.90%, Manurathna: 15.37; Kanchana: 14.50%) and SC4 (Harsha: 15.27%; Matta Triveni: 15.43%, Manurathna: 15.93; Kanchana: 15.53%), registered a higher moisture content compared to those stored in other conditions. Seed moisture in variety Kanchana reached above 13.00 per cent by 8 MAS under SC1(13.50%), by 6 MAS in SC2 (13.37%), SC3 (13.27%) and SC5(13.77%), and by 4 MAS (13.53%) in SC4, while it reached above this estimate in Manurathna by 6 MAS in SC1 (13.47%), 5 MAS in SC2 (13.60%), SC3 (13.67%) and SC5 (13.47), and by 3 MAS in SC4 (13.13%).

**Table 21. Impact of varieties, storage period and their interactions on seed moisture content of short duration varieties.**

| Varieties (VAR) | Seed moisture content (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean VAR** |
| **Harsha** | 10.80$^{b}$ | 11.27$^{c}$ | 11.76$^{de}$ | 12.19$^{gh}$ | 12.92$^{j}$ | 13.53$^{k}$ | 14.09$^{lm}$ | 14.56$^{op}$ | 15.09$^{rs}$ | **12.92$^{b}$** |
| **Matta Triveni** | 10.80$^{b}$ | 11.61$^{d}$ | 12.04$^{fg}$ | 12.44$^{i}$ | 12.84$^{j}$ | 13.33$^{k}$ | 14.24$^{mn}$ | 14.64$^{p}$ | 14.90$^{qr}$ | **12.99$^{c}$** |
| **Manuratna** | 10.80$^{b}$ | 11.84$^{ef}$ | 12.29$^{hi}$ | 12.71$^{j}$ | 13.44$^{k}$ | 13.96$^{l}$ | 14.61$^{op}$ | 15.16$^{s}$ | 15.51$^{t}$ | **13.37$^{d}$** |
| **Kanchana** | 10.10$^{a}$ | 11.21$^{c}$ | 11.64$^{de}$ | 12.05$^{fg}$ | 12.84$^{j}$ | 13.48$^{k}$ | 13.97$^{l}$ | 14.40$^{no}$ | 14.72$^{pq}$ | **12.72$^{a}$** |
| **Mean MAS** | **10.63$^{a}$** | **11.49$^{b}$** | **11.94$^{c}$** | **12.35$^{d}$** | **13.01$^{e}$** | **13.58$^{f}$** | **14.23$^{g}$** | **14.70$^{h}$** | **15.06$^{i}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| MAS | 0.058 | 0.029 | 0.021 |
| VAR | 0.038 | 0.019 | 0.014 |
| VAR x MAS | 0.115 | 0.058 | 0.041 |

**Table 22. Impact of storage condition, storage period and their interactions on seed moisture content of short duration varieties.**

| Storage condition (SC) | Seed moisture content (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean SC** |
| **SC 1** | 10.62$^{a}$ | 11.00$^{b}$ | 11.39$^{d}$ | 11.77$^{ef}$ | 12.24$^{gh}$ | 12.83$^{k}$ | 13.53$^{mn}$ | 14.00$^{op}$ | 14.36$^{qr}$ | **12.42$^{a}$** |
| **SC 2** | 10.62$^{a}$ | 11.69$^{e}$ | 12.15$^{gh}$ | 12.52$^{ij}$ | 13.25$^{l}$ | 13.76$^{no}$ | 14.42$^{r}$ | 14.91$^{tu}$ | 15.26$^{v}$ | **13.18$^{c}$** |
| **SC 3** | 10.62$^{a}$ | 11.31$^{cd}$ | 11.76$^{ef}$ | 12.19$^{gh}$ | 12.65$^{jk}$ | 13.19$^{l}$ | 13.97$^{op}$ | 14.45$^{r}$ | 14.81$^{st}$ | **12.78$^{b}$** |
| **SC 4** | 10.62$^{a}$ | 12.30$^{hi}$ | 12.80$^{k}$ | 13.27$^{lm}$ | 14.05$^{p}$ | 14.55$^{r}$ | 15.08$^{uv}$ | 15.54$^{w}$ | 15.867$^{x}$ | **13.79$^{d}$** |
| **SC 5** | 10.62$^{a}$ | 11.12$^{bc}$ | 11.55d$^{e}$ | 11.99$^{fg}$ | 12.85$^{k}$ | 13.55$^{n}$ | 14.13$^{pq}$ | 14.55$^{rs}$ | 14.97$^{tu}$ | **12.82$^{b}$** |
| **Mean MAS** | **10.63$^{a}$** | **11.49$^{b}$** | **11.94$^{c}$** | **12.35$^{d}$** | **13.01$^{e}$** | **13.58$^{f}$** | **14.23$^{g}$** | **14.70$^{h}$** | **15.06$^{i}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.043 | 0.022 | 0.015 |
| MAS | 0.058 | 0.029 | 0.021 |
| SC x MAS | 0.129 | 0.065 | 0.046 |

**Table 23. Impact of varieties, storage condition and their interactions on seed moisture content of short duration varieties.**

| Varieties (VAR) | Seed moisture content (%) | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| **Harsha** | 12.51[c] | 13.16[g] | 12.71[de] | 13.56[i] | 12.61[cd] | **12.92[b]** |
| **Matta Triveni** | 12.29[b] | 13.33[h] | 12.58[cd] | 13.88[j] | 12.83[ef] | **12.99[c]** |
| **Manuratna** | 12.88[f] | 13.54[i] | 13.19[gh] | 14.04[k] | 13.19[gh] | **13.37[d]** |
| **Kanchana** | 11.99[a] | 12.67[d] | 12.61[cd] | 13.66[i] | 12.63[cd] | **12.72[a]** |
| **Mean SC** | **12.42[a]** | **13.18[c]** | **12.78[b]** | **13.79[d]** | **12.82[b]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.043 | 0.022 | 0.015 |
| VAR | 0.038 | 0.019 | 0.014 |
| VAR x SC | 0.086 | 0.044 | 0.031 |

**Table 24. Impact of varieties, storage conditions, storage periods and their interactions on seed moisture content (%) of short duration varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| 1MAS | 10.80 | 10.80 | 10.80 | 10.10 | 10.80 | 10.80 | 10.80 | 10.10 | 10.80 | 10.80 | 10.80 | 10.10 |
| 2MAS | 10.97 | 11.07 | 11.37 | 10.60 | 11.40 | 12.10 | 12.13 | 11.13 | 11.20 | 11.20 | 11.67 | 11.20 |
| 3MAS | 11.40 | 11.23 | 11.83 | 11.10 | 11.97 | 12.60 | 12.53 | 11.53 | 11.67 | 11.50 | 12.17 | 11.73 |
| 4MAS | 11.83 | 11.53 | 12.27 | 11.47 | 12.40 | 12.97 | 13.00 | 11.73 | 12.10 | 11.93 | 12.57 | 12.17 |
| 5MAS | 12.30 | 11.87 | 12.87 | 11.93 | 13.40 | 13.27 | 13.60 | 12.73 | 12.50 | 12.20 | 13.20 | 12.73 |
| 6MAS | 13.07 | 12.30 | 13.47 | 12.50 | 13.87 | 13.73 | 14.10 | 13.37 | 13.20 | 12.67 | 13.67 | 13.23 |
| 7MAS | 13.63 | 13.53 | 14.03 | 12.93 | 14.33 | 14.47 | 14.73 | 14.17 | 13.80 | 13.90 | 14.40 | 13.80 |
| 8MAS | 14.03 | 14.00 | 14.50 | 13.50 | 14.90 | 14.90 | 15.37 | 14.50 | 14.30 | 14.40 | 14.97 | 14.13 |
| 9MAS | 14.57 | 14.30 | 14.80 | 13.80 | 15.43 | 15.20 | 15.63 | 14.80 | 14.90 | 14.63 | 15.33 | 14.40 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| 1MAS | 10.80 | 10.80 | 10.80 | 10.10 | 10.80 | 10.80 | 10.80 | 10.10 |
| 2MAS | 11.83 | 12.47 | 12.77 | 12.13 | 10.97 | 11.23 | 11.30 | 11.00 |
| 3MAS | 12.40 | 13.13 | 13.13 | 12.57 | 11.37 | 11.73 | 11.80 | 11.30 |
| 4MAS | 12.83 | 13.60 | 13.53 | 13.13 | 11.80 | 12.20 | 12.20 | 11.77 |
| 5MAS | 13.90 | 14.13 | 14.10 | 14.10 | 12.53 | 12.73 | 13.47 | 12.70 |
| 6MAS | 14.40 | 14.67 | 14.57 | 14.57 | 13.13 | 13.30 | 14.00 | 13.77 |
| 7MAS | 14.90 | 15.17 | 15.20 | 15.07 | 13.80 | 14.13 | 14.70 | 13.90 |
| 8MAS | 15.27 | 15.43 | 15.93 | 15.53 | 14.33 | 14.50 | 15.03 | 14.37 |
| 9MAS | 15.77 | 15.53 | 16.37 | 15.80 | 14.80 | 14.87 | 15.43 | 14.80 |

| Factors | C.D. | SE(d) | SE(m) |
|---|---|---|---|
| VAR x SC x MAS | 0.257 | 0.131 | 0.092 |

### 4.1.2.5 ELECTRICAL CONDUCTIVITY OF SEED LEACHATE (EC) (µ$Sm^{-1}$)

The results on electrical conductivity (EC) (µ$Sm^{-1}$) as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are presented in Tables 25, 26, 27 and 28.

#### 4.1.2.5.1 Effect of varieties (VAR)

Irrespective of the period of storage and storage condition, electrical conductivity of seed leachate (EC) was found to be vary significantly between the varieties (Table 25).

Variety Kanchana (118.19 µ$Sm^{-1}$) and Harsha (118.83 µ$Sm^{-1}$), recorded significantly low electrical conductivity. These were on par with each other and differed significantly from Matta Triveni (143.97 µ$Sm^{-1}$) and Manurathna (175.90 µ$Sm^{-1}$).

#### 4.1.2.5.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, EC was found to be significantly influenced by the period of storage (Table 25).

Electrical conductivity of seed leachate increased significantly as the storage period prolonged. The estimate ranged from 60.13 µ$Sm^{-1}$ during 1 MAS to 211.96 µ$Sm^{-1}$ at 9 MAS.

#### 4.1.2.5.3 Effect of storage condition (SC)

Irrespective of varieties and the period of storage, electrical conductivity of seed leachate was found to be vary significantly between the storage conditions (Table 26).

EC of seed leachate in SC1 (Asbestos + ventilation: 120.41 µ$Sm^{-1}$) was the least and significantly different from that observed in other storage conditions. EC estimates in SC5 (Asbestos + forced ventilation: 132.28 µ$Sm^{-1}$) and SC3 (R.C.C. + ventilation: 132.75 µ$Sm^{-1}$) were found to be on par with each other. However, they differed significantly from SC2 (Asbestos + without ventilation: 148.63 µ$Sm^{-1}$) and SC4 (R.C.C. + without ventilation: 162.05 µ$Sm^{-1}$).

**4.1.2.5.4 Effect to interaction**

**4.1.2.5.4.1 Varieties × Storage period (VAR × MAS)**

Irrespective of the storage conditions, electrical conductivity was significantly influenced (Table 25) by the interaction between varieties and storage period.

Variety Manuratna, registered high EC estimates throughout the storage period (1 MAS: 102.20 $\mu Sm^{-1}$; 9 MAS: 243.22 $\mu Sm^{-1}$). At 9 MAS, EC estimate was significantly high in Manuratna (243.22 $\mu Sm^{-1}$) followed by variety Matta Triveni (218.86 $\mu Sm^{-1}$). These varieties differed significantly from Kanchana (14.72 $\mu Sm^{-1}$) and Harsha (190.70 $\mu Sm^{-1}$). EC estimate in variety Harsha was significantly lower than in other varieties.

**4.1.2.5.4.2 Storage condition × Storage period (SC × MAS)**

Irrespective of the varieties, electrical conductivity was significantly influenced by the interaction between different storage condition and the storage period (Table 26).

Initially, the EC of seed leachate of seeds was found to be the same (1 MAS: 60.13 $\mu Sm^{-1}$) under various storage environments. Starting from 2 MAS, the EC of seeds stored in SC4 (R.C.C. + without ventilation- 2 MAS: 101.60 $\mu Sm^{-1}$) was found to be significantly high till the end of the storage period. Throughout storage, seeds stored in SC2 (Asbestos + without ventilation- 2 MAS: 90.98 $\mu Sm^{-1}$), registered significantly high estimates next to those in SC4.

At 9 MAS, seeds in SC1 (Asbestos + ventilation: 183.09 $\mu Sm^{-1}$) was the least and significantly lower than SC3 (R.C.C. + ventilation: 204.40 $\mu Sm^{-1}$)) and SC5 (Asbestos + forced ventilation: 132.28 $\mu Sm^{-1}$). SC3 and SC5 were found to be on par with each other. SC2 (Asbestos + without ventilation: 226.65 $\mu Sm^{-1}$) followed by SC4 (R.C.C. + without ventilation: 241.27 $\mu Sm^{-1}$), registered significantly high EC estimates.

#### 4.1.2.5.4.3 Varieties × Storage condition (VAR × SC)

Significant differences in electrical conductivity of seed leachate was observed due to the interaction of varieties and storage condition, irrespective of the storage period (Table 27).

All the varieties stored under SC4 (Harsha: 146.92 $\mu Sm^{-1}$; MT: 160.55 $\mu Sm^{-1}$; Mauratana: 205.90 $\mu Sm^{-1}$; Kanchana: 134.83 $\mu Sm^{-1}$), registered high EC estimates followed by those stored in SC2 (Harsha: 131.91 $\mu Sm^{-1}$; MT: 145.37 $\mu Sm^{-1}$; Mauratana: 192.31 $\mu Sm^{-1}$; Kanchana: 124.92 $\mu Sm^{-1}$). The EC of seed leachate was found to be lower in seeds stored in SC1 (Harsha:100.96 $\mu Sm^{-1}$; MT:125.78 $\mu Sm^{-1}$; Maurathana: 156.37 $\mu Sm^{-1}$; Kanchana: 98.50 $\mu Sm^{-1}$) and SC5 (Harsha: 98.54 $\mu Sm^{-1}$; MT: 148.70 $\mu Sm^{-1}$; Maurathana: 161.37 $\mu Sm^{-1}$; Kanchana: 120.49 $\mu Sm^{-1}$), compared to SC3 (Harsha: 115.83 $\mu Sm^{-1}$; MT: 139.6 $\mu Sm^{-1}$; Maurathana: 163.53 $\mu Sm^{-1}$; Kanchana: 112.18 $\mu Sm^{-1}$).

#### 4.1.2.5.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)

Electrical conductivity of seed leachate was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 28).

EC of seed leachate in the varieties increased with increase in storage period, across all storage conditions. The EC estimates of varieties under Asbestos + Forced ventilation (SC5) and Asbestos + ventilation (SC1) was found to be lower than that in R.C.C. + ventilation (SC3), during the corresponding period. The EC estimate of the seeds stored in and SC4 (R.C.C. + without ventilation) and SC2 (Asbestos + without ventilation), was significantly high throughout the storage period. The EC of seeds stored in SC4 at 9 MAS was 229.63 $\mu Sm^{-1}$, 228.40 $\mu Sm^{-1}$, 267.07 $\mu Sm^{-1}$, and 220.03 $\mu Sm^{-1}$, respectively in variety Harsha, MT, Manuratna and Kanchana, whereas, it was 187.60 $\mu Sm^{-1}$, 214.57 $\mu Sm^{-1}$, 232.63 $\mu Sm^{-1}$, and 182.80 $\mu Sm^{-1}$, respectively in variety Harsha, MT, Manuratna and Kanchana stored under SC2, during the corresponding period.

**Table 25. Impact of varieties, storage period and their interactions on electrical conductivity of short duration varieties.**

| Varieties (VAR) | Electrical conductivity ($\mu Sm^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean VAR** |
| **Harsha** | $40.60^{a}$ | $72.97^{c}$ | $79.51^{d}$ | $95.05^{f}$ | $117.10^{hi}$ | $135.10^{kl}$ | $159.20^{o}$ | $179.00^{p}$ | $190.70^{q}$ | **$118.83^{a}$** |
| **Matta Triveni** | $58.72^{b}$ | $86.34^{e}$ | $104.34^{g}$ | $125.22^{j}$ | $141.64^{m}$ | $163.02^{o}$ | $189.75^{q}$ | $207.88^{s}$ | $218.86^{t}$ | **$143.97^{b}$** |
| **Manuratna** | $102.20^{g}$ | $120.67^{i}$ | $131.51^{k}$ | $154.90^{n}$ | $177.61^{p}$ | $198.52^{r}$ | $217.04^{t}$ | $237.40^{u}$ | $243.22^{v}$ | **$175.90^{c}$** |
| **Kanchana** | $39.02^{a}$ | $57.90^{b}$ | $77.10^{d}$ | $92.21^{f}$ | $116.08^{h}$ | $136.18^{l}$ | $161.40^{o}$ | $188.83^{q}$ | $194.98^{r}$ | **$118.19^{a}$** |
| **Mean MAS** | **$60.13^{a}$** | **$84.47^{b}$** | **$98.11^{c}$** | **$116.85^{d}$** | **$138.12^{e}$** | **$158.22^{f}$** | **$181.87^{g}$** | **$203.28^{h}$** | **$211.96^{i}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| MAS | 1.008 | 0.512 | 0.362 |
| VAR | 0.672 | 0.342 | 0.242 |
| VAR x MAS | 2.016 | 1.025 | 0.725 |

**Table 26. Impact of storage condition, storage period and their interactions on electrical conductivity of seed leachate of short duration varieties.**

| Storage condition (SC) | Electrical conductivity (µSm$^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean SC** |
| **SC 1** | $60.13^{a}$ | $70.31^{b}$ | $81.90^{c}$ | $99.98^{f}$ | $116.74^{j}$ | $136.85^{m}$ | $157.73^{o}$ | $176.93^{q}$ | $183.09^{r}$ | **$120.41^{a}$** |
| **SC 2** | $60.13^{a}$ | $90.98^{de}$ | $105.25^{gh}$ | $124.92^{k}$ | $148.17^{n}$ | $167.96^{p}$ | $196.57^{s}$ | $217.02^{v}$ | $226.65^{w}$ | **$148.63^{c}$** |
| **SC 3** | $60.13^{a}$ | $79.76^{c}$ | $89.39^{d}$ | $109.20^{hi}$ | $130.01^{l}$ | $151.64^{n}$ | $174.62^{q}$ | $195.60^{s}$ | $204.40^{t}$ | **$132.75^{b}$** |
| **SC 4** | $60.13^{a}$ | $101.60^{fg}$ | $119.40^{j}$ | $139.50^{m}$ | $165.10^{p}$ | $186.45^{r}$ | $211.26^{u}$ | $233.71^{x}$ | $241.27^{y}$ | **$162.05^{d}$** |
| **SC 5** | $60.13^{a}$ | $79.69^{c}$ | $94.58^{e}$ | $110.62^{i}$ | $130.57^{l}$ | $148.19^{n}$ | $169.18^{p}$ | $193.15^{s}$ | $204.38^{t}$ | **$132.28^{b}$** |
| **Mean MAS** | **$60.13^{a}$** | **$84.47^{b}$** | **$98.11^{c}$** | **$116.85^{d}$** | **$138.12^{e}$** | **$158.22^{f}$** | **$181.87^{g}$** | **$203.28^{h}$** | **$211.96^{i}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| MAS | 1.008 | 0.512 | 0.362 |
| SC | 0.751 | 0.382 | 0.270 |
| SC x MAS | 2.254 | 1.146 | 0.810 |

**Table 27. Impact of varieties, storage condition and their interactions on electrical conductivity of seed leachate of short duration varieties.**

| Varieties (VAR) | Electrical conductivity ($\mu Sm^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| **Harsha** | $100.96^{a}$ | $131.91^{f}$ | $115.83^{c}$ | $146.92^{ij}$ | $98.54^{a}$ | **$118.83^{a}$** |
| **Matta Triveni** | $125.78^{e}$ | $145.37^{i}$ | $139.46^{h}$ | $160.55^{l}$ | $148.70^{j}$ | **$143.97^{b}$** |
| **Manuratna** | $156.37^{k}$ | $192.31^{n}$ | $163.53^{m}$ | $205.90^{o}$ | $161.37^{lm}$ | **$175.90^{c}$** |
| **Kanchana** | $98.50^{a}$ | $124.92^{e}$ | $112.18^{b}$ | $134.83^{g}$ | $120.49^{d}$ | **$118.19^{a}$** |
| **Mean SC** | **$120.41^{a}$** | **$148.63^{c}$** | **$132.75^{b}$** | **$162.05^{d}$** | **$132.28^{b}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.672 | 0.342 | 0.242 |
| SC | 0.751 | 0.382 | 0.270 |
| VAR x SC | 1.502 | 0.764 | 0.540 |

**Table 28. Impact of varieties, storage conditions, storage periods and their interactions on electrical conductivity of seed leachate ($\mu Sm^{-1}$) of short duration varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 40.60 | 58.72 | 102.20 | 39.02 | 40.60 | 58.72 | 102.20 | 39.02 | 40.60 | 58.72 | 102.20 | 39.02 |
| **2MAS** | 56.67 | 66.67 | 104.50 | 53.41 | 87.00 | 84.80 | 135.20 | 56.93 | 72.67 | 83.83 | 108.97 | 53.60 |
| **3MAS** | 68.33 | 83.00 | 104.47 | 72.00 | 87.47 | 101.13 | 156.40 | 76.00 | 71.33 | 99.67 | 114.57 | 72.00 |
| **4MAS** | 80.67 | 111.53 | 130.40 | 77.33 | 100.83 | 122.57 | 183.30 | 93.00 | 91.33 | 119.33 | 135.40 | 90.77 |
| **5MAS** | 96.23 | 121.27 | 154.47 | 95.00 | 128.43 | 142.67 | 197.03 | 124.57 | 113.50 | 135.33 | 161.37 | 109.87 |
| **6MAS** | 114.73 | 143.07 | 175.77 | 113.83 | 147.03 | 165.90 | 213.83 | 145.10 | 133.60 | 156.43 | 185.43 | 131.10 |
| **7MAS** | 133.93 | 168.00 | 196.33 | 132.67 | 184.47 | 193.97 | 232.23 | 175.63 | 156.53 | 185.63 | 203.83 | 152.50 |
| **8MAS** | 153.90 | 185.77 | 217.93 | 150.13 | 199.53 | 212.43 | 252.43 | 203.70 | 175.33 | 201.70 | 227.43 | 177.97 |
| **9MAS** | 163.63 | 194.07 | 221.33 | 153.33 | 211.87 | 226.20 | 258.17 | 210.37 | 187.60 | 214.57 | 232.63 | 182.80 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| **1MAS** | 40.60 | 58.72 | 102.20 | 39.02 | 40.60 | 58.72 | 102.20 | 39.02 |
| **2MAS** | 94.07 | 102.40 | 144.77 | 65.20 | 54.47 | 94.00 | 109.93 | 60.37 |
| **3MAS** | 105.43 | 123.17 | 163.83 | 85.20 | 65.00 | 114.73 | 118.30 | 80.30 |
| **4MAS** | 121.10 | 141.77 | 193.10 | 102.07 | 81.33 | 130.93 | 132.33 | 97.90 |
| **5MAS** | 145.93 | 163.40 | 218.90 | 132.17 | 101.63 | 145.53 | 156.30 | 118.83 |
| **6MAS** | 168.77 | 184.10 | 238.33 | 154.63 | 111.63 | 165.63 | 179.27 | 136.23 |
| **7MAS** | 197.40 | 207.48 | 252.33 | 187.83 | 124.10 | 193.70 | 200.47 | 158.47 |
| **8MAS** | 219.37 | 228.40 | 267.07 | 220.03 | 147.00 | 211.13 | 222.17 | 192.33 |
| **9MAS** | 229.63 | 235.53 | 272.57 | 227.37 | 161.13 | 223.97 | 231.40 | 201.03 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | 4.507 | 2.292 | 1.621 |

### 4.1.2.6 FIELD ESTABLISHMENT (%)

The results on field establishment per cent as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are enumerated in Table 29, 30, 31and 32.

#### 4.1.2.6.1 Effect of varieties (VAR)

Irrespective of storage condition and period of storage, field establishment varied significantly between the varieties (Table 29).

Over the storage period of nine months, irrespective of all other factors, field establishment of Matta Triveni (91.01%) was significantly superior to other varieties. Field establishment in Harsha (89.93%) and Manuratna (89.28%) differed significantly from each other and also from variety Kanchana (86.24%).

#### 4.1.2.6.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, field establishment was found to be significantly influenced by the period of storage (Table 29).

Field establishment declined progressively as well as differed significantly as the storage period progressed. Field establishment was found to be above 90.00 per cent, up to 5 MAS (91.38%). From 6 MAS onwards, there was a drastic decline in field establishment. It fell below 80.00 per cent at 8 MAS (78.15%).

#### 4.1.2.6.3 Effect of storage condition (SC)

Irrespective of varieties and the period of storage, storage condition exerted significant influence on field establishment (Table 30).

Field establishment in seeds stored under treatments SC1 (Asbestos + ventilation: 90.20%) and SC3 (R.C.C. + ventilation: 90.05%), were found to be on par with each other and significantly superior to all other treatments. Field establishment in SC5 (Asbestos + forced ventilation: 89.46%) was found to be the next best and also significantly superior to that in SC2 (Asbestos + without ventilation: 89.08%). Field establishment was the least in SC4 (R.C.C. + without ventilation: 87.09%).

#### 4.1.2.6.4 Effect to interaction

#### 4.1.2.6.4.1 Varieties × Storage period (VAR × MAS)

Irrespective of the storage conditions, field establishment was significantly influenced by the interaction between varieties and storage period (Table 29).

Field establishment of all the varieties declined progressively over the storage period. Initially, all the four varieties registered a FE of 99.00 per cent. Subsequently, as storage period increased, significant variations occurred between varieties. Variety Matta Triveni, had registered the highest field establishment (1 MAS: 100.00% and 9 MAS: 75.46%) throughout the storage period. At 9 MAS, field establishment in variety Matta Triveni was observed to be on par with Harsha (75.33%). These were significantly superior over Manuratna (72.86 %) and Kanchana (72.46%). Field establishment in all the varieties, except Kanchana, fell below 90.00 per cent at 7 MAS. In variety Kanchana, it was retained above 90.00 per cent for 3 MAS only. The variety had registered the least field establishment at the start of the storage (96.00%) and in the subsequent months (72.46 % at 9 MAS).

#### 4.1.2.6.4.2 Storage condition × Storage period (SC × MAS)

Irrespective of the varieties, the interaction between different storage condition and storage period significantly influenced field establishment (Table 30).

Initially, all the four varieties in all storage conditions registered a FE of 99.00 per cent. However, a significant decline in FE was observed as the period of storage progressed. Field establishment in seeds stored under SC1 (Asbestos + ventilation), SC3 (R.C.C. + ventilation), SC5 (Asbestos + forced ventilation) as well as SC2 (Asbestos + without ventilation), was on par with each other, for most of the storage period. At 7 MAS (SC1: 85.66%, SC3:86.00%, SC5:85.16%) and at 8 MAS, (SC1: 79.41 %, SC3: 79.83 %, SC5: 79.08 %), seeds stored in SC1, SC3 and SC5 were found to be on par with each other in the respective months of storage. At the end of storage (9 MAS) FE in SC1 (75.58%) and SC3 (74.41%), were on par with each other and significantly superior to all other storage conditions.

Field establishment in storage condition, SC3 (90.16%), was retained above 90.00 per cent up to 6 MAS, while it was retained for 5 MAS each in SC2 (91.83%), SC1 (91.66%) and SC5 (91.58%). The FE estimate of seeds stored under SC4 was above 90.00 per cent up to 4 MAS only.

**4.1.2.6.4.3 Varieties × Storage condition (VAR × SC)**

Irrespective of storage period, significant difference in field establishment was observed due to the interaction of varieties and storage condition (Table 31).

The highest field establishment estimate in varieties was observed under SC3 (Matta Triveni: 91.81%; Harsha: 90.92%, Manuratna: 90.14% and Kanchana: 87.66%). Variety Matta Triveni followed by Harsha, registered significant high FE over other varieties in the various storage conditions. The FE of variety Matta Triveni under SC1 (91.37%), SC3 (91.81%) and SC5 (91.59%), was on par with each other.

**4.1.2.6.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

Field establishment was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 32).

Field establishment in varieties Harsha and Matta Triveni was retained above MSCS for 8 MAS under SC1 (80.67% each), SC3 (80.33% each) and SC5 (Harsha: 80.00%; Matta Triveni: 80.33%). These were on par with each other and also significantly superior to all other varieties stored under these environments at 8 MAS.

Field establishment in all the varieties stored under SC2 (Harsha: 86.33%; Matta Triveni: 87.33%; Manuratna: 82.00%; Kanchana: 81.33%) and SC4 (Harsha: 84.67%; Matta Triveni: 85.33%; Manuratna: 80.00%; Kanchana: 80.00%) as well as varieties Manuratna and Kanchana stored under SC1 (Manuratna: 84.33%; Kanchana: 82.67%), SC3 (Manuratna: 84.00%; Kanchana: 83.33%) and SC5 (Manuratna: 83.00%; Kanchana: 82.67%) were retained above 80.00 per cent, for 7 MAS. In addition, at 7 MAS, FE in varieties Harsha and Matta Triveni, were found to be on par with each other as well as significantly superior to other varieties, across all storage environments.

**Table 29. Impact of varieties, storage period and their interactions on field establishment of short duration varieties.**

| Varieties | Field establishment (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean VAR |
| **Harsha** | 100.00 (10.00) [a] | 97.53 (9.92)[b] | 95.33 (9.81)[c] | 93.73 (9.73)[d] | 92.13 (9.65)[ef] | 90.06 (9.54)[g] | 86.56 (9.35)[i] | 78.66 (8.92)[n] | 75.23 (8.73)[q] | **89.93 (9.52)[b]** |
| **Matta Triveni** | 100.00 (10.00) [a] | 98.06 (9.95)[b] | 97.46 (9.93)[b] | 95.80 (9.83)[c] | 93.73 (9.73)[d] | 91.26 (9.60)[f] | 87.60 (9.41)[h] | 79.60 (8.97)[m] | 75.46 (8.74)[q] | **91.01 (9.58)[a]** |
| **Manuratna** | 100.00 (10.00) [a] | 97.73 (9.93)[b] | 96.06 (9.85)[c] | 94.00 (9.74)[d] | 92.26 (9.65)[e] | 90.20 (9.55)[g] | 82.66 (9.14)[k] | 77.73 (8.87)[o] | 72.76 (8.59)[r] | **89.28 (9.48)[c]** |
| **Kanchana** | 96.00 (9.84)[c] | 94.26 (9.76)[d] | 92.60 (9.67)[e] | 89.66 (9.52)[g] | 87.40 (9.40)[hi] | 85.46 (9.29)[j] | 81.73 (9.09)[l] | 76.60 (8.80)[p] | 72.46 (8.56)[r] | **86.24 (9.33)[d]** |
| **Mean MAS** | **99.00 (9.94)[a]** | **96.90 (9.89)[b]** | **95.40 (9.81)[c]** | **93.30 (9.71)[d]** | **91.38 (9.61)[e]** | **89.25 (9.49)[f]** | **84.65 (9.25)[g]** | **78.15 (8.89)[h]** | **74.03 (8.66)[i]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.141 | 0.072 | 0.051 |
| MAS | 0.211 | 0.107 | 0.076 |
| VAR x MAS | 0.423 | 0.215 | 0.152 |

**Table 30. Impact of storage condition, storage period and their interactions on field establishment of short duration varieties.**

| Storage conditions | Field establishment (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean SC** |
| **SC 1** | 99.00 (9.95)$^{a}$ | 97.33 (9.91)$^{bc}$ | 95.66 (9.83)$^{de}$ | 94.08 (9.75)$^{f}$ | 91.66 (9.62)$^{hi}$ | 89.33 (9.50)$^{k}$ | 85.66 (9.30)$^{m}$ | 79.41 (8.96)$^{p}$ | 75.58 (8.75)$^{r}$ | **90.20 (9.51)$^{a}$** |
| **SC 2** | 99.00 (9.95)$^{a}$ | 97.00 (9.89)$^{bc}$ | 95.15 (9.81)$^{e}$ | 93.83 (9.73)$^{f}$ | 91.83 (9.63)$^{hi}$ | 89.25 (9.49)$^{k}$ | 84.25 (9.23)$^{n}$ | 77.75 (8.87)$^{q}$ | 73.58 (8.63)$^{t}$ | **89.08 (9.48)$^{c}$** |
| **SC 3** | 99.00 (9.95)$^{a}$ | 97.66 (9.93)$^{b}$ | 96.23 (9.86)$^{cd}$ | 93.91 (9.74)$^{f}$ | 92.50 (9.66)$^{gh}$ | 90.16 (9.54)$^{jk}$ | 86.00 (9.32)$^{m}$ | 79.83 (8.99)$^{p}$ | 74.41 (8.79)$^{r}$ | **90.05 (9.54)$^{a}$** |
| **SC 4** | 99.00 (9.95)$^{a}$ | 95.58 (9.82)$^{de}$ | 94.08 (9.75)$^{f}$ | 91.16 (9.56)$^{ij}$ | 89.33 (9.50)$^{k}$ | 87.75 (9.42)$^{l}$ | 82.16 (9.11)$^{o}$ | 74.66 (8.69)$^{s}$ | 70.08 (8.43)$^{u}$ | **87.09 (9.37)$^{d}$** |
| **SC 5** | 99.00 (9.95)$^{a}$ | 96.91 (9.82)$^{bc}$ | 95.66 (9.83)$^{de}$ | 93.50 (9.72)$^{f}$ | 91.58 (9.62)$^{hi}$ | 89.75 (9.52)$^{k}$ | 85.16 (9.28)$^{m}$ | 79.08 (8.94)$^{p}$ | 74.50 (8.68)$^{s}$ | **89.46 (9.50)$^{b}$** |
| **Mean MAS** | **99.00 (9.95)$^{a}$** | **96.90 (9.82)$^{b}$** | **95.40 (9.81)$^{c}$** | **93.30 (9.71)$^{d}$** | **91.38 (9.61)$^{e}$** | **89.25 (9.49)$^{f}$** | **84.65 (9.25)$^{g}$** | **78.15 (8.89)$^{h}$** | **74.03 (8.66)$^{i}$** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.157 | 0.08 | 0.057 |
| MAS | 0.211 | 0.107 | 0.076 |
| SC x MAS | 0.472 | 0.240 | 0.170 |

**Table 31. Impact of varieties, storage condition and their interactions on field establishment of short duration varieties.**

| Varieties | Field establishment (%) | | | | | |
|---|---|---|---|---|---|---|
| | **SC 1** | **SC 2** | **SC 3** | **SC 4** | **SC 5** | **Mean VAR** |
| **Harsha** | 90.59 (9.53)[cd] | 90.07 (9.53)[de] | 90.92 (9.58)[bc] | 87.92 (9.47)[g] | 90.14 (9.53)[de] | **89.93 (9.52)[b]** |
| **Matta Triveni** | 91.37 (9.60)[ab] | 90.81 (9.57)[bc] | 91.81 (9.62)[a] | 89.48 (9.50)[f] | 91.59 (9.61)[a] | **91.01 (9.58)[a]** |
| **Manuratna** | 89.92 (9.52)[ef] | 89.40 (9.49)[f] | 90.14 (9.55)[cde] | 87.29 (9.38)[hi] | 89.37 (9.49)[f] | **89.28 (9.48)[c]** |
| **Kanchana** | 87.11 (9.38)[hi] | 86.03 (9.31)[j] | 87.66 (9.40)[gh] | 83.66 (9.8)[k] | 86.74 (9.35)[i] | **86.24 (9.33)[d]** |
| **Mean SC** | **90.20 (9.51)[a]** | **89.08 (9.48)[c]** | **90.05 (9.54)[a]** | **87.09 (9.37)[d]** | **89.46 (9.50)[b]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.141 | 0.072 | 0.051 |
| SC | 0.157 | 0.080 | 0.057 |
| VAR x SC | 0.315 | 0.160 | 0.113 |

**Table 32. Impact of varieties, storage conditions, storage periods and their interactions on field establishment (%) of short duration varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| 1MAS | 100.00 | 100.00 | 100.00 | 96.00 | 100.00 | 100.00 | 100.00 | 96.00 | 100.00 | 100.00 | 100.00 | 96.00 |
| 2MAS | 98.00 | 98.67 | 98.00 | 95.00 | 97.33 | 98.00 | 97.67 | 94.33 | 98.33 | 99.00 | 98.00 | 95.67 |
| 3MAS | 96.33 | 98.00 | 96.67 | 93.00 | 95.67 | 97.00 | 95.67 | 92.33 | 96.67 | 98.00 | 97.00 | 93.67 |
| 4MAS | 95.33 | 96.67 | 95.67 | 90.67 | 95.00 | 96.00 | 94.67 | 90.00 | 94.33 | 97.33 | 94.33 | 90.33 |
| 5MAS | 93.33 | 94.33 | 93.33 | 88.00 | 93.33 | 94.67 | 93.67 | 88.33 | 93.67 | 95.67 | 93.00 | 89.33 |
| 6MAS | 90.67 | 92.00 | 91.33 | 86.00 | 90.67 | 92.00 | 91.00 | 85.67 | 91.33 | 92.00 | 91.67 | 86.67 |
| 7MAS | 87.33 | 88.67 | 84.33 | 83.67 | 86.33 | 87.67 | 82.67 | 83.67 | 87.67 | 89.00 | 84.00 | 84.00 |
| 8MAS | 81.33 | 81.33 | 79.33 | 79.00 | 79.33 | 79.67 | 78.33 | 77.67 | 81.33 | 81.00 | 79.67 | 79.67 |
| 9MAS | 77.67 | 77.67 | 75.67 | 75.67 | 75.33 | 75.33 | 74.33 | 73.67 | 75.67 | 76.33 | 75.67 | 75.67 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | Harsha | Matta Triveni | Manuratna | Kanchana |
| 1MAS | 100.00 | 100.00 | 100.00 | 96.00 | 100.00 | 100.00 | 100.00 | 96.00 |
| 2MAS | 96.33 | 97.00 | 97.00 | 92.67 | 97.67 | 98.33 | 98.00 | 94.67 |
| 3MAS | 93.33 | 96.33 | 95.33 | 91.33 | 95.67 | 98.00 | 96.33 | 93.67 |
| 4MAS | 92.33 | 95.67 | 92.33 | 87.00 | 93.67 | 97.00 | 94.33 | 90.00 |
| 5MAS | 90.33 | 93.00 | 90.33 | 85.00 | 93.00 | 94.67 | 92.33 | 88.33 |
| 6MAS | 89.33 | 90.33 | 88.33 | 84.33 | 90.67 | 93.00 | 91.00 | 86.00 |
| 7MAS | 85.00 | 85.33 | 81.00 | 80.00 | 86.67 | 88.33 | 83.67 | 83.67 |
| 8MAS | 78.00 | 78.33 | 75.33 | 73.67 | 80.33 | 81.00 | 79.33 | 79.67 |
| 9MAS | 71.33 | 73.67 | 71.00 | 69.67 | 76.33 | 76.33 | 74.67 | 75.33 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | 0.157 | 0.08 | 0.057 |

### 4.1.2.7 SEED MICROFLORA (%)

The results of per cent occurrence of microflora in seed at the end of seed storage, as influenced by varieties, storage condition and their interactions are enumerated in Table 33.

#### 4.1.2.7.1 Effect of varieties (VAR)

Irrespective of the storage condition, at the end of the storage period, seed microflora was found to vary significantly between the varieties (Table 33).

The seeds of variety Matta Triveni (1.43%) registered significant low seed infection than the other varieties. Seed infection in variety Harsha (2.33%) differed significantly from Manuratna (2.60%). Variety Kanchana (3.20%) had registered the highest seed infection per cent.

#### 4.1.2.7.2 Effect of storage condition (SC)

Irrespective of the varieties, at the end of the storage period seed microflora was found to vary significantly between the storage conditions (Table 33).

The seed infection in seeds stored under storage condition SC4 (R.C.C. + without ventilation: 3.41%) was significantly high compared to all other storage conditions. Significantly high seed infection was observed in SC2 (Asbestos + without ventilation: 2.50%) compared to SC5 (Asbestos + forced ventilation: 2.13%) and SC1 (Asbestos + ventilation: 2.08%). SC5 and SC1 were found to be on par with each other. Seeds stored in SC3 (R.C.C. + ventilation: 1.66%), registered the least incidence of seed microflora.

#### 4.1.2.7.3 Effect of interaction (VAR x SC)

The interaction between varieties and storage condition did not significantly influence seed infection (Table 33).

**Table 33. Impact of varieties, storage condition and their interaction on seed microflora of short duration rice varieties.**

| Storage condition (SC) | Seed microflora ( % ) | | | | Mean SC |
|---|---|---|---|---|---|
| | Harsha | Matta Triveni | Manuratna | Kanchana | |
| **SC1** | 1.66 | 1.33 | 2.33 | 3.00 | **2.08$^{b}$** |
| **SC2** | 2.33 | 1.33 | 3.00 | 3.33 | **2.50$^{c}$** |
| **SC3** | 2.00 | 0.66 | 1.66 | 2.33 | **1.66$^{a}$** |
| **SC4** | 3.33 | 2.33 | 3.66 | 4.33 | **3.41$^{d}$** |
| **SC5** | 2.33 | 1.66 | 2.33 | 3.00 | **2.13$^{b}$** |
| **Mean VAR** | **2.33$^{b}$** | **1.43$^{a}$** | **2.60$^{c}$** | **3.20$^{d}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.146 | 0.074 | 0.052 |
| VAR | 0.130 | 0.066 | 0.047 |
| VAR x SC | N/A | 0.148 | 0.105 |

**4.2 Experiment 2: Impact of storage structure on seed longevity of medium duration rice varieties.**

**4.2.1 Seed quality before storage**

The seeds important quality parameters of medium duration varieties were recorded before storage (Table 34).

**Table 34. Seed quality parameters of medium duration rice varieties before storage**

| Parameters | Varieties | | | |
|---|---|---|---|---|
| | Aiswarya | Jyothi | Sreyas | Uma |
| Germination (%) | 100.00 | 98.00 | 100.00 | 98.00 |
| Seedling shoot length (cm) | 9.30 | 10.50 | 9.20 | 9.70 |
| Seedling root length (cm) | 11.30 | 11.20 | 11.10 | 11.00 |
| Seedling dry weight (g) | 0.238 | 0.258 | 0.194 | 0.183 |
| Vigour index -I | 2060.00 | 2126.00 | 2030.00 | 2029.00 |
| Vigour index- II | 2380.00 | 2528.00 | 1940.00 | 1793.00 |
| Seed moisture content (%) | 11.00 | 10.80 | 10.30 | 11.00 |
| Electrical conductivity (EC) of seed leachate ($\mu Sm^{-1}$) | 81.20 | 127.02 | 90.80 | 146.50 |
| Field establishment (%) | 100.00 | 98.00 | 100.00 | 98.00 |

Germination before storage, ranged from 98.00 per cent (Jyothi and Uma) to 100.00 per cent (Aiswarya and Sreyas). Shoot length varied between 9.20 cm (Sreyas) and 10.50 cm (Jyothi), while, the length of root in seedlings ranged between 11.00 cm (Uma) and 11.30 cm (Aiswarya). Seedling dry weight was maximum in variety Jyothi (0.258 g) and the least in Uma (0.183 g). Vigour index – I, varied between 2029.00 (Uma) and 2126.00 (Jyothi), while, vigour index - II (VI-I) ranged from 1793.00 (Uma) and 2528.00 (Jyothi). Moisture content in seeds before storage was the least in Sreyas (10.30%), while it was 10.80 per cent in Jyothi and 11.00 per cent each in Uma and Aiswarya. The electrical conductivity (EC) of seed leachate ranged from 81.20 $\mu Sm^{-1}$ (Aiswarya) to 146.50 $\mu Sm^{-1}$ (Uma). The field establishment estimates of the varieties were the same as their germination per cent. Field establishment varied between 98.00 per cent in variety Jyothi and Uma, and 100.00 per cent in varieties Aiswarya and Sreyas.

**4.2.2 Seed quality during storage**

Analysis of variance for various traits studied indicated existence of wide variability in the impact of varieties, storage conditions, storage period and their interaction on most of the seed indices studied. The results obtained are enumerated henceforth.

**4.2.2.1 GERMINATION (%)**

The results on per cent germination as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are enumerated in Table 35, 36 37 and 38.

**4.2.2.1.1 Effect of varieties (VAR)**

Irrespective of the period of storage and the storage conditions, germination was found to vary significantly between the varieties during the storage period (Table 35).

Germination in variety Aiswarya (90.39%), was significantly superior to other varieties. Germination in Sreyas (89.89%) differed significantly from Uma (89.52%). Varity Uma in turn, differed significantly from variety Jyothi (88.74%) that exhibited the least estimate.

**4.2.2.1.2 Effect of period of storage (MAS)**

Irrespective of varieties and the storage conditions, germination was found to vary significantly during the storage period (Table 35).

Germination during each MAS was found to significantly differ from the preceding as well as succeeding months of storage. Germination was found to be above 90 per cent up to 5 MAS (91.68%). Later, from 6 MAS onwards, there was a drastic decline in germination and it fell below IMSCS at 9 MAS (75.17%).

**4.2.2.1.2 Effect of storage condition (SC)**

Irrespective of varieties and the period of storage, storage condition exerted significant influence on germination (Table 36).

Germination in seeds stored under treatments SC3 (R.C.C. + ventilation: 90.39%) SC1 and (Asbestos + ventilation: 90.30%) were found to be on par with each other and significantly superior to all other treatments. Germination in SC5 (Asbestos + forced ventilation: 89.94%) was found to be the next best and significantly superior to that in SC2 (Asbestos + without ventilation: 89.58%), whereas, germination was the least in SC4 (R.C.C. + without ventilation: 87.84%).

**4.2.2.1.3 Effect to interaction**

**4.2.2.1.3.1 Varieties × Storage period (VAR × MAS)**

Irrespective of the storage conditions, germination was significantly influenced by the interaction between varieties and storage period (Table 35).

Germination of all the varieties declined progressively with an increase in the storage period. Varieties Aiswarya and Sreyas had registered the highest germination per cent throughout the storage period. Germination in all the varieties was observed to be above IMSCS up to 8 MAS. At 8 MAS, germination in varieties Aiswarya (81.73%) and Sreyas (81.46%) was significantly superior to Uma (80.93 %) and Jyothi (80.20%). Varieties Jyothi and Uma had registered the least germination at the start of the storage (98.00%) and these had also registered lower germination estimates in the subsequent months of storage. Germination of the varieties, except variety Aiswarya (6 MAS: 90.00%), was retained above 90.00 per cent up to 5 MAS (Jyothi and Uma: 91.06%; Sreyas: 91.66%).

#### 4.2.2.1.3.2 Storage condition × Storage period (SC × MAS)

Irrespective of the varieties, the interaction between storage condition and storage period, significantly influenced germination (Table 36).

Germination in seeds stored under treatments, SC1 (Asbestos + ventilation), SC3 (R.C.C. + ventilation) and SC5 (Asbestos + forced ventilation) was observed to be above IMSCS up to 8 MAS and also significantly superior to the other storage conditions. At 7 MAS, germination under storage condition SC2 (Asbestos + without ventilation: 85.08%) and SC4 (R.C.C. + without ventilation: 83.16%), fell below IMSCS.

Germination in storage condition, SC3 (90.58%) and SC5 (90.00%) was retained above 90.00 per cent up to 6 MAS, while it was for 5 MAS in SC1 (92.5%) and SC2 (91.83%). However, in SC4 (92.25%) germination was above 90.00 per cent for 4 MAS only.

#### 4.2.2.1.3.3 Varieties × Storage condition (VAR × SC)

Irrespective of storage period, significant difference in germination was observed due to the interaction of varieties and storage conditions (Table 37).

With the exception of SC4 (R.C.C. + without ventilation), germination in Aiswarya (88.66%) stored under various storage conditions were observed to be above 90.00 per cent, while, in variety Sreyas it was observed to be so only in SC1 (Asbestos + ventilation: 90.37 %) and SC3 (R.C.C. + ventilation: 90.48 %) and SC5 (Asbestos + forced ventilation: 90.25%). Variety Jyothi stored under various storage conditions registered germination below 90 per cent.

#### 4.2.2.1.3.4 Varieties x Storage condition x Storage period (VAR × SC × MAS)

Germination was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 38).

Germination in all varieties was retained above IMSCS for 8 MAS under SC1 (Aiswarya: 81.33%; Jyothi: 80.33%; Sreyas: 80.67%; Uma; 80.67%), SC3 (Aiswarya and

Jyothi: 80.67 each; Sreyas: 80.00%; Uma; 81.33%) and SC5 (Aiswarya and Jyothi: 80.00% each; Sreyas and Uma: 80.33% each). At 8 MAS, except variety Jyothi under SC1 and Sreyas under SC3, germination in all other cases was found to be on par with each other.

Germination in all the varieties stored under SC2 (Aiswarya: 85.67%; Jyothi: 83.67%; Sreyas: 84.67%; Uma; 86.33%) and SC4 (Aiswarya: 83.67%; Jyothi: 81.33%; Sreyas: 84.00%; Uma; 83.67%) were retained above, IMSCS for 7 MAS. Among these, except varieties Jyothi under SC2 and SC4 and Sreyas under SC2, all were on par with each other. In these instances, significant low germination was observed.

**4.2.2.1.5 Influence of storage environment on germination (%)**

**4.2.2.1.5.1 Comparison between ambient environment within and outside the storage structures**

The average weekly temperature and RH (%) in various storage environments and the parameters recorded outside the storage environment is detailed in Table 9 and Fig.3 and 4.

The temperature inside SC3 (R.C.C. + ventilation) varied between 26.0 $^{O}$C and 31.5 $^{O}$C, while in SC1 (Asbestos + ventilation), it ranged between 26.5 $^{O}$C and 31.5 $^{O}$C. In SC5 (Asbestos + forced ventilation), it ranged between 27.0 $^{O}$C and 32.0$^{O}$C, respectively. The temperature inside SC4 (R.C.C. + ventilation) varied between 28.0 $^{O}$C and 33.0 $^{O}$C, while in SC2 (Asbestos + ventilation) it varied from 27.0 $^{O}$C to 31.5 $^{O}$C.

The relative humidity inside SC5 (Asbestos + forced ventilation: 64.0% to 87.0%) was relatively lower than that in SC1 (Asbestos + ventilation: 66.0% to 88.0%) and SC3 (R.C.C. + ventilation: 69.5% to 90.0%). Throughout the storage period, higher RH was observed in SC4 (R.C.C. + without ventilation: 74.0% to 96.0%) and SC2 (Asbestos + without ventilation: 72.0% to 92.0%).

**Table 35. Impact of varieties, storage period and their interactions on germination of medium duration rice varieties.**

| Varieties (VAR) | Germination (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean VAR** |
| **Aiswarya** | 100.00 (10) [a] | 98.20 (9.96)[b] | 96.00 (9.84)[d] | 95.26 (9.81)[d] | 92.93 (9.69)[f] | 90.00 (9.53)[h] | 85.73 (9.31)[j] | 81.73 (9.04)[m] | 74.80 (8.70)[pq] | **90.30 (9.50)[a]** |
| **Jyothi** | 98.00 (9.94)[b] | 97.86 (9.94)[b] | 93.46 (9.71)[ef] | 91.60 (9.62)[g] | 91.06 (9.59)[g] | 89.06 (9.49)[i] | 83.86 (9.21)[l] | 80.20 (8.95) [n] | 74.53 (8.69)[q] | **88.74 (9.42)[d]** |
| **Sreyas** | 100.00 (10)[a] | 97.60 (9.93)[bc] | 95.26 (9.81)[d] | 94.20 (9.75)[e] | 91.66 (9.62)[g] | 89.73 (9.52)[hi] | 85.00 (9.27)[k] | 81.46 (9.02)[m] | 76.06 (8.77)[o] | **89.89 (9.48)[b]** |
| **Uma** | 98.00 (9.94)[b] | 97.00 (9.89) [c] | 95.66 (9.83)[d] | 93.46 (9.71)[ef] | 91.06 (9.59)[g] | 89.26 (9.50)[hi] | 86.00 (9.32) [j] | 80.93 (8.99)[n] | 75.26 (8.73)[p] | **89.52 (9.46)[c]** |
| **Mean MAS** | **99.00 (9.95)[a]** | **97.67 (9.88)[b]** | **95.10 (9.75)[c]** | **93.63 (9.67)[d]** | **91.68 (9.57)[e]** | **89.52 (9.46)[f]** | **85.15 (9.23)[g]** | **81.08 (9.00)[h]** | **75.17 (8.67)[i]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.124 | 0.063 | 0.045 |
| MAS | 0.187 | 0.095 | 0.067 |
| VAR x MAS | 0.373 | 0.19 | 0.134 |

**Table 36. Impact of storage condition, storage period and their interactions on germination of medium duration rice varieties.**

| Storage condition (SC) | Germination (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean SC |
| **SC 1** | 99.00 (9.95)[a] | 98.00 (9.89)[b] | 95.3 (9.82)[cd] | 94.30 (9.76)[fg] | 92.16 (9.65)[h] | 89.83 (9.53)[ij] | 86.00 (9.32)[mn] | 82.75 (9.09)[p] | 76.75 (8.81)[rs] | **90.30 (9.50)[a]** |
| **SC 2** | 99.00 (9.95)[a] | 97.91 (9.89)[b] | 95.16 (9.80)[ef] | 93.40 (9.71)[h] | 91.83 (9.63)[i] | 89.58 (9.51)[k] | 85.08 (9.27)[o] | 79.16 (8.72)[r] | 75.08 (8.72)[t] | **89.58 (9.46)[c]** |
| **SC 3** | 99.00 (9.95)[a] | 98.08 (9.90)[ab] | 95.83 (9.84)[d] | 94.16 (9.75)[fg] | 92.33 (9.66)[h] | 90.58 (9.57)[ij] | 86.25 (9.34)[lm] | 81.62 (9.03)[p] | 76.58 (8.80)[st] | **90.39 (9.50)[a]** |
| **SC 4** | 99.00 (9.95)[a] | 96.66 (9.83)[c] | 93.33 (9.71)[h] | 92.25 (9.65)[h] | 89.83 (9.53)[j] | 87.58 (9.41)[l] | 83.16 (9.17)[p] | 78.16 (8.84)[r] | 71.58 (8.51)[u] | **87.84 (9.37)[d]** |
| **SC 5** | 99.00 (9.95)[a] | 97.66 (9.88)[b] | 95.33 (9.81)[de] | 94.00 (9.74)[g] | 92.25 (9.65)[h] | 90.00 (9.53)[ij] | 85.25 (9.28)[n] | 81.16 (9.00)[q] | 75.83 (8.76)[t] | **89.94 (9.48)[b]** |
| **Mean MAS** | **99.00 (9.95)[a]** | **97.67 (9.88)[b]** | **95.10 (9.75)[c]** | **93.63 (9.67)[d]** | **91.68 (9.57)[e]** | **89.52 (9.46)[f]** | **85.15 (9.23)[g]** | **81.08 (9.00)[h]** | **75.17 (8.67)[i]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.139 | 0.071 | 0.05 |
| MAS | 0.187 | 0.095 | 0.067 |
| SC x MAS | 0.417 | 0.212 | 0.150 |

**Table 37. Impact of storage condition, varieties and their interactions on germination of medium duration rice varieties.**

| Varieties (VAR) | Germination (%) | | | | | |
|---|---|---|---|---|---|---|
| | **SC 1** | **SC 2** | **SC 3** | **SC 4** | **SC 5** | **Mean VAR** |
| **Aiswarya** | 91.11 (9.58)[a] | 90.33 (9.54)[bc] | 91.03 (9.58)[a] | 88.66 (9.45)[f] | 90.33 (9.54)[bc] | **90.30 (9.50)[a]** |
| **Jyothi** | 89.55 (9.50)[e] | 88.59 (9.45)[f] | 89.63 (9.51)[de] | 86.55 (9.34)[h] | 89.3 (9.49)[e] | **88.74 (9.42)[d]** |
| **Sreyas** | 90.40 (9.55)[b] | 89.81 (9.52)[cde] | 90.59 (9.56)[ab] | 88.37 (9.44)[f] | 90.25 (9.54)[bc] | **89.89 (9.48)[b]** |
| **Uma** | 90.11 (9.53)[bcd] | 89.59 (9.51)[e] | 90.29 (9.49)[bc] | 87.77 (9.40)[g] | 89.81 (9.52)[cde] | **89.52 (9.46)[c]** |
| **Mean SC** | **90.30 (9.50)[a]** | **89.58 (9.46)[c]** | **90.39 (9.50)[a]** | **87.84 (9.37)[d]** | **89.94 (9.48)[b]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.146 | 0.074 | 0.052 |
| VAR | 0.13 | 0.066 | 0.047 |
| VAR x SC | 0.291 | 0.148 | 0.105 |

**Table 38. Impact of varieties, storage conditions, storage periods and their interactions on germination of medium duration rice varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **1MAS** | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 |
| **2MAS** | 98.67 | 98.00 | 98.00 | 97.33 | 98.33 | 98.00 | 98.00 | 97.33 | 99.00 | 98.00 | 98.00 | 97.33 |
| **3MAS** | 96.67 | 94.67 | 96.00 | 96.00 | 95.67 | 93.67 | 95.67 | 95.67 | 97.00 | 94.00 | 96.00 | 96.33 |
| **4MAS** | 96.00 | 93.00 | 94.33 | 94.00 | 95.33 | 91.00 | 93.67 | 93.67 | 95.67 | 92.00 | 95.00 | 94.00 |
| **5MAS** | 93.67 | 91.67 | 92.00 | 91.33 | 93.33 | 91.33 | 91.67 | 91.00 | 93.67 | 91.67 | 92.33 | 91.67 |
| **6MAS** | 90.33 | 89.67 | 89.67 | 89.67 | 90.00 | 89.33 | 89.67 | 89.33 | 91.00 | 90.33 | 90.67 | 90.33 |
| **7MAS** | 86.67 | 85.00 | 85.67 | 86.67 | 85.67 | 83.67 | 84.67 | 86.33 | 86.67 | 85.33 | 85.67 | 87.33 |
| **8MAS** | 81.33 | 80.33 | 80.67 | 80.67 | 79.33 | 78.67 | 79.00 | 79.67 | 80.67 | 80.67 | 80.00 | 81.33 |
| **9MAS** | 76.67 | 75.67 | 77.33 | 77.33 | 75.33 | 73.67 | 76.00 | 75.33 | 75.67 | 76.67 | 77.67 | 76.33 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **1MAS** | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 |
| **2MAS** | 97.00 | 97.33 | 96.33 | 96.00 | 98.00 | 98.00 | 97.67 | 97.00 |
| **3MAS** | 94.67 | 91.00 | 93.33 | 94.33 | 96.00 | 94.00 | 95.33 | 96.00 |
| **4MAS** | 94.33 | 89.33 | 93.33 | 92.00 | 95.00 | 92.67 | 94.67 | 93.67 |
| **5MAS** | 91.33 | 88.67 | 90.00 | 89.33 | 92.67 | 92.00 | 92.33 | 92.00 |
| **6MAS** | 88.33 | 86.33 | 88.33 | 87.33 | 90.33 | 89.67 | 90.33 | 89.67 |
| **7MAS** | 83.67 | 81.33 | 84.00 | 83.67 | 86.00 | 84.00 | 85.00 | 86.00 |
| **8MAS** | 77.33 | 76.33 | 77.33 | 77.67 | 80.00 | 80.00 | 80.33 | 80.33 |
| **9MAS** | 71.33 | 70.67 | 72.67 | 71.67 | 75.00 | 76.00 | 76.67 | 75.67 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | 0.835 | 0.425 | 0.3 |

#### 4.2.2.1.5.2 Impact of storage temperature (T) on germination (%)

The correlation between weekly storage temperatures recorded during the 38 weeks of storage period and reduction in germination per cent of different medium duration varieties stored various different storage condition was analyzed. The results are presented in Table 39.

**Table 39. Correlation between storage temperature and reduction in germination (%) of medium duration varieties.**

| Storage temperature (Weeks) | Varieties | | | |
|---|---|---|---|---|
| | Aiswarya | Jyothi | Sreyas | Uma |
| 1 | 0.909* | 0.975* | 0.971* | 0.941* |
| 2 | 0.896* | 0.827* | 0.838* | 0.916* |
| 10 | 0.774* | 0.900** | 0.854* | 0.994** |
| 13 | 0.899* | 0.973* | 0.967* | 0.900* |

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Temperature within the storage environment during 1st, 2nd, 10th and 13th weeks registered a significant positive correlation with reduction in germination, the correlation being highly significant in case of variety Jyothi (r = 0.900**) and Uma (r = 0.994**) at the 10th week of storage.

Storage temperature during the 1st week (4th to 11th May, 2019), was 28.4 $^{O}$C in SC1, 29.0 $^{O}$C in SC2, 28.3 $^{O}$C in SC3, 29.5 $^{O}$C in SC4 and 28.2 $^{O}$C in SC5.

During the 2nd week (18th to 25th June, 2019) it varied between 27.5 $^{O}$C in SC1 and 28.9 $^{O}$C in SC4 (SC1: 27.5 $^{O}$C, SC2: 28.4 $^{O}$C, SC3: 28 $^{O}$C, SC4: 28.9 $^{O}$C and SC5: 27.6 $^{O}$C).

It was 29.6 $^{O}$C in SC1, 30.2 $^{O}$C in SC2, 29.0 $^{O}$C in SC3, 31.2 $^{O}$C in SC4 and 29.0 $^{O}$C in SC5 during the 10$^{th}$ week (12$^{th}$ to 19$^{th}$ July, 2019) and 27.8 $^{O}$C in SC1, 28.1 $^{O}$C in SC2, 27.1 $^{O}$C in SC3, 28.8 $^{O}$C in SC4 and 27.9 $^{O}$C in SC5 during 13$^{th}$ week (26$^{th}$ July to 3$^{rd}$ Aug, 2019).

**4.2.2.1.4.3 Impact of relative humidity (RH) on germination (%)**

The correlation between weekly relative humidity recorded during the 38 weeks of storage period and reduction in germination per cent of different medium duration varieties stored various different storage condition was analyzed. The results are presented in Table 40.

**Table 40. Influence of relative humidity (%) and reduction in germination (%) of medium duration varieties.**

| **Relative humidity (Weeks)** | **Varieties** | | | |
|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **24** | 0.900* | 0.860* | 0.871* | 0.934* |
| **31** | 0.993* | 0.806* | 0.870* | 0.975** |
| **32** | 0.957* | 0.819* | 0.897* | 0.969** |
| **33** | 0.957* | 0.814* | 0.851* | 0.952* |
| **34** | 0.960* | 0.858* | 0.888* | 0.967** |
| **36** | 0.886* | 0.786* | 0.872* | 0.918* |

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Relative humidity showed a significant positive correlation with reduction in germination during 24$^{th}$, 31$^{st}$, 32$^{nd}$, 33$^{rd}$, 34$^{th}$, and 36$^{th}$ weeks, the correlation being highly significant in case of variety Uma during 31$^{st}$ (r = 0.975**), 32$^{nd}$ (r = 0.969**) and 34$^{th}$ (r = 0.967**) week of storage.

Relative humidity during the 24th week (11th to 18th Oct, 2019), was 72.0 per cent in SC1, 75.5 per cent in SC2, 74.5 per cent in SC3, 78.5 per cent in SC4 and 72.5 per cent in SC5.

During the 31st week (29th Nov to 6th Dec, 2019), it varied between 68 per cent in SC1 and 74.0 per cent in SC4 (SC1: 68%, SC2: 72.0%, SC3: 70.0%, SC4: 74.0% and SC5: 70.0%).

It was 69.0 per cent in SC1, 72.0 per cent in SC2, 70.5 per cent in SC3, 76.0 per cent in SC4 and 72.5 per cent in SC5 during the 32nd week (6th to 13th Dec, 2019) and 70.6 per cent in SC1, 73.6 per cent in SC2, 73.8 per cent in SC3, 78.3 per cent in SC4 and 72.0 per cent in SC5 during 33rd week (13th to 20th Dec, 2019).

During the 34th week (20th to 27th Dec), it varied between 73.2 per cent in SC1 and 82.7 per cent in SC4 (SC1: 73.2%, SC2: 77.2%, SC3: 76.6%, SC4: 82.7% and SC5: 74.7%). It was 74.0 per cent in SC1, 77.0 per cent in SC2, 75.0 per cent in SC3, 83.0 per cent in SC4 and 71.0 per cent in SC5 during the 36th week (3rd to 10th Jan, 2020).

**4.2.2.1.5.4 Impact of Temperature Humidity Index (THI) on germination (%)**

The correlation between combined effect of weekly storage temperature and relative humidity recorded during the 38 weeks of storage period and reduction in germination per cent of different medium duration varieties stored various different storage condition was analyzed. The results are presented in Table 41.

Temperature-Humidity Index (THI) showed a significant positive correlation with reduction in germination during 1st, 2nd, 11th, 13th, 14th, 19th, 20th and 21st weeks, the correlation being highly significant in case of variety Jyothi and Uma during 11th (Jyothi: r = 0.967**; Uma: r = 0.937**), 20th (Jyothi: r = 0.973**; Uma: r = 0.848**) and 21st (Jyothi: r = 0.978**; Uma: r = 0.968**) week of storage respectively.

THI during the 1st week (4th to 11th May, 2019), was 80.38 in SC1, 81.41 in SC2, 80.46 in SC3, 82.79 in SC4 and 80.26 in SC5.

During the 2nd week (11th to 18th May, 2019) it varied between 79 in SC1 and 82.08 in SC4 (SC1: 79, SC2: 80.51, SC3: 80.32, SC4: 82.08 and SC5: 79.16).

It was 81.97 in SC1, 83.28 in SC2, 81.89 in SC3, 85.77 in SC4 and 79.92 in SC5 during the 11th week (5th to 12th July, 2019) and 80.19 in SC1, 80.73 in SC2, 79.68 in SC3, 82.79 in SC4 and 79.78 in SC5 during 13th week (19th to 26th July, 2019).

During the 14th week (26th July to 3rd Aug, 2019) it varied between 81.28 in SC1 and 84.92 in SC4 (SC1: 81.28, SC2: 81.85, SC3: 82.19, SC4: 84.92 and SC5: 82.12). It was 82.71 in SC1, 83.50 in SC2, 82.19 in SC3, 84.45 in SC4 and 82.19 in SC5 during the 19th week (6th to 13th Sept, 2020) and 82.80 in SC1, 83.62 in SC2, 82.20 in SC3, 83.91 in SC4 and 83.51 in SC5 during 20th week (13th to 20th Sept, 2020). It was 82.38 in SC1, 83.33 in SC2, 80.15 in SC3, 82.71 in SC4 and 81.84 in SC5 during the 21st week.

**Table 41. Influence of Temperature Humidity Index (THI) on reduction in germination (%) of medium duration varieties**

| **Temperature Humidity Index (Weeks)** | **Varieties** | | | |
|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **1** | 0.909* | 0.975* | 0.971* | 0.941* |
| **2** | 0.896* | 0.827* | 0.838* | 0.916* |
| **11** | 0.938* | 0.967** | 0.978* | 0.937** |
| **13** | 0.899* | 0.973* | 0.967* | 0.900* |
| **14** | 0.808* | 0.966* | 0.930* | 0.823* |
| **19** | 0.798* | 0.989* | 0.956* | 0.848** |
| **20** | 0.874* | 0.973** | 0.955* | 0.902** |
| **21** | 0.978** | 0.922* | 0.947* | 0.968** |

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

### 4.2.2.2 VIGOUR INDEX –I

The results on vigour index - I as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are presented in Table 42, 43, 44 and 45.

#### 4.2.2.2.1 Effect of varieties

Irrespective of storage period and the storage conditions, vigour index - I varied significantly between the varieties during the storage period (Table 42).

Variety Jyothi (1822.00) registered the highest vigour index - I estimate followed by Uma (1788.00) and Aiswarya (1777.00). Uma and Aiswarya were found to be on par with each other. Varieties Sreyas (1743.00) recorded significantly low vigour index-I.

#### 4.2.2.2.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, vigour index – I was found to significantly differ with storage duration (Table 42).

Vigour index – I declined progressively over the storage period from 2095.00 during 1 MAS to 1341.00 at 9 MAS. VI-I during the initial months i.e., up to 4 MAS (4MAS: 1900.08) were on par with each other and later, towards the end of storage period differed significantly (5MAS: 5MAS: 1820.00; 6MAS: 1745.00; 7MAS: 1602.00; 8MAS: 1459.00; 9 MAS: 1341.00) from estimates in the initial months.

#### 4.2.2.2.3 Effect of storage condition (SC)

Irrespective of varieties and the storage period, vigour index – I was found to be significantly influenced by storage condition (Table 43).

VI-I varied between 1736.00 (SC4: R.C.C. + without ventilation) and 1810.00 (SC3: R.C.C. + ventilation). SC3 (R.C.C + ventilation: 1810.00), SC1 (Asbestos + ventilation: 1788.00) and SC5 (Asbestos + forced ventilation: 1784.00) registered significantly superior vigour index -I over all other storage conditions. These were also found to be on par with each other. Vigour index-I in SC2 (Asbestos + without ventilation: 1746.00) followed by SC4 (R.C.C. + without ventilation: 1736.00) was significantly low, but was on par with each other.

**4.2.2.2.4 Effect to interaction**

**4.2.2.2.4.1 Varieties × Storage period (VAR × MAS)**

The interaction between varieties and storage period did not significantly influence Vigour index - I (Table 42).

**4.2.2.2.3.2 Storage condition × Storage period (SC×MAS)**

The interaction between different storage conditions and storage period did not significantly influence Vigour index - I (Table 43).

**4.2.2.2.4.3 Varieties × Storage condition (VAR × SC)**

The interaction between varieties and storage conditions did not significantly influence Vigour index - I (Table 44).

**4.2.2.2.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

The interaction between varieties, storage conditions and period of storage did not significantly influence Vigour index - I (Table 45).

**Table 42. Impact of short duration varieties, storage period and their interactions on vigour index-I of medium duration rice varieties.**

| VAR | Vigour index –I | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean VAR** |
| **Aiswarya** | 2060.00 | 2028.00 | 1977.00 | 1934.00 | 1850.00 | 1770.00 | 1599.00 | 1449.00 | 1321.00 | **1777.00[b]** |
| **Jyothi** | 2127.00 | 2081.00 | 2017.00 | 1939.00 | 1871.00 | 1769.00 | 1693.00 | 1455.00 | 1225.00 | **1822.00[a]** |
| **Sreyas** | 2030.00 | 1959.00 | 1908.00 | 1880.00 | 1797.00 | 1724.00 | 1590.00 | 1439.00 | 1352.00 | **1743.00[c]** |
| **Uma** | 2029.00 | 2003.00 | 1975.00 | 1945.00 | 1811.00 | 1744.00 | 1625.00 | 1491.00 | 1466.00 | **1788.00[b]** |
| **Mean MAS** | **2095.00[a]** | **2018.00[ab]** | **2061.00[ab]** | **1900.00[abc]** | **1820.00[bc]** | **1745.00[c]** | **1602.00[cd]** | **1459.00[de]** | **1341.00[e]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 52.24 | 45.11 | 31.90 |
| MAS | 133.07 | 67.66 | 47.84 |
| VAR x MAS | N/A | 135.32 | 95.69 |

**Table 43. Impact of storage condition, storage period and their interactions on vigour index-I of medium duration rice varieties.**

| Storage condition (SC) | Vigour index –I | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean SC** |
| **SC 1** | 2061.00 | 2040.00 | 1980.00 | 1921.00 | 1829.00 | 1757.00 | 1628.00 | 1495.00 | 1373.00 | **1788.00[a]** |
| **SC 2** | 2061.00 | 2005.00 | 1935.00 | 1894.00 | 1816.00 | 1735.00 | 1586.00 | 1434.00 | 1329.00 | **1746.00[b]** |
| **SC 3** | 2061.00 | 2067.00 | 1998.00 | 1933.00 | 1878.00 | 1804.00 | 1650.00 | 1507.00 | 1388.00 | **1810.00[a]** |
| **SC 4** | 2061.00 | 2594.00 | 1953.00 | 1823.00 | 1730.00 | 1656.00 | 1531.00 | 1378.00 | 1250.00 | **1736.00[b]** |
| **SC 5** | 2061.00 | 2023.00 | 1964.00 | 1926.00 | 1847.00 | 1770.00 | 1616.00 | 1478.00 | 1364.00 | **1784.00[a]** |
| **Mean MAS** | **2061.00[a]** | **2018.00[ab]** | **2061.00[ab]** | **1900.00[abc]** | **1820.00[bc]** | **1745.00[c]** | **1602.00[cd]** | **1459.00[de]** | **1341.00[e]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 36.50 | 50.43 | 35.66 |
| MAS | 133.07 | 67.66 | 47.84 |
| SC x MAS | N/A | 151.30 | 106.98 |

**Table 44. Impact of varieties, storage condition and their interactions on vigour index-I of medium duration rice varieties.**

| VAR | Vigour index –I | | | | | |
|---|---|---|---|---|---|---|
| | **SC 1** | **SC 2** | **SC 3** | **SC 4** | **SC 5** | **Mean VAR** |
| **Aiswarya** | 1799.00 | 1766.00 | 1822.00 | 1708.00 | 1787.00 | **1777.00[b]** |
| **Jyothi** | 1783.00 | 1786.00 | 1862.00 | 1714.00 | 1799.00 | **1822.00[a]** |
| **Sreyas** | 1761.00 | 1731.00 | 1782.00 | 1676.00 | 1761.00 | **1743.00[c]** |
| **Uma** | 1805.00 | 1777.00 | 1833.00 | 1718.00 | 1771.00 | **1788.00[b]** |
| **Mean SC** | **1788.00[a]** | **1746.00[b]** | **1810.00[a]** | **1736.00[b]** | **1784.00[a]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 36.50 | 50.43 | 35.66 |
| VAR | 52.24 | 45.11 | 31.90 |
| VAR x SC | N/A | 100.86 | 71.32 |

**Table 45. Impact of varieties, storage conditions, storage periods and their interactions on vigour index-I of medium duration rice varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aiswarya | Jyothi | Sreyas | Uma | Aiswarya | Jyothi | Sreyas | Uma | Aiswarya | Jyothi | Sreyas | Uma |
| 1MAS | 2060.00 | 2127.00 | 2030.00 | 2029.00 | 2060.00 | 2127.00 | 2030.00 | 2029.00 | 2060.00 | 2127.00 | 2030.00 | 2029.00 |
| 2MAS | 2069.00 | 2100.00 | 1976.00 | 2018.00 | 2006.00 | 2071.00 | 1957.00 | 1989.00 | 2096.00 | 2120.00 | 2006.00 | 2047.00 |
| 3MAS | 2011.00 | 1985.00 | 1936.00 | 1990.00 | 1948.00 | 1930.00 | 1910.00 | 1955.00 | 2040.00 | 1983.00 | 1952.00 | 2020.00 |
| 4MAS | 1942.00 | 1897.00 | 1887.00 | 1958.00 | 1932.00 | 1826.00 | 1864.00 | 1958.00 | 1971.00 | 1861.00 | 1919.00 | 1983.00 |
| 5MAS | 1864.00 | 1833.00 | 1800.00 | 1821.00 | 1864.00 | 1814.00 | 1788.00 | 1799.00 | 1898.00 | 1879.00 | 1856.00 | 1879.00 |
| 6MAS | 1776.00 | 1758.00 | 1728.00 | 1769.00 | 1758.00 | 1739.00 | 1710.00 | 1736.00 | 1832.00 | 1819.00 | 1771.00 | 1798.00 |
| 7MAS | 1621.00 | 1615.00 | 1619.00 | 1658.00 | 1576.00 | 1573.00 | 1566.00 | 1629.00 | 1652.00 | 1656.00 | 1631.00 | 1662.00 |
| 8MAS | 1497.00 | 1483.00 | 1484.00 | 1516.00 | 1433.00 | 1426.00 | 1417.00 | 1463.00 | 1490.00 | 1511.00 | 1475.00 | 1553.00 |
| 9MAS | 1360.00 | 1256.00 | 1389.00 | 1487.00 | 1318.00 | 1211.00 | 1345.00 | 1445.00 | 1362.00 | 1262.00 | 1401.00 | 1529.00 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Aiswarya | Jyothi | Sreyas | Uma | Aiswarya | Jyothi | Sreyas | Uma |
| 1MAS | 2060.00 | 2127.00 | 2030.00 | 2029.00 | 2060.00 | 2127.00 | 2030.00 | 2029.00 |
| 2MAS | 1950.00 | 2028.00 | 1898.00 | 1939.00 | 2022.00 | 2087.00 | 1960.00 | 2024.00 |
| 3MAS | 1903.00 | 4720.00 | 1836.00 | 1918.00 | 1984.00 | 1971.00 | 1910.00 | 1994.00 |
| 4MAS | 1874.00 | 1736.00 | 1829.00 | 1855.00 | 1954.00 | 1875.00 | 1906.00 | 1973.00 |
| 5MAS | 1772.00 | 1726.00 | 1701.00 | 1721.00 | 1853.00 | 1855.00 | 1844.00 | 1837.00 |
| 6MAS | 1687.00 | 1635.00 | 1643.00 | 1662.00 | 1801.00 | 1749.00 | 1774.00 | 1757.00 |
| 7MAS | 1528.00 | 1518.00 | 1540.00 | 1540.00 | 1620.00 | 1607.00 | 1598.00 | 1640.00 |
| 8MAS | 1371.00 | 1377.00 | 1359.00 | 1408.00 | 1456.00 | 1480.00 | 1462.00 | 1516.00 |
| 9MAS | 1227.00 | 1131.00 | 1252.00 | 1390.00 | 1340.00 | 1264.00 | 1372.00 | 1481.00 |

| Factors | C.D. | SE(d) | SE(m) |
|---|---|---|---|
| VAR x SC x MAS | N/A | 302.59 | 213.97 |

#### 4.2.2.3 VIGOUR INDEX –II

The results on vigour index - II as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are enumerated in Table 46, 47, 48 and 49.

#### 4.2.2.3.1 Effect of varieties (VAR)

Irrespective of the period of storage and storage condition, vigour index - II was found to vary significantly between the varieties (Table 46).

Variety Jyothi (2128.00) and Aiswarya (2111.00) registered high significant vigour index – II. They were found to be on par with each other. Sreyas (1644.00) and Uma (1594.00) were on par with each other and had registered the lower vigour index –II.

#### 4.1.2.3.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, vigour index - II was found to be significantly influenced by the period of storage (Table 46).

Vigour index – II declined progressively and significantly over the storage period. It varied from 2160.00 at 1 MAS to 1426.00 at 9 MAS. VI-II at 1 MAS was on par with the estimate at 2 MAS (2106.00) and significantly superior over other months. VI-II at 2 MAS was however, on par with the estimates up to 5MAS (2004.00). The VI-II towards the end of storage *i.e.,* 8 MAS (1552.00) and 9 MAS (1426.00) were on par with each other.

#### 4.2.2.3.3 Effect of storage condition (SC)

Irrespective of varieties and the storage period, vigour index - II was found to be significantly influenced by the different storage conditions (Table 47).

Vigour Index-II of seeds stored in SC3 (R.C.C. + ventilation: 1911.00), SC1 (Asbestos + ventilation: 1889.00) and SC5 (Asbestos + forced ventilation: 1885.00) were found to be on par with each other. They were significantly superior over those stored in SC2 (Asbestos + without ventilation: 1816.00) and SC4 (R.C.C. + without ventilation: 1777.00).

**4.2.2.3.4 Effect to interaction**

**4.2.2.3.4.1 Varieties × Storage period (VAR × MAS)**

Irrespective of the storage conditions, vigour index -II was found to be significantly influenced by the interaction between varieties and storage period (Table 46). All the varieties registered a progressive decline in vigour index - II over the storage period. Vigour index -II of variety Jyothi and Aiswarya was significantly superior throughout the storage period and varied between 2528.00 (1 MAS) to 1581.00 (9 MAS) in Jyothi and 2380.00 (1 MAS) to 1591.00 (9 MAS) in Aiswarya. Varieties Sreyas and Uma had registered significant lower estimate for most part of storage, the values ranging between 1940.00 (1 MAS) and 1280.00 (9 MAS) in Sreyas, and 1793.00 (1 MAS) to 1249.00 (9 MAS) in Uma.

**4.2.2.3.4.2 Storage condition × Storage period (SC × MAS)**

Irrespective of the varieties, the interaction between storage conditions and storage period did not significantly influence vigour index -II (Table 47).

**4.2.2.4.3.3 Varieties × Storage condition (VAR × SC)**

Irrespective of the storage period, the interaction between varieties and storage conditions did not significantly influence vigour index -II (Table 48).

**4.2.2.4.3.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

The interaction between varieties, storage conditions and storage period on vigour index -II was found to be non-significant (Table 49).

**Table 46. Impact of varieties, storage period and their interactions on vigour index – II of medium duration rice varieties.**

| VAR | Vigour index – II | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 MAS | 2 MAS | 3 MAS | 4 MAS | 5 MAS | 6 MAS | 7 MAS | 8 MAS | 9 MAS | Mean VAR |
| **Aiswarya** | 2380.00 | 2349.00 | 2287.00 | 2283.00 | 2197.00 | 2135.00 | 2014.00 | 1761.00 | 1591.00 | **2111.00[a]** |
| **Jyothi** | 2528.00 | 2486.00 | 2304.00 | 2221.00 | 2205.00 | 2131.00 | 1960.00 | 1728.00 | 1581.00 | **2128.00[a]** |
| **Sreyas** | 1940.00 | 1833.00 | 1781.00 | 1805.00 | 1707.00 | 1635.00 | 1535.00 | 1368.00 | 1280.00 | **1644.00[b]** |
| **Uma** | 1793.00 | 1751.00 | 1692.00 | 1614.00 | 1906.00 | 1505.00 | 1484.00 | 1349.00 | 1249.00 | **1594.00[b]** |
| **Mean MAS** | **2160.00[a]** | **2106.00[ab]** | **2017.00[b]** | **1981.00[b]** | **2004.00[bc]** | **1852.00[cd]** | **1748.00[d]** | **1552.00[e]** | **1426.00[e]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 54.77 | 27.85 | 19.69 |
| MAS | 82.15 | 41.77 | 29.54 |
| VAR x MAS | 164.30 | 83.54 | 59.07 |

**Table 47. Impact of storage condition, storage period and their interactions on vigour index – II of medium duration rice varieties.**

| Storage condition (SC) | Vigour index – II | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean SC |
| **SC 1** | 2160.00 | 2127.00 | 2068.00 | 2037.00 | 1939.00 | 1868.00 | 1779.00 | 1570.00 | 1449.00 | **1889.00[a]** |
| **SC 2** | 2160.00 | 2095.00 | 2014.00 | 1949.00 | 2346.00 | 1834.00 | 1727.00 | 1522.00 | 1354.00 | **1816.00[b]** |
| **SC 3** | 2160.00 | 2167.00 | 2062.00 | 2047.00 | 1976.00 | 1920.00 | 1787.00 | 1598.00 | 1481.00 | **1911.00[a]** |
| **SC 4** | 2160.00 | 2033.00 | 1903.00 | 1873.00 | 1801.00 | 1754.00 | 1682.00 | 1473.00 | 1313.00 | **1777.00[b]** |
| **SC 5** | 2160.00 | 2103.00 | 2034.00 | 1998.00 | 1956.00 | 1881.00 | 1765.00 | 1594.00 | 1469.00 | **1885.00[a]** |
| **Mean MAS** | **2160.00[a]** | **2106.00[ab]** | **2017.00[b]** | **1981.00[b]** | **2004.00[bc]** | **1852.00[cd]** | **1748.00[d]** | **1552.00[e]** | **1426.00[e]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 61.23 | 31.14 | 22.02 |
| MAS | 82.15 | 41.77 | 29.54 |
| SC x MAS | N/A | 93.40 | 66.05 |

**Table 48. Impact of varieties, storage condition and their interactions on vigour index – II of medium duration rice varieties.**

| VAR | Vigour index – II | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| **Aiswarya** | 2114.00 | 2092.00 | 2171.00 | 2035.00 | 2141.00 | **2111.00[a]** |
| **Jyothi** | 2181.00 | 2122.00 | 2185.00 | 2000.00 | 2148.00 | **2128.00[a]** |
| **Sreyas** | 1686.00 | 1637.00 | 1692.00 | 1574.00 | 1679.00 | **1644.00[b]** |
| **Uma** | 1573.00 | 1732.00 | 1595.00 | 1499.00 | 1570.00 | **1594.00[b]** |
| **Mean SC** | **1889.00[a]** | **1816.00[b]** | **1911.00[a]** | **1777.00[b]** | **1885.00[a]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 61.23 | 31.14 | 22.02 |
| VAR | 54.77 | 27.85 | 19.69 |
| VAR x SC | N/A | 62.27 | 44.03 |

**Table 49. Impact of varieties, storage conditions, storage periods and their interactions on vigour index - II of medium duration rice varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aiswarya | Jyothi | Shreyas | Uma | Aiswarya | Jyothi | Shreyas | Uma | Aiswarya | Jyothi | Shreyas | Uma |
| 1MAS | 2380.00 | 2528.00 | 1940.00 | 1793.00 | 2380.00 | 2528.00 | 1940.00 | 1793.00 | 2380.00 | 2528.00 | 1940.00 | 1793.00 |
| 2MAS | 2309.00 | 2558.00 | 1875.00 | 1768.00 | 2334.00 | 2509.00 | 1800.00 | 1739.00 | 2409.00 | 2558.00 | 1901.00 | 1801.00 |
| 3MAS | 2233.00 | 2471.00 | 1853.00 | 1718.00 | 2277.00 | 2351.00 | 1757.00 | 1671.00 | 2338.00 | 2297.00 | 1853.00 | 1763.00 |
| 4MAS | 2320.00 | 2337.00 | 1824.00 | 1670.00 | 2269.00 | 2157.00 | 1770.00 | 1602.00 | 2337.00 | 2294.00 | 1897.00 | 1661.00 |
| 5MAS | 2201.00 | 2273.00 | 1742.00 | 1541.00 | 2200.00 | 2183.00 | 1693.00 | 3309.00 | 2257.00 | 2301.00 | 1748.00 | 1598.00 |
| 6MAS | 2102.00 | 2209.00 | 1647.00 | 1516.00 | 2127.00 | 2108.00 | 1620.00 | 1483.00 | 2257.00 | 2183.00 | 1689.00 | 1554.00 |
| 7MAS | 2043.00 | 1964.00 | 1591.00 | 1522.00 | 1967.00 | 1941.00 | 1521.00 | 1479.00 | 2094.00 | 2037.00 | 1508.00 | 1511.00 |
| 8MAS | 1795.00 | 1719.00 | 1412.00 | 1355.00 | 1706.00 | 1723.00 | 1348.00 | 1312.00 | 1826.00 | 1812.00 | 1371.00 | 1385.00 |
| 9MAS | 1651.00 | 1574.00 | 1299.00 | 1276.00 | 1572.00 | 1599.00 | 1284.00 | 1203.00 | 1647.00 | 1661.00 | 1323.00 | 1295.00 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Aiswarya | Jyothi | Shreyas | Uma | Aiswarya | Jyothi | Shreyas | Uma |
| 1MAS | 2380.00 | 2528.00 | 1940.00 | 1793.00 | 2380.00 | 2528.00 | 1940.00 | 1793.00 |
| 2MAS | 2296.00 | 2352.00 | 1773.00 | 1715.00 | 2401.00 | 2457.00 | 1820.00 | 1736.00 |
| 3MAS | 2225.00 | 2114.00 | 1665.00 | 1610.00 | 2365.00 | 2290.00 | 1780.00 | 1702.00 |
| 4MAS | 2201.00 | 2075.00 | 1689.00 | 1527.00 | 2290.00 | 2246.00 | 1846.00 | 1614.00 |
| 5MAS | 2104.00 | 2048.00 | 1572.00 | 1483.00 | 2224.00 | 2220.00 | 1782.00 | 1601.00 |
| 6MAS | 2055.00 | 1989.00 | 1540.00 | 1435.00 | 2135.00 | 2167.00 | 1683.00 | 1539.00 |
| 7MAS | 1933.00 | 1868.00 | 1509.00 | 1420.00 | 2035.00 | 1994.00 | 1547.00 | 1488.00 |
| 8MAS | 1663.00 | 1595.00 | 1307.00 | 1331.00 | 1819.00 | 1795.00 | 1403.00 | 1363.00 |
| 9MAS | 1462.00 | 1435.00 | 1180.00 | 1178.00 | 1623.00 | 1642.00 | 1319.00 | 1294.00 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | N/A | 186.81 | 132.09 |

### 4.2.2.4 SEED MOISTURE CONTENT (%)

The results on per cent seed moisture content as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are enumerated in Table 50, 51, 52 and 53.

#### 4.2.2.4.1 Effect of varieties (VAR)

Irrespective of the period of storage and storage condition, seed moisture content was found to vary significantly between the varieties during storage (Table 50).

The seeds of variety Sreyas (13.20%) registered significant low moisture content than the other varieties. Seed moisture content in variety Aiswarya (13.42%) differed significantly from Jyothi (13.48%). Variety Uma had registered the highest seed moisture estimate (13.96%).

#### 4.2.2.4.2 Effect of period of storage (MAS)

Irrespective of the varieties and storage condition, seed moisture content was found to vary significantly during storage (Table 50).

Seed moisture content increased progressively, differing significantly with increase in the storage period. It varied between 11.03 per cent (1 MAS) and 15.41 per cent (9 MAS). Seed moisture content was found to be below 13 per cent up to 3 MAS (12.62%).

#### 4.2.2.4.3 Effect of storage condition (SC)

Irrespective of varieties and the period of storage, storage condition exerted significant influence on seed moisture content (Table 51).

The moisture content in seeds stored under storage condition SC4 (R.C.C. + without ventilation: 14.15%) was significantly high compared to all other storage conditions. Seed moisture in SC2 (Asbestos + without ventilation: 13.68%) was significantly higher than SC5 (Asbestos + forced ventilation: 13.33%) and SC3 (R.C.C. + ventilation: 13.37%). SC5 and SC3 were found to be on par with each other. Seeds stored in SC1 (Asbestos + ventilation: 13.14%) registered the least moisture estimate. It was observed to be significantly lower than in the others.

#### 4.2.2.3.4 Effect to interaction

#### 4.2.2.3.4.1 Varieties × Storage period (VAR × MAS)

Irrespective of the storage conditions, moisture content in the seed content was significantly influenced by the interaction between varieties and storage period (Table 50).

Seed moisture content in all the varieties increased gradually with an increase in the storage period. At 9 MAS, Uma (15.81%) registered significantly high seed moisture content followed by Aiswarya (15.37%) and Sreyas (15.31%). Aiswarya and Sreyas were found to be on par with each other. Jyothi (15.14%) registered lower seed moisture content at 9 MAS. Seed moisture in variety Aiswarya and Sreyas reached above 13.00 per cent at 5 MAS, while in Uma, it reached 13.07 per cent at 3 MAS.

#### 4.2.2.3.4.2 Storage condition × Storage period (SC × MAS)

Irrespective of the varieties, seed moisture content was significantly influenced by the interaction between different storage condition and storage period (Table 51).

Initially, the seed moisture content of seeds in all storage conditions was 11.03 per cent (1 MAS). However, as storage period increased, significant variations in moisture content was observed. Seed moisture was found to be the high under SC4 ((R.C.C. + without ventilation) throughout the storage period (2 MAS: 12.85%; 9 MAS: 15.93%) and the least under SC1 (Asbestos + ventilation- 2 MAS: 11.63%; 9 MAS: 14.97%).

At 9 MAS, moisture content in seeds stored under treatments SC4 (R.C.C. + without ventilation: 15.93%) and SC2 (Asbestos + without ventilation: 15.60%), registered significantly high seed moisture content over SC3 (R.C.C. + ventilation: 15.30%), SC5 (Asbestos + forced ventilation (15.21%), and SC1 (Asbestos + ventilation: 14.97%). Seed moisture content reached above 13.00 per cent in SC1 (13.18%), SC3 (13.42%), and SC5 (13.24%) at 5 MAS, while, in SC2 (13.34%) and SC4 (13.48%), it reached above 13.00 per cent at 4 MAS, 3 MAS respectively.

**4.1.2.3.4.3 Varieties × Storage condition (VAR × SC)**

Irrespective of storage period, significant difference in seed moisture content was observed due to the interaction of varieties and storage condition (Table 52).

Seed moisture content in variety Uma was found to be significantly high (SC1:13.65%; SC2:13.90%; SC3:13.96%; SC4:14.60%; and SC5: 13.67%) under all storage environments, while, it was found to be the least in variety Sreyas (SC1:12.80%; SC2:13.46%; SC3:13.26%; SC4:13.77% and SC5:12.70%). Variety Jyothy under SC1 (12.84%) and SC3 (13.12%), and variety Aiswarya under SC2 (13.52%), SC3 (13.14%) and SC4 (13.86%), were on par with Sreyas in the respective storage environments.

**4.2.2.3.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

Seed moisture content was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 53).

At 8 MAS, seeds of varieties stored under SC2 (Aiswarya: 14.93%; Jyothi: 14.53%, Shreyas: 15.00; Uma: 15.17%) and SC4 (Aiswarya: 15.37%; Jyothi: 15.60%, Shreyas: 15.23%; Uma: 16.03%) registered higher moisture content compared to those stored in other conditions, while, those in SC1 had registered significant low estimates (Aiswarya: 14.80%; Jyothi: 14.07%, Sreyas: 14.40%; Uma: 15.17%). Moisture content in varieties stored in SC4 reached above 13.00 per cent earlier (Jyothi and Uma: 13.27% each by 2 MAS; Aiswarya: 13.10% and Sreyas: 13.00% by 3 MAS) than in other conditions. Seed moisture in varieties Sreyas in SC1 (13.37%) and SC5 (13.07%) and Jyothi under SC1 (13.43%), exceeded 13.00 per cent much later (by 6 MAS).

**Table 50. Impact of varieties, storage period and their interactions on seed moisture content of medium duration rice varieties.**

| Varieties (VAR) | Seed moisture content (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean VAR |
| Aiswarya | $11.10^{b}$ | $11.89^{d}$ | $12.47^{fg}$ | $12.91^{hi}$ | $13.49^{kl}$ | $13.97^{m}$ | $14.59^{o}$ | $14.99^{pq}$ | $15.37^{stu}$ | **$13.42^{b}$** |
| Jyothi | $11.00^{b}$ | $12.23^{ef}$ | $12.71^{gh}$ | $13.32^{jk}$ | $13.55^{klm}$ | $14.05^{n}$ | $14.53^{o}$ | $14.82^{op}$ | $15.14^{rs}$ | **$13.48^{c}$** |
| Sreyas | $10.50^{a}$ | $11.75^{d}$ | $12.21^{e}$ | $12.80^{h}$ | $13.28^{ij}$ | $13.71^{lm}$ | $14.39^{o}$ | $14.83^{op}$ | $15.31^{rst}$ | **$13.20^{a}$** |
| Uma | $11.50^{c}$ | $12.52^{g}$ | $13.07^{i}$ | $13.49^{kl}$ | $14.09^{n}$ | $14.60^{op}$ | $15.08^{qr}$ | $15.45^{tu}$ | $15.81^{u}$ | **$13.96^{d}$** |
| **Mean VAR** | **$11.03^{a}$** | **$12.10^{b}$** | **$12.62^{c}$** | **$13.13^{d}$** | **$13.60^{e}$** | **$14.08^{f}$** | **$14.65^{g}$** | **$15.02^{h}$** | **$15.41^{i}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.04 | 0.02 | 0.02 |
| MAS | 0.06 | 0.03 | 0.02 |
| VAR x MAS | 0.13 | 0.06 | 0.05 |

**Table 51. Impact of storage condition, storage period and their interactions on seed moisture content of medium duration rice varieties.**

| Storage condition (SC) | Seed moisture content (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean SC |
| **SC 1** | 11.03[a] | 11.63[b] | 12.09[cd] | 12.79[g] | 13.18[h] | 13.68[jk] | 14.26[no] | 14.61[pqr] | 14.97[st] | **13.14[a]** |
| **SC 2** | 11.03[a] | 12.40[ef] | 12.88[g] | 13.34[hi] | 13.77[kl] | 14.16[mno] | 14.81[qrs] | 15.16[tuv] | 15.60[w] | **13.68[c]** |
| **SC 3** | 11.03[a] | 11.85[bc] | 12.40[ef] | 12.83[g] | 13.42[hij] | 13.97[lm] | 14.55[pq] | 14.98[stu] | 15.32[uv] | **13.37[b]** |
| **SC 4** | 11.03[a] | 12.85[g] | 13.48[ij] | 14.02[lmn] | 14.41[op] | 14.84[rs] | 15.26[uv] | 15.56[w] | 15.93[x] | **14.15[d]** |
| **SC 5** | 11.03[a] | 11.76[b] | 12.23[de] | 12.68[fg] | 13.24[hi] | 13.77[kl] | 14.36[op] | 14.81[qrs] | 15.21[tuv] | **13.33[b]** |
| **Mean MAS** | **11.03[a]** | **12.10[b]** | **12.62[c]** | **13.13[d]** | **13.60[e]** | **14.08[f]** | **14.65[g]** | **15.02[h]** | **15.41[i]** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.05 | 0.02 | 0.02 |
| MAS | 0.06 | 0.03 | 0.02 |
| SC x MAS | 0.06 | 0.03 | 0.02 |

**Table 52. Impact of varieties, storage condition and their interactions on seed moisture content of medium duration rice varieties.**

| Varieties (VAR) | Seed moisture content (%) | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| Aiswarya | $13.26^{bc}$ | $13.52^{ef}$ | $13.14^{bc}$ | $13.86^{hi}$ | $13.31^{cd}$ | **$13.42^{b}$** |
| Jyothi | $12.84^{a}$ | $13.84^{hi}$ | $13.12^{b}$ | $14.38^{j}$ | $13.24^{bc}$ | **$13.48^{c}$** |
| Sreyas | $12.80^{a}$ | $13.46^{de}$ | $13.26^{bc}$ | $13.77^{gh}$ | $12.70^{a}$ | **$13.20^{a}$** |
| Uma | $13.65^{fg}$ | $13.90^{hi}$ | $13.96^{i}$ | $14.60^{k}$ | $13.67^{g}$ | **$13.96^{d}$** |
| **Mean SC** | **$13.14^{a}$** | **$13.68^{c}$** | **$13.37^{b}$** | **$14.15^{d}$** | **$13.33^{b}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.04 | 0.02 | 0.02 |
| SC | 0.05 | 0.02 | 0.02 |
| SC x VAR | 0.14 | 0.07 | 0.05 |

**Table 53. Impact of varieties, storage conditions, storage periods and their interactions on seed moisture content (%) of medium duration rice varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **1MAS** | 11.10 | 11.00 | 10.50 | 11.50 | 11.10 | 11.00 | 10.50 | 11.50 | 11.10 | 11.00 | 10.50 | 11.50 |
| **2MAS** | 11.77 | 11.47 | 11.13 | 12.13 | 11.37 | 11.83 | 11.73 | 12.47 | 12.20 | 12.77 | 12.20 | 12.43 |
| **3MAS** | 12.27 | 11.90 | 11.50 | 12.70 | 12.00 | 12.23 | 12.23 | 13.13 | 12.70 | 13.23 | 12.70 | 12.87 |
| **4MAS** | 12.77 | 12.73 | 12.50 | 13.17 | 12.33 | 12.67 | 12.73 | 13.60 | 13.20 | 13.73 | 13.13 | 13.30 |
| **5MAS** | 13.23 | 12.80 | 12.97 | 13.73 | 13.10 | 13.07 | 13.40 | 14.10 | 13.60 | 13.93 | 13.53 | 14.00 |
| **6MAS** | 13.67 | 13.43 | 13.37 | 14.23 | 13.73 | 13.70 | 13.83 | 14.60 | 13.90 | 14.33 | 13.87 | 14.53 |
| **7MAS** | 14.43 | 13.83 | 14.00 | 14.77 | 14.50 | 14.20 | 14.50 | 15.00 | 14.60 | 14.87 | 14.63 | 15.13 |
| **8MAS** | 14.80 | 14.07 | 14.40 | 15.17 | 14.93 | 14.53 | 15.00 | 15.43 | 14.97 | 15.17 | 15.03 | 15.47 |
| **9MAS** | 15.27 | 14.33 | 14.80 | 15.47 | 15.23 | 14.80 | 15.43 | 15.80 | 15.43 | 15.53 | 15.57 | 15.87 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **1MAS** | 11.10 | 11.00 | 10.50 | 11.50 | 11.10 | 11.00 | 10.50 | 11.50 |
| **2MAS** | 12.37 | 13.27 | 12.50 | 13.27 | 11.73 | 11.80 | 11.20 | 12.30 |
| **3MAS** | 13.10 | 13.90 | 13.00 | 13.90 | 12.27 | 12.30 | 11.63 | 12.73 |
| **4MAS** | 13.57 | 14.53 | 13.63 | 14.33 | 12.70 | 12.93 | 12.00 | 13.07 |
| **5MAS** | 14.10 | 14.77 | 13.97 | 14.80 | 13.43 | 13.20 | 12.53 | 13.80 |
| **6MAS** | 14.53 | 15.03 | 14.43 | 15.37 | 14.00 | 13.73 | 13.07 | 14.27 |
| **7MAS** | 14.90 | 15.40 | 14.93 | 15.80 | 14.50 | 14.33 | 13.90 | 14.70 |
| **8MAS** | 15.37 | 15.60 | 15.23 | 16.03 | 14.90 | 14.73 | 14.47 | 15.13 |
| **9MAS** | 15.73 | 15.93 | 15.70 | 16.37 | 15.17 | 15.10 | 15.03 | 15.53 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | 0.28 | 0.14 | 0.10 |

### 4.2.2.5 ELECTRICAL CONDUCTIVITY OF SEED LEACHATE (EC) (μ$Sm^{-1}$)

The results on electrical conductivity of seed leachate (EC) (μ$Sm^{-1}$) as influenced by varieties, storage condition, the period of storage and their interactions during seed storage are presented in Table 54, 55, 56 and 57.

#### 4.2.2.5.1 Effect of varieties

Irrespective of the period of storage and storage condition, electrical conductivity of seed leachate (EC) was found to be vary significantly between the varieties (Table 54).

Variety Sreyas (160.66μ$Sm^{-1}$) recorded significantly EC followed by Aiswarya (177.55μ$Sm^{-1}$). Variety Jyothi (209.92 μ$Sm^{-1}$) and Uma (211.45μ$Sm^{-1}$) recorded significantly higher electrical conductivity and were found to be on par with each other.

#### 4.2.2.5.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, EC was found to be significantly influenced by the period of storage (Table 54).

Electrical conductivity of seed leachate increased significantly as the storage period prolonged. The estimate ranged from 111.38 μ$Sm^{-1}$ during 1 MAS to 259.47 μ$Sm^{-1}$ in 9 MAS.

#### 4.2.2.5.3 Effect of storage condition (SC)

Irrespective of varieties and the period of storage, electrical conductivity of seed leachate was found to be vary significantly between the storage conditions (Table 55).

EC of seed leachate in SC5 (Asbestos + ventilation: 164.56 μ$Sm^{-1}$) was the least and it was significantly different from that observed in other storage conditions. EC estimates in SC1 (Asbestos + forced ventilation: 168.88 μ$Sm^{-1}$) followed by SC3 (R.C.C. + ventilation: 187.31 μ$Sm^{-1}$) were differed significantly from SC2 (Asbestos + without ventilation).

### 4.2.2.5.4 Effect to interaction

#### 4.2.2.5.4.1 Varieties × Storage period (VAR × MAS)

Irrespective of the storage conditions, electrical conductivity was significantly influenced by the interaction between different varieties and storage period (Table 54).

Variety Uma, registered high EC estimates throughout the storage period (1 MAS: 146.5 $\mu Sm^{-1}$; 9 MAS: 279.12 $\mu Sm^{-1}$). At 9 MAS, in Uma (279.12 $\mu Sm^{-1}$) and Jyothi (276.30 $\mu Sm^{-1}$) EC estimate was significantly high and on par with each other, followed by Aiswarya (252.71 $\mu Sm^{-1}$). Variety Sreyas (279.12 $\mu Sm^{-1}$) registered the least electrical conductivity and differed from all other varieties.

#### 4.2.2.5.4.2 Storage condition × Storage period (SC × MAS)

Irrespective of the varieties, electrical conductivity was significantly influenced by the interaction between different storage condition and the storage period (Table 55).

Although initially, the EC of seed leachate of seeds was found to be the same (1 MAS: 111.38 $\mu Sm^{-1}$) under all conditions. However, the EC of seed stored in SC4 (R.C.C. + without ventilation) was found to be significantly high as the storage period progressed. Seeds stored in SC2 registered significantly high estimates next to those in SC4.

At 9 MAS, EC of seeds in SC5 (Asbestos + forced ventilation: 132.28 $\mu Sm^{-1}$) and SC1 (Asbestos + ventilation: 228.42 $\mu Sm^{-1}$) were found to be significantly least and on par with each other. SC3 (R.C.C. + ventilation: 256.81 $\mu Sm^{-1}$), SC2 (Asbestos + without ventilation: 281.13 $\mu Sm^{-1}$) followed by SC4 (R.C.C. + without ventilation: 300.61 $\mu Sm^{-1}$), registered significantly high EC estimates.

#### 4.1.2.5.4.3 Varieties × Storage condition (VAR × SC)

Significant differences in electrical conductivity of seed leachate was observed due to the interaction of varieties and storage condition, irrespective of the storage period (Table 56).

All the varieties stored under SC4 (Aiswarya: 210.99 $\mu Sm^{-1}$; Jyothi: 255.46 $\mu Sm^{-1}$; Sreyas: 189.93 $\mu Sm^{-1}$; Uma: 227.69 $\mu Sm^{-1}$) registered significant high EC estimates followed by those stored in SC2 (Aiswarya: 192.66 $\mu Sm^{-1}$; Jyothi: 240.44 $\mu Sm^{-1}$; Sreyas: 179.10 $\mu Sm^{-1}$; Uma: 218.50 $\mu Sm^{-1}$). The EC of seed leachate was found to be lower in seeds of all varieties stored in SC1 (Aiswarya:151.20 $\mu Sm^{-1}$; Jyothi:178.28 $\mu Sm^{-1}$; Sreyas:141.67 $\mu Sm^{-1}$; Uma:204.39 $\mu Sm^{-1}$) and SC5 (Aiswarya:154.53 $\mu Sm^{-1}$; Jyothi:171.35 $\mu Sm^{-1}$; Sreyas:134.30 $\mu Sm^{-1}$; Uma:227.69 $\mu Sm^{-1}$) compared to SC3 (Aiswarya:178.35 $\mu Sm^{-1}$; Jyothi:204.05 $\mu Sm^{-1}$; Sreyas:158.31 $\mu Sm^{-1}$; Uma:208.52 $\mu Sm^{-1}$).

#### 4.2.2.5.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)

Electrical conductivity of seed leachate was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 57).

EC of seed leachate in the varieties increased with increase in storage period, across all storage conditions. The EC estimate of the seeds stored in SC4 and SC2 was significantly high throughout the storage period. The EC estimates of varieties under Asbestos + Forced ventilation (SC5) and Asbestos + ventilation (SC1) was found to be lower than that in R.C.C. + ventilation (SC3), during the corresponding period. The EC estimate of seeds stored in SC4 at 9 MAS was, 296.50 $\mu Sm^{-1}$, 337.27 $\mu Sm^{-1}$, 265.00 $\mu Sm^{-1}$, and 303.67 $\mu Sm^{-1}$ respectively in variety Aiswarya, Jyothi, Sreyas and Uma, whereas it was 252.20 $\mu Sm^{-1}$, 273.97 $\mu Sm^{-1}$, 226.77 $\mu Sm^{-1}$, and 274.30 $\mu Sm^{-1}$, respectively in variety Aiswarya, Jyothi, Sreyas and Uma under SC2 in the corresponding period.

**Table 54. Impact of varieties, storage period and their interactions on electrical conductivity of seed leachate of medium duration rice varieties.**

| Varieties (VAR) | Electrical conductivity ($\mu Sm^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean VAR** |
| **Aiswarya** | 81.20$^{a}$ | 116.41$^{cd}$ | 135.68$^{efg}$ | 159.05 $^{hi}$ | 178.53$^{jk}$ | 207.49$^{mno}$ | 223.04$^{opq}$ | 243.78 $^{pq}$ | 252.71$^{st}$ | **177.55$^{b}$** |
| **Jyothi** | 127.02$^{def}$ | 151.68$^{gh}$ | 169.15$^{ij}$ | 195.85$^{lm}$ | 212.86$^{no}$ | 235.40$^{qr}$ | 252.25$^{s}$ | 268.72$^{tu}$ | 276.30$^{u}$ | **209.92$^{c}$** |
| **Sreyas** | 90.80$^{ab}$ | 106.81$^{bc}$ | 121.41$^{cde}$ | 140.77$^{fg}$ | 157.51$^{hi}$ | 178.23$^{jk}$ | 201.45$^{lmn}$ | 219.22$^{op}$ | 229.73$^{pq}$ | **160.66$^{a}$** |
| **Uma** | 146.50$^{gh}$ | 158.10$^{hi}$ | 168.93$^{ij}$ | 187.5$^{kl}$ | 207.48$^{mno}$ | 234.61$^{pq}$ | 250.84$^{rs}$ | 269.95$^{u}$ | 279.12$^{u}$ | **211.45$^{c}$** |
| **Mean MAS** | **111.38$^{a}$** | **133.25$^{b}$** | **148.80$^{c}$** | **170.80$^{d}$** | **189.10$^{e}$** | **213.94$^{f}$** | **231.90$^{g}$** | **250.42$^{h}$** | **259.47$^{i}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| MAS | 2.445 | 1.243 | 0.879 |
| VAR | 1.630 | 0.829 | 0.586 |
| VAR x MAS | 4.889 | 2.486 | 1.758 |

**Table 55. Impact of storage condition, storage period and their interactions on electrical conductivity of seed leachate of medium duration rice varieties.**

| Storage condition (SC | Electrical conductivity (µS$m^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8 MAS** | **9MAS** | **Mean SC** |
| **SC 1** | 111.38$^{a}$ | 119.39$^{abc}$ | 128.09$^{bcd}$ | 149.24$^{fgh}$ | 164.26$^{ghij}$ | 191.60$^{lmn}$ | 203.66$^{mno}$ | 221.93$^{mno}$ | 230.39$^{st}$ | **168.88$^{a}$** |
| **SC 2** | 111.38$^{a}$ | 147.02$^{efg}$ | 166.98$^{hij}$ | 191.69$^{lmn}$ | 211.54$^{n}$ | 232.77$^{rst}$ | 254.56$^{uv}$ | 272.05$^{stu}$ | 281.13$^{wx}$ | **207.68$^{d}$** |
| **SC 3** | 111.38$^{a}$ | 130.66$^{cde}$ | 150.04$^{fgh}$ | 170.20$^{ijk}$ | 185.78$^{klm}$ | 207.00$^{mn}$ | 227.69$^{p}$ | 246.20$^{tu}$ | 256.81$^{uv}$ | **187.31$^{c}$** |
| **SC 4** | 111.38$^{a}$ | 160.18$^{ghij}$ | 177.86$^{jkl}$ | 201.89$^{mno}$ | 225.31$^{o}$ | 248.30$^{tu}$ | 271.46$^{vw}$ | 292.18$^{xy}$ | 300.61$^{y}$ | **221.02$^{e}$** |
| **SC 5** | 111.38$^{a}$ | 116.03$^{a}$ | 121.02$^{abc}$ | 140.95$^{def}$ | 158.59$^{fghi}$ | 190.02$^{lmn}$ | 202.13$^{mno}$ | 219.73$^{mno}$ | 228.42$^{qrs}$ | **164.58$^{b}$** |
| **Mean MAS** | **111.38$^{a}$** | **133.25$^{b}$** | **148.80$^{c}$** | **170.80$^{d}$** | **189.10$^{e}$** | **213.94$^{f}$** | **231.90$^{g}$** | **250.42$^{h}$** | **259.47$^{i}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| MAS | 2.445 | 1.243 | 0.879 |
| SC | 1.822 | 0.927 | 0.655 |
| SC x MAS | 5.466 | 2.78 | 1.965 |

**Table 56. Impact of varieties, storage condition and their interactions on electrical conductivity of seed leachate of medium duration rice varieties.**

| Varieties (VAR) | Electrical conductivity ($\mu Sm^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | **SC 1** | **SC 2** | **SC 3** | **SC 4** | **SC 5** | **Mean VAR** |
| **Aiswarya** | 151.20$^{c}$ | 192.66$^{e}$ | 178.35$^{c}$ | 210.99$^{gh}$ | 154.53$^{c}$ | **177.55$^{b}$** |
| **Jyothi** | 178.28$^{c}$ | 240.44$^{j}$ | 204.05$^{ef}$ | 255.46$^{k}$ | 171.35$^{c}$ | **209.92$^{c}$** |
| **Sreyas** | 141.67$^{b}$ | 179.10$^{cd}$ | 158.31$^{c}$ | 189.93$^{de}$ | 134.30$^{a}$ | **160.66$^{a}$** |
| **Uma** | 204.39$^{fg}$ | 218.50$^{hi}$ | 208.52$^{fgh}$ | 227.69$^{i}$ | 198.16$^{ef}$ | **211.45$^{c}$** |
| **Mean SC** | **168.88$^{a}$** | **207.68$^{d}$** | **187.31$^{c}$** | **221.02$^{e}$** | **164.58$^{b}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 1.63 | 0.829 | 0.586 |
| SC | 1.822 | 0.927 | 0.655 |
| VAR x SC | 3.644 | 1.853 | 1.31 |

**Table 57. Impact of varieties, storage conditions, storage periods and their interactions on electrical conductivity of seed leachate ($\mu Sm^{-1}$) of medium duration rice varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **1MAS** | 81.20 | 127.02 | 90.80 | 146.50 | 81.20 | 127.02 | 90.80 | 146.50 | 81.20 | 127.02 | 90.80 | 146.50 |
| **2MAS** | 97.20 | 130.67 | 93.53 | 156.17 | 118.30 | 142.03 | 102.07 | 160.23 | 133.70 | 182.67 | 114.77 | 156.93 |
| **3MAS** | 110.73 | 140.60 | 99.03 | 162.00 | 144.17 | 163.07 | 122.00 | 170.93 | 154.67 | 197.67 | 141.33 | 174.23 |
| **4MAS** | 132.33 | 161.33 | 121.00 | 182.30 | 162.20 | 190.27 | 140.67 | 187.67 | 181.33 | 232.33 | 161.67 | 191.43 |
| **5MAS** | 145.00 | 179.77 | 135.23 | 197.03 | 185.17 | 201.10 | 156.40 | 200.47 | 201.47 | 247.93 | 180.93 | 215.83 |
| **6MAS** | 167.73 | 196.73 | 154.83 | 247.10 | 200.43 | 227.23 | 176.30 | 224.03 | 219.50 | 270.97 | 201.77 | 238.83 |
| **7MAS** | 190.00 | 212.37 | 176.87 | 235.40 | 219.57 | 246.50 | 197.03 | 247.67 | 240.90 | 290.33 | 224.27 | 262.73 |
| **8MAS** | 215.13 | 223.17 | 196.93 | 252.47 | 241.93 | 265.30 | 212.73 | 264.83 | 254.60 | 304.93 | 243.20 | 285.47 |
| **9MAS** | 221.43 | 232.87 | 206.77 | 260.50 | 252.20 | 273.97 | 226.77 | 274.30 | 266.60 | 310.13 | 253.20 | 294.57 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** | **Aiswarya** | **Jyothi** | **Sreyas** | **Uma** |
| **1MAS** | 81.20 | 127.02 | 90.80 | 146.50 | 81.20 | 127.02 | 90.80 | 146.50 |
| **2MAS** | 145.77 | 197.57 | 131.57 | 165.80 | 87.10 | 105.47 | 92.13 | 151.40 |
| **3MAS** | 167.87 | 208.83 | 151.47 | 183.27 | 101.00 | 135.60 | 93.23 | 154.23 |
| **4MAS** | 195.07 | 241.67 | 169.83 | 201.00 | 124.33 | 153.67 | 110.70 | 175.10 |
| **5MAS** | 217.20 | 262.17 | 192.67 | 229.20 | 143.83 | 173.33 | 122.33 | 194.87 |
| **6MAS** | 239.10 | 289.03 | 215.27 | 249.80 | 210.70 | 193.07 | 143.00 | 213.30 |
| **7MAS** | 268.30 | 304.80 | 239.23 | 273.50 | 196.43 | 207.27 | 169.87 | 234.93 |
| **8MAS** | 287.93 | 330.77 | 253.57 | 296.47 | 219.30 | 219.43 | 189.67 | 250.53 |
| **9MAS** | 296.50 | 337.27 | 265.00 | 303.67 | 226.83 | 227.30 | 196.93 | 262.60 |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR x SC x MAS | 10.933 | 5.559 | 3.931 |

### 4.2.2.6 FIELD ESTABLISHMENT (%)

The results on per cent field establishment as influenced by varieties, storage condition, period of storage and their interactions during seed storage are enumerated in Table 58, 59, 60 and 61.

#### 4.2.2.6.1 Effect of varieties (VAR)

Irrespective of storage condition and period of storage, field establishment varied significantly between the varieties during the storage period (Table 58).

Over the storage period of nine months, irrespective of all other factors, field establishment of Aiswarya (90.06%) was significantly superior to other varieties. Field establishment of Sreyas (89.36%) and Uma (89.02%) differed significantly from each other and variety Jyothi (88.50%).

#### 4.2.2.6.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, was found to be significantly influenced by the period of storage (Table 58).

Field establishment declined progressively as well as differed significantly as the storage period progressed. Field establishment was found to be above 90 per cent, up to 5 MAS (91.10%). From 6 MAS onwards, there was a drastic decline field establishment and it fell below MSCS at 8 MAS (78.63%).

#### 4.2.2.6.3 Effect of storage condition (SC)

Irrespective of varieties and the period of storage, storage condition exerted significant influence on field establishment (Table 59).

Field establishment in seeds stored under treatments SC3 (R.C.C. + ventilation: 90.09%) was found to be significantly superior to all other treatments. Field establishment in SC1 (Asbestos + ventilation: 89.89%) and SC5 (Asbestos + forced ventilation: 89.46%) was found to be the next best and were on par with each other. The estimates in SC1 and SC5 were as significantly superior to that in SC2 (Asbestos + without ventilation: 89.21%) and SC4 (R.C.C. + without ventilation: 87.34%) Field establishment was the least in SC4.

#### 4.2.2.6.4 Effect to interaction

#### 4.2.2.6.4.1 Varieties × Storage period (VAR × MAS)

Irrespective of the storage conditions, field establishment was significantly influenced by the interaction between varieties and storage period (Table 58).

Field establishment of all the varieties declined progressively over the storage period. Variety Aiswarya had registered the highest field establishment (1 MAS: 100% and 9 MAS: 74.40%) throughout the storage period. At 9 MAS, field establishment in varieties Aiswarya (74.40%) and Uma (74.80%) was found to be on par with each other and observed to be significantly superior over Varieties Uma was also on par with Jyothi (74.16%) which in turn was found to be on par with Sreyas (84.87%). Field establishment in all the variety, fell below 90.00 per cent at 6 MAS, wherein varieties Jyothi and Uma had registered the least field establishment at the start of the storage (98.00%).

#### 4.2.2.6.4.2 Storage condition × Storage period (SC × MAS)

Irrespective of the varieties, the interaction between different storage condition and storage period significantly influenced field establishment (Table 59).

Initially, all the four varieties in all storage conditions registered a FE of 99.00 per cent. Subsequently, as storage period increased, significant variations occurred between varieties. Up to 5 MAS, field establishment in seeds stored under treatments, SC1 (Asbestos + ventilation), SC3 (R.C.C. + ventilation), SC5 (Asbestos + forced ventilation) as well as SC2 (Asbestos + without ventilation) was on par with each other. Later, FE in SC1, SC3 and SC5 differed significantly from that observed in SC2 and was also found to be on par with each other in the respective months of storage. At the end of storage (9 MAS) FE in SC1 (76.00%), SC3 (76.50%) and SC5 (75.72%) were on par with each other and significantly superior to all other storage conditions.

Field establishment in storage condition, SC3 (90.25%), was retained above 90.00 per cent up to 6 MAS, while it was retained for 5 MAS in SC2 (91.25%), SC1 (91.50%) and SC5 (91.75%). The FE estimate of seeds stored under SC4 was above 90.00 per cent up to 4 MAS only.

#### 4.2.2.6.4.3 Varieties × Storage condition (VAR × SC)

Irrespective of storage period, significant difference in field establishment was observed due to the interaction of varieties and storage condition (Table 60).

The highest field establishment estimate in all varieties was observed under SC3 (Aiswarya: 90.82%; Jyothi: 89.33%, Sreyas: 90.22% and Uma: 90.00%). Variety Aiswarya followed by Sreyas, registered significantly high FE over all other varieties in the various storage conditions, the FE of variety Aiswarya under SC1 (90.67%), SC3 (90.82%) and SC5 (90.533%) being on par with each other.

#### 4.2.2.6.4.4 Varieties x Storage condition x Storage period (VAR × SC × MAS)

Field establishment was found to be significantly influenced by the interaction between varieties, storage condition and the storage period (Table 61).

Field establishment in varieties Aiswarya and Sreyas was retained above MSCS for 8 MAS under SC1 (80.00% each), SC3 (Aiswarya: 80.00%; Sreyas: 80.33%) and SC5 (80.00% each). These were on par with each other and also significantly superior to all other varieties stored under these environments at 8 MAS.

Field establishment in all the varieties stored under SC2 (Aiswarya: 85.67%; Sreyas: 84.33%; Jyothi: 84.33%; Uma: 81.33%) and SC4 (Aiswarya: 83.33%; Sreyas: 81.33%; Jyothi: 84.00%; Uma: 82.33%) as well as varieties Jyothi and Uma stored under SC1 (Jyothi: 85.00%; Uma: 86.00%), SC3 (Jyothi: 85.00%; Uma: 87.00%) and SC5 (Jyothi: 84.00%; Uma: 85.67%) were retained above, MSCS for 7 MAS. However, at 7 MAS, field establishment in varieties Aiswarya and Sreyas were found to be on par with each other as well as significantly superior to other varieties, across all storage environments.

**Table 58. Impact of varieties, storage period and their interactions on field establishment of medium duration rice varieties.**

| Varieties (VAR) | Field establishment (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean VAR |
| **Aiswarya** | 100.00 (10.00)$^{a}$ | 98.07 (9.91)$^{b}$ | 95.80 (9.78)$^{d}$ | 94.80 (9.72)$^{e}$ | 92.47 (9.66)$^{g}$ | 89.53 (9.51)$^{i}$ | 85.53 (9.30)$^{l}$ | 78.93 (8.94)$^{n}$ | 74.40 (8.74)$^{o}$ | **90.06 (9.48)$^{a}$** |
| **Jyothi** | 98.00 (9.90)$^{bc}$ | 97.80 (9.89)$^{bc}$ | 93.20 (9.70)$^{fg}$ | 91.20 (9.60)$^{h}$ | 90.47 (9.56)$^{h}$ | 88.73 (9.47)$^{jk}$ | 83.93 (9.21)$^{m}$ | 78.60 (8.92)$^{n}$ | 74.16 (8.69)$^{pq}$ | **88.50 (9.40)$^{d}$** |
| **Sreyas** | 100.00 (10.00)$^{a}$ | 97.60 (9.88)$^{bc}$ | 95.00 (9.75)$^{e}$ | 93.60 (9.72)$^{f}$ | 91.00 (9.59)$^{h}$ | 89.47 (9.51)$^{ij}$ | 84.87 (9.26)$^{l}$ | 78.60 (8.92)$^{n}$ | 74.07 (8.66)$^{q}$ | **89.36 (9.45)$^{b}$** |
| **Uma** | 98.00 (9.90)$^{bc}$ | 97.02 (9.85)$^{c}$ | 95.40 (9.76)$^{de}$ | 93.07 (9.69)$^{fg}$ | 90.47 (9.56)$^{h}$ | 88.67 (9.46)$^{k}$ | 85.33 (9.29)$^{l}$ | 78.40 (8.91)$^{n}$ | 74.80 (8.70)$^{op}$ | **89.02 (9.43)$^{c}$** |
| **Mean VAR** | **99.00 (9.95)$^{a}$** | **97.63 (9.88)$^{b}$** | **94.85 (9.73)$^{c}$** | **93.17 (9.65)$^{d}$** | **91.10 (9.57)$^{e}$** | **89.10 (9.48)$^{f}$** | **84.92 (9.24)$^{g}$** | **78.63 (8.92)$^{h}$** | **74.72 (8.68)$^{i}$** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.13 | 0.07 | 0.05 |
| MAS | 0.19 | 0.10 | 0.07 |
| VAR x MAS | 0.38 | 0.20 | 0.14 |

**Table 59. Impact of storage condition, storage period and their interactions on field establishment of medium duration rice varieties.**

| Storage condition (SC) | Field establishment (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8 MAS | 9MAS | Mean SC |
| **SC 1** | 99.00 (9.95)[a] | 98.00 (9.90)[ab] | 95.28 (9.82)[d] | 93.75 (9.73)[e] | 91.50 (9.61)[f] | 89.67 (9.52)[gh] | 85.75 (9.31)[kl] | 79.75 (8.98)[n] | 76.00 (8.77)[p] | **89.89 (9.48)[b]** |
| **SC 2** | 99.00 (9.95)[a] | 97.58 (9.88)[bc] | 95.08 (9.80)[d] | 93.08 (9.69)[e] | 91.25 (9.60)[f] | 89.25 (9.50)[i] | 85.00 (9.27)[l] | 78.42 (8.91)[o] | 74.25 (8.67)[q] | **89.21 (9.44)[c]** |
| **SC 3** | 99.00 (9.95)[a] | 98.05 (9.92)[ab] | 95.58 (9.82)[d] | 93.58 (9.72)[e] | 91.92 (9.63)[f] | 90.25 (9.55)[g] | 85.92 (9.32)[k] | 79.83 (8.99)[n] | 76.50 (8.80)[p] | **90.09 (9.49)[a]** |
| **SC 4** | 99.00 (9.95)[a] | 96.62 (9.84)[c] | 93.08 (9.69)[e] | 91.83 (9.63)[f] | 89.08 (9.49)[i] | 86.92 (9.37)[j] | 82.75 (9.15)[m] | 75.83 (8.76)[p] | 70.92 (8.48)[r] | **87.34 (9.34)[d]** |
| **SC 5** | 99.00 (9.95)[a] | 97.67 (9.87)[b] | 94.92 (9.79)[d] | 93.58 (9.72)[e] | 91.75 (9.63)[f] | 89.42 (9.50)[gh] | 85.17 (9.28)[kl] | 79.33 (8.96)[n] | 75.52 (8.77)[p] | **89.76 (9.46)[b]** |
| **Mean MAS** | **99.00 (9.95)[a]** | **97.63 (9.88)[b]** | **94.85 (9.73)[c]** | **93.17 (9.65)[d]** | **91.10 (9.57)[e]** | **89.10 (9.48)[f]** | **84.92 (9.24)[g]** | **78.63 (8.92)[h]** | **74.72 (8.68)[i]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.14 | 0.07 | 0.05 |
| MAS | 0.19 | 0.10 | 0.07 |
| SC x MAS | 0.43 | 0.22 | 0.15 |

**Table 60. Impact of varieties, storage condition and their interactions on field establishment of medium duration rice varieties.**

| Varieties (VAR) | Field establishment (%) | | | | | |
|---|---|---|---|---|---|---|
| | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 | Mean VAR |
| **Aiswarya** | 90.67 (9.56)[ab] | 90.07 (9.53)[cd] | 90.82 (9.57)[a] | 88.41 (9.44)[g] | 90.33 (9.54)[abc] | **90.06 (9.48)[a]** |
| **Jyothi** | 89.30 (9.49)[ef] | 88.41 (9.44)[ef] | 89.33 (9.49)[ef] | 86.26 (9.32)[j] | 89.22 (9.49)[ef] | **88.50 (9.40)[d]** |
| **Sreyas** | 89.93 (9.52)[cd] | 89.22 (9.49)[g] | 90.22 (9.54)[bc] | 87.74 (9.40)[h] | 89.67 (9.51)[def] | **89.36 (9.45)[b]** |
| **Uma** | 89.67 (9.51)[de] | 89.15 (9.48)[f] | 90.00 (9.53)[cd] | 86.96 (9.36)[i] | 89.33 (9.49)[ef] | **89.02 (9.43)[c]** |
| **Mean SC** | **89.89 (9.48)[b]** | **89.21 (9.44)[c]** | **90.09 (9.49)[a]** | **87.34 (9.34)[d]** | **89.76 (9.46)[b]** | |

(Figures in parenthesis are square root transformed values)

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| VAR | 0.13 | 0.07 | 0.05 |
| SC | 0.14 | 0.07 | 0.05 |
| VAR x SC | 0.29 | 0.15 | 0.10 |

**Table 61. Impact of varieties, storage conditions, storage periods and their interactions on field establishment (%) of medium duration rice varieties.**

| Storage condition | SC1 | | | | SC2 | | | | SC3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aiswarya | Jyothi | Sreyas | Uma | Aiswarya | Jyothi | Sreyas | Uma | Aiswarya | Jyothi | Sreyas | Uma |
| 1MAS | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 |
| 2MAS | 98.67 | 98.00 | 98.00 | 97.33 | 98.00 | 97.67 | 97.67 | 97.00 | 99.00 | 98.00 | 98.00 | 98.00 |
| 3MAS | 96.00 | 94.67 | 95.67 | 96.00 | 96.00 | 93.67 | 95.33 | 95.33 | 96.33 | 94.00 | 96.00 | 96.00 |
| 4MAS | 95.33 | 92.33 | 93.67 | 93.67 | 95.33 | 90.33 | 93.33 | 93.33 | 95.00 | 91.33 | 94.33 | 93.67 |
| 5MAS | 93.00 | 91.00 | 91.00 | 91.00 | 92.67 | 90.67 | 91.00 | 90.67 | 93.33 | 90.67 | 92.33 | 91.33 |
| 6MAS | 90.33 | 89.33 | 89.67 | 89.33 | 89.33 | 89.33 | 89.33 | 89.00 | 90.67 | 90.00 | 90.33 | 90.00 |
| 7MAS | 86.33 | 85.00 | 85.67 | 86.00 | 85.67 | 84.33 | 84.33 | 85.67 | 86.33 | 85.00 | 85.33 | 87.00 |
| 8MAS | 80.00 | 79.67 | 80.00 | 79.33 | 78.33 | 78.00 | 78.67 | 78.67 | 80.00 | 79.67 | 80.33 | 79.33 |
| 9MAS | 76.33 | 75.67 | 75.67 | 76.33 | 75.33 | 73.67 | 73.33 | 74.67 | 76.67 | 76.67 | 76.00 | 76.67 |

| Storage condition | SC4 | | | | SC5 | | | |
|---|---|---|---|---|---|---|---|---|
| | Aiswarya | Jyothi | Sreyas | Uma | Aiswarya | Jyothi | Sreyas | Uma |
| 1MAS | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 | 100.00 | 98.00 |
| 2MAS | 96.67 | 97.33 | 96.67 | 96.00 | 98.00 | 98.00 | 97.67 | 97.00 |
| 3MAS | 94.67 | 90.33 | 93.33 | 94.00 | 96.00 | 93.33 | 94.67 | 95.67 |
| 4MAS | 93.67 | 89.67 | 92.67 | 91.33 | 94.67 | 92.33 | 94.00 | 93.33 |
| 5MAS | 90.67 | 88.33 | 89.00 | 88.33 | 92.67 | 91.67 | 91.67 | 91.00 |
| 6MAS | 87.67 | 85.67 | 88.00 | 86.33 | 89.67 | 89.33 | 90.00 | 88.67 |
| 7MAS | 83.33 | 81.33 | 84.00 | 82.33 | 86.00 | 84.00 | 85.00 | 85.67 |
| 8MAS | 77.00 | 75.00 | 75.67 | 75.67 | 80.00 | 79.33 | 80.00 | 79.00 |
| 9MAS | 72.00 | 70.67 | 70.33 | 70.67 | 76.67 | 76.33 | 75.00 | 75.67 |

| Factors | C.D. | SE(d) | SE(m) |
|---|---|---|---|
| VAR x SC x MAS | 0.86 | 0.44 | 0.31 |

### 4.2.2.7 SEED MICROFLORA (%)

The results of occurrence of microflora (%) in seed at the end of storage, as influenced by varieties, storage condition and their interactions are enumerated in Table 62.

#### 4.2.2.7.1 Effect of varieties (VAR)

Irrespective of the storage condition, at the end of the storage period, seed microflora was found to vary significantly between the varieties (Table 62).

The seeds of variety Uma (1.46%) registered significant low seed infection than the other varieties. Seed infection in variety Aiswarya (2.33%) differed significantly from Sreyas (2.60%). Variety Jyothi (3.13%) had registered the highest seed infection per cent.

#### 4.2.2.7.2 Effect of storage condition (SC)

Irrespective of the varieties, at the end of the storage period seed microflora was found to vary significantly between the storage conditions (Table 62).

The seed infection in seeds stored under storage condition SC4 (R.C.C. + without ventilation: 3.23%) was significantly high compared to all other storage conditions. Seed infection in SC2 (Asbestos + without ventilation: 2.70%) was significantly higher than SC5 (Asbestos + forced ventilation: 2.14%) and SC1 (Asbestos + ventilation: 2.23%). SC5 and SC1 were found to be on par with each other. Seeds stored in SC3 (R.C.C. + ventilation: 1.73%) registered the least seed infection per cent. Significantly high seed infection was observed in SC2 (Asbestos + without ventilation: 2.70%) compared to SC5 (Asbestos + forced ventilation: 2.14%) and SC1 (Asbestos + ventilation: 2.23%). SC5 and SC1 were found to be on par with each other. Seeds stored in SC3 (R.C.C. + ventilation: 1.73%), registered the least incidence of seed microflora.

**Table 62. Impact of storage condition, varieties and their interactions on seed infection of medium duration rice varieties.**

| Storage condition | Seed microflora ( Agar plate ) | | | | Mean SC |
|---|---|---|---|---|---|
| | Aiswarya | Jyothi | Shreyas | Uma | |
| **SC1** | 2.33 | 3.00 | 2.33 | 1.66 | **2.23$^{b}$** |
| **SC2** | 2.33 | 3.33 | 3.00 | 1.33 | **2.70$^{c}$** |
| **SC3** | 2.00 | 2.33 | 1.66 | 0.66 | **1.73$^{a}$** |
| **SC4** | 3.33 | 4.33 | 3.66 | 2.33 | **3.23$^{d}$** |
| **SC5** | 1.66 | 3.00 | 2.33 | 1.33 | **2.14$^{b}$** |
| **Mean VAR** | **2.33$^{b}$** | **3.13$^{d}$** | **2.60$^{c}$** | **1.46$^{a}$** | |

| **Factors** | **C.D.** | **SE(d)** | **SE(m)** |
|---|---|---|---|
| SC | 0.139 | 0.071 | 0.05 |
| MAS | 0.187 | 0.095 | 0.067 |
| VAR x SC | N/A | 0.212 | 0.150 |

# Discussion

# 5. DISCUSSION

Ventilation is a critical factor controlling the storage environment in a seed store and eventually the quality of seed at the time of planting. The present investigation, 'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),' was carried out in the Department of Seed Science and Technology, College of Horticulture, Vellanikkara, Kerala Agricultural University (KAU), Thrissur, during the year 2019 – 2020. It envisaged to elucidate the quality and longevity of seeds of both short and medium duration rice varieties in storage structures with asbestos or R.C.C. roofing with ventilation or no ventilation. The study comprised of two experiments, one comprising of four short duration (SD) rice varieties; Harsha, Matta Triveni, Manuratna and Kanchana, while the second comprised of for medium duration (MD) rice varieties; Aiswarya, Jyothi, Sreyas and Uma. The results obtained are discussed below.

## 5.1 Impact of storage structure on seed longevity of rice varieties.

### 5.1.1 Seed quality before storage

The quality parameters of the seeds of the varieties were analysed before storage.

Among the short duration varieties germination, ranged from 96.00 per cent (Kanchana) to 100.00 per cent (Harsha, Matta Triveni and Manuratna). Variety Matta Triveni was harvested at a later date *i.e.,* about one week later than the other varieties. Hence, the high germination in Matta Triveni on par with other varieties may be an indication that the variety takes less time for after-ripening and maturation and to break out of dormancy.

In the medium duration group, germination, ranged from 98.00 per cent (Jyothi and Uma) to 100.00 per cent (Aiswarya and Sreyas). Variety Sreyas was harvested at a later date *i.e.,* about two weeks later than the variety Aiswarya, and three weeks later than varieties Jyothi and Uma. Yet, the variety exhibited 100 per cent germination unlike varieties Jyothi and Uma that had recorded 98.00 per cent germination. This is an indication that the variety Sreyas was earliest to break dormancy, while, variety Uma takes more time for after-ripening and maturation and to break out of dormancy. Varietal variation with respect to dormancy in rice varieties is well-known and this is in agreement with Tung and Seranno (2011). They opined that the degree of dormancy in different rice varieties varies greatly and is influenced by genes, duration of maturity and environment.

The highest seedling vigour (VI-I: 2110.00 and VI-II: 2170.00) in the short duration group was recorded in variety Matta Triveni, and it was the least in variety Manuratna (VI-I: 1870.00 and VI-II: 1700.00), followed by variety Harsha (VI-I: 1930.00 and VI-II: 1980.00).

In case of medium duration varieties, seedling vigour (VI-I: 2126.00 and VI-II: 2528.00) in variety Jyothi was the highest, and it was the least in variety Uma (VI-I: 2029.00 and VI-II: 1793.00) followed by variety Sreyas (VI-I: 2030.00 and VI-II: 1940.00). Variety Sreyas was harvested at a later date than varieties Uma and Aiswarya. Therefore, the difference in vigour may be attributed to ageing, although the difference is a meagre period of two weeks only. Deterioration can occur in seed in a few days or years but becomes evident as germination per cent reduces and produces weak seedlings, leading ultimately to its death. However, its rate depends on several factors including, seed moisture, storage temperature, and genetic factors (Walters *et al.,* 2010).

Short duration variety Manuratna (102.20 $\mu Sm^{-1}$) and medium duration variety Uma (146.50 $\mu Sm^{-1}$), both of which were harvested the earliest, registered the highest EC of seed leachate in the respective groups. According to Mathew and Brandnock (1967), high leakage would mean high conductivity, which is associated with seeds that emerged with low vigour. In comparison, low leakage of electrolyte, resulting in decreased EC was associated with increased seed-vigour and` superior emergence. However, no such relationship was evident with respect to variety Matta Triveni.

It is to be noted that, in addition to the least EC of seed leachate (39.02 $\mu Sm^{-1}$), the seed moisture content (10.10 %) was also the least in variety Kanchana. Similarly, among the medium duration varieties, seed moisture content in variety Aiswarya (11.30%) and Sreyas (11.20%) was higher when compared to Uma and Jyothi. Tajbakhsh (2000) and Vieira *et al.* (1999) revealed that all germination parameters in wheat crop were inversely proportional to electrical conductivity and moisture content or vice- versa as storage period increases.

It was evident that the seeds used for the storage study were of good quality. Before the initiation of storage, the germination per cent of all varieties studied was found to be above the minimum standards (>80 per cent) required for seed certification in rice crop. However, the quality parameters varied marginally between the varieties.

### 5.1.2 Seed quality during storage

Analysis of variance for various traits studied indicated existence of wide variability in the impact of varieties, storage conditions, period of storage and their interactions, on most of the seed indices studied.

#### 5.1.2.1 GERMINATION (%)

The results on germination per cent as influenced by varieties, storage condition, the period of storage and their interactions are discussed below.

##### 5.1.2.1.1 Effect of varieties (VAR)

Irrespective of the storage condition and the period of storage, germination during storage was found to be significantly influenced by the varieties. Significant variation in germination was found to exist between both short duration and medium duration varieties.

Matta Triveni and Harsha registered higher germination than varieties Manurathna and Kanchana in the SD group. Variety Kanchana had exhibited the least estimate during storage.

Medium duration varieties Aiswarya and Sreyas had registered higher average germination than varieties Jyothi and Uma. Variety Jyothi had exhibited the least estimate throughout the storage period. Simic *et al.* (2007) revealed that the longevity of seeds in storage was affected by the factors like genotype, initial seed quality, storage conditions, and moisture content among others. Among the same plant species, different varieties may exhibit different storing abilities either from genetic variations or from other external factors.

##### 5.1.2.1.2 Effect of period of storage (MAS)

Irrespective of factors such as variety and the storage condition, germination declined progressively and significantly over the storage period in both the short and medium duration groups.

In Short duration varieties, viability of seed fell below IMSCS (80.00%) after 7 MAS. The decline in germination up to 90.00 per cent was gradual, spanning over 6 MAS and then dropped quickly to less than 80.00 per cent in two months (at 8 MAS). Considering the time period between harvest and beginning of storage *i.e.,* two to two and a half-month, it can be concluded that retention of viability above IMSCS in short duration varieties would be between eight and nine months.

Among the medium duration varieties, viability of seed fell below MSCS (80.00%) after 8 MAS. The decline in germination up to 90.00 per cent was gradual, spanning over 5 MAS and then dropped sharply to less than 80.00 per cent in three months. Considering the time period between harvest and beginning of storage *i.e.,* a few days just over two months, it can be concluded that retention of viability above IMSCS in medium duration varieties would be for about ten months only.

The result is in in agreement with Tekrony *et al.* (2005). They observed that, seed lots that had high germination (87–99%) before storage, when stored in the 'uncontrolled' warehouse, a decline up to 50–80 per cent in the germination and vigour was observed after eight months of storage.

**5.1.2.1.3 Effect of storage condition (SC)**

Irrespective of varieties and the period of storage, storage condition exerted significant influence on germination in both short and medium duration varieties.

It was obvious that, in both SD and MD varieties, seeds stored in ventilated stores (SC3, SC1 and SC5) retained viability longer than those in stores without ventilation. Neither R.C.C roofing nor Asbestos roofing affected viability as long as the store was ventilated. The fact that seeds stored under R.C.C. + ventilation (SC3) and Asbestos and + ventilation (SC1) were not only on par with each other but also significantly superior to Asbestos + forced ventilation (S5) indicated that, investing on forced ventilated structures (SC5) for seed storage, did not bestow any advantage or help prolong seed viability in humid regions.

According to McCormack (2004), high relative humidity and temperature leads to high moisture content in seeds, leading to low germination at the end of storage. By enhancing movement of air through stored grain, the rate of grain deterioration and prevent storage losses can be reduced. This practice of aeration, greatly improves the storability of grain by maintaining a cool, uniform temperature throughout the storage. Aeration reduces mould development and insect activities both issues that relate to moisture content and temperature as well as prevent moisture migration. Smith (1975) found that uneven air distribution and high static pressures in the storage systems contributed to the poor storage conditions. By moving relatively small amounts of atmospheric air through stored cotton seed, heat can be removed, minimizing or eliminating mould growth. Aeration, in most cases, can effectively remove any hot spots that may develop during storage from excessive moisture or other causes.

**5.1.2.1.4 Effect to interaction**

Germination (%) during storage was strongly affected by the interaction between varieties, storage conditions and the period of storage in both short and medium duration varieties.

**5.1.2.1.4.1 Varieties × Storage period (VAR × MAS)**

Irrespective of storage condition, the interaction between different varieties and storage period, significantly influenced germination in both short and medium duration varieties.

Longevity of seed varied significantly between the varieties in both short as well as medium duration groups. Considering the time of harvest, seed longevity was higher (10 months each) in SD varieties Harsha and Matta Triveni compared to varieties Manurathna and Kanchana (9 months each). Variety Kanchana had registered the least germination throughout the storage period.

Seed longevity of the medium duration varieties can be summed up to be just over 8 months after storage *i.e.,* 10 months from harvest. Variety Jyothi had registered the least germination for most of the storage period. Hendry *et al*. (1994) revealed that the rates of ageing and potential life spans of seeds vary among species. Even within species, various accessions often exhibit differences in their storage properties.

#### 5.1.2.1.4.2 Storage condition × Storage period (SC × MAS)

Irrespective of varieties, the interaction between different storage condition and storage period significantly influenced germination in both short and medium duration varieties.

Results indicated that, ventilated godowns, irrespective of the type of roofing (Asbestos or R.C.C), are best suited for seed storage, as seed viability of both short and medium duration varieties in these structures were found to be retained above IMSCS, one month longer (8 MAS) than when stored under non-ventilated environment (7 MAS). Lack of aeration within the storage structure strongly influences the storage environment. This may lead to increased temperature not only because of poor or no air-flow but also because respiring seeds also emit heat into the surrounding. Mbofung (2012) observed that, sorghum seeds stored at low temperature registered higher germination than those stored at high temperatures. He concluded that it was because, storing seeds under high temperature increases the respiration rate and enzyme activity, resulting in the overhaul of food reserves before the seeds germinate. This resulted in decreased germination and physical quality of seed.

#### 5.1.2.1.4.3 Varieties × Storage condition (VAR × SC)

Irrespective of the period of storage, the interaction between different storage condition and storage period significantly influenced germination in both short and medium duration varieties.

Short duration varieties Matta Triveni followed by Harsha registered high germination in all storage environments and differed significantly from other varieties. Although germination of variety Kanchana was lower than in other varieties under all storage environments, it did not vary significantly between the ventilated structures. This was found to be true in the case of all other short duration varieties.

In the MD group, germination in variety Aiswarya followed by Sreyas was high in all storage environments and differed significantly from other varieties. Storability of variety Jyothi was lower than other varieties under all storage environments. It is to be noted that germination in this variety was the least throughout storage period. As in the case of Kanchana, germination in Jyothi did not vary significantly between the ventilated structures. This was evident in case of the other MD varieties also.

Hence, it is evident that storing seeds in godowns with forced ventilation does not confer any advantage over storing them in structures with provision for natural ventilation. Sun *et al*. (2007) reported that higher viability and storability of seeds during room temperature storage are mainly due to the storage conditions and seed quality at the beginning of storage.

Results also indicated that, storing seeds of varieties both SD and MD, in non-ventilated structures with R.C.C. roofing (SC4) is more detrimental than storing them in such structures with Asbestos roofing. This may be attributed to the higher temperature and humidity within such R.C.C. structures compared to the ones with asbestos roofing (Fig 3 and 4). Sawant (1994) worked up a comparison between metal silos and R.C.C silos and found storing seeds in galvanized iron corrugated (GIC) silos advantageous over metal and R.C.C silos for reducing the storage loss. The loss was attributed to the higher temperature and moisture built up owing to air-tight nature of R.C.C silos.

**5.1.2.1.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

The interaction between varieties, storage condition and storage period was found to significantly influence germination during storage in both short and medium duration varieties.

Germination in SD varieties Harsha and Matta Triveni stored in ventilated godowns [Asbestos + ventilation (SC1), (R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5)] was found to retain above IMSCS for a month longer (8 MAS) than in non-ventilated conditions *viz.,* Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4) and (7 MAS). These varieties exhibited significant high germination under ventilated storage over non-ventilated storage. Hence, it can be inferred that longevity of seeds of varieties Harsha and Matta Triveni was prolonged by one month in stores with provision for ventilation than under non-ventilated condition. In contrast, the longevity of SD varieties Manurathna and Kanchana, was found to be only for 7 MAS under all storage environments. Moreover, under all environments germination in varieties Manurathna and Kanchana, were significantly lower than the other varieties. Hence, it is inferred that storability of varieties Harsha and Matta Triveni is better than that of varieties Manurathna and Kanchana under ventilated storage than under non-ventilated condition.

In addition, at 8 MAS, germination of seeds of Harsha and Matta Triveni stored in ventilated structures with provision for natural ventilation (SC1 and SC3), was found to be higher than in storage condition with provision for forced ventilation (SC5). However, as the seed longevity of these varieties in all the ventilated structures was the same, it can be inferred that, storing seed under ventilated structures with provision for natural ventilation would be more advantageous and economic than storing them in godowns with forced ventilation. In similar lines, the germination in SD varieties Manurathna and Kanchana stored under all ventilated conditions was found to be on par with each other at both 7 and 8 MAS. This once again reiterated that there is no specific advantage in storing seeds structures with forced ventilation.

Germination in all the medium duration varieties stored in ventilated godowns was found to retain above IMSCS for 8 MAS. However, germination in Jyothi under SC1 and Sreyas under SC3 at 8 MAS, was significantly lower than the others under ventilated storage. In non-ventilated godowns, germination of MD varieties was found to be above IMSCS only up to 7 MAS *i.e.,* one month shorter than under ventilated condition. Hence, it can be inferred that storing seeds of medium duration varieties in ventilated structures [Asbestos + ventilation (SC1), (R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5)], helped retain viability above IMSCS by one month *i.e.,* 8 MAS compared to 7 MAS in non-ventilated structures.

As the seed longevity of the medium duration varieties stored under asbestos + natural ventilation (SC1) asbestos + forced ventilation (SC5), or R.C.C. + natural ventilation (SC3), was not extended beyond 8 MAS, it can be inferred that storing seed under ventilated structures with provision for natural ventilation would be more advantageous and more economic that storing seeds in godowns with forced ventilation

To summarise, genotypic differences in seed viability loss during the period of was evident. This loss that occurs across varieties due to ageing or owing to the impact of storage environment, is inexorable and irreversible. Although inevitable, the rate of deterioration can be reduced when the key storage factors such as temperature and humidity during storage are well managed (Ellis and Roberts, 1981; Rindels, 1995; Adetumbi *et al*., 2009).

**5.1.2.1.4 Influence of storage environment on germination (%)**

**5.1.2.1.4.1 Comparison between ambient environment within and outside the storage structures**

The data on ambient temperature and RH (%) and that recorded within the storage conditions revealed that on an average, the storage environment inside the various storage conditions (Fig 3 and 4) were cooler than the ambient environment by 2.31$^{O}$C (SC2) to 2.99 $^{O}$C (SC3). Among the storage structures, the temperature inside R.C.C. + ventilation (SC3) was relatively lower than that in Asbestos + ventilation (SC1) by 0.2 $^{O}$C and by 0.5 $^{O}$C from Asbestos + forced ventilation (SC5). However, the average difference in temperature between SC3 and ventilated storage structures were higher, the difference between SC3 and R.C.C. + without ventilation (SC4) being 0.9$^{O}$C, followed by that in Asbestos + without ventilation (SC2: 0.7$^{O}$C). Hence, it was evident that the temperature under R.C.C. + without ventilation (SC4) followed by Asbestos + without ventilation (SC2) was hotter than in other structures, throughout the storage period.

The relative humidity inside the various storage conditions was lower than that of the ambient environment by 4.70 per cent (SC4) to 13.89 per cent (SC5). The relative humidity inside Asbestos + forced ventilation (SC5) was relatively lower than Asbestos + ventilation (SC1) by 2.33 per cent and by 4.46 per cent in R.C.C. + ventilation (SC3). The difference in RH was the highest between SC5 and SC4 (9.11%), followed by SC5 and SC2 (4.56%). In general, RH was higher under R.C.C. + without ventilation (SC4) followed by Asbestos + without ventilation (SC2), throughout the storage period.

Sawant, (1994) revealed that inside storage temperature and relative humidity varied from the outer environmental conditions by several degrees during the different season and may result in loss of seed quality parameters. However, unlike in their study the ambient environment in the present study area was hot and humid and therefore, the temperature within the storage environment was cooler and less humid.

**5.1.2.1.4.2 Impact of storage temperature (T) on germination (%)**

The correlation between weekly storage temperatures recorded during the 38 weeks of storage period and reduction in germination per cent of both the short and medium duration varieties stored in different storage condition were analyzed.

In case of SD varieties, temperature within the storage environment during 1st, 10th, 11th and 13th weeks, registered a significant positive correlation with reduction in germination, the correlation being highly significant in case of variety Kanchana at the 13th week of storage, while in MD varieties, temperature within the storage environment during 1st, 2nd, 10th and 13th weeks, registered a significant positive correlation with reduction in germination, the correlation being highly significant in case of variety Jyothi and Uma at the 10th week of storage.

**Fig 3.**

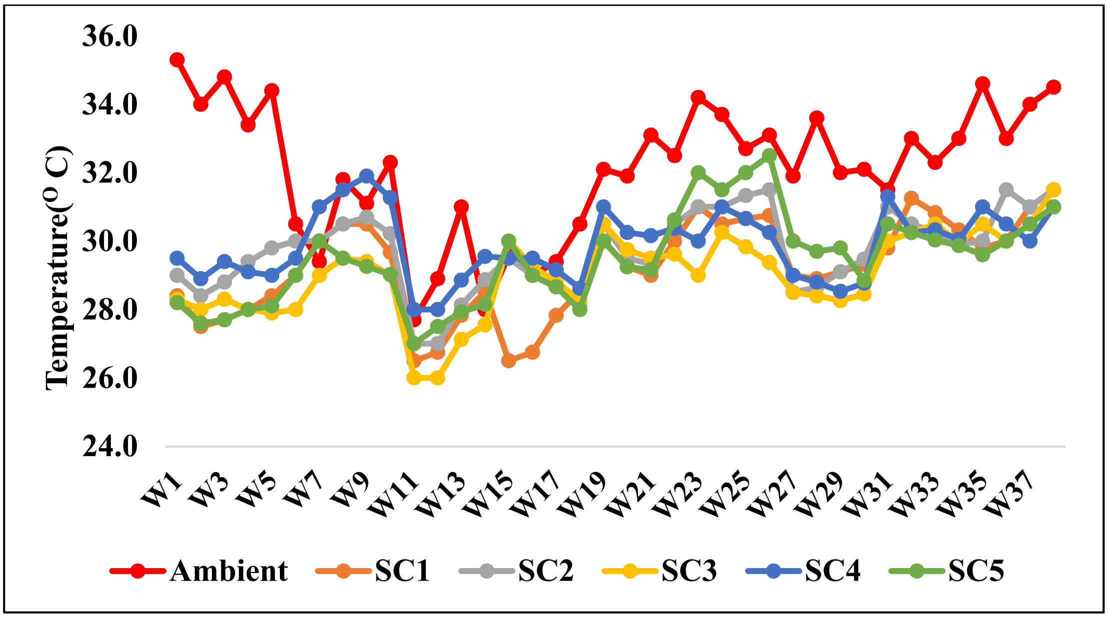



Fig 3. Average weekly temperature prevailing inside and outside the storage conditions during the study period

**Fig 4.**

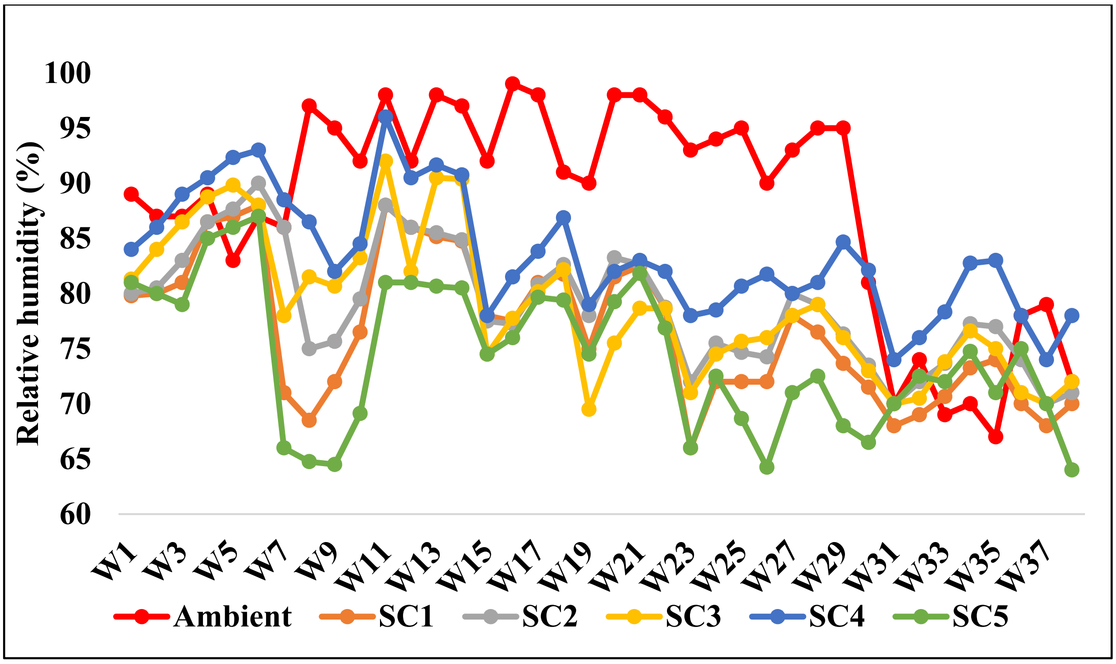



Fig 4. Average weekly RH (%) prevailing inside and outside the storage conditions during the study period

High temperature within the storage environment strongly influenced not only the germination but also longevity in both the groups. The decline in germination was found to be more pronounced when the seed was exposed to high temperatures in the early period of storage *i.e.,* between 1 and 13$^{th}$ week. The storage temperature under different storage conditions was found to be the highest during the 10$^{th}$ week followed by 1$^{st}$ week.

The storage temperature that built up during all the four crucial weeks (1$^{st}$, 10$^{th}$, 11$^{th}$ and 13$^{th}$ in case of SD varieties and 1$^{st}$, 2$^{nd}$, 10$^{th}$ and 13$^{th}$ in case of MD varieties), that caused significant impact on germination, were found to the highest under R.C.C. + without ventilation (SC4) followed by Asbestos + without ventilation (SC2) with a corresponding decline in germination (Fig 5 and Fig 6). The temperature and decline in germination during the corresponding period in both groups wer lower in ventilated stores, with the trend being nearly similar among the three storage condition (Asbestos + ventilation: SC1, R.C.C + ventilation: SC3 and Asbestos + forced ventilation: SC5).

Seed longevity was greatly influenced by storage conditions, such as relative humidity and temperature and lowering of these parameters significantly increases the storage life of seeds (Sharma *et al*., 2007). Devereau *et al*. (2000) reported that, storing wheat seeds at room temperature tend to decrease the viability and vigour of seeds faster than storage at low temperatures. Environmental conditions surrounding the storage will affect the quality of seeds during the storage period. Fukai *et al*. (2003) and Rehman (2006) also reported that in low-temperature storage, it is possible to store rice for the long term without deterioration in quality.

Marginal variations in temperature between the three ventilated structures (SC1, SC3 and SC5) was evident, although there was no associated improvement in seed longevity. This finding again reiterates the fact that there was no significant advantage in storing seeds in godowns with provision for forced ventilation over natural ventilation. Hence, it would be more economic, if seed is stored in structures with natural ventilation under the prevailing hot and high humid condition.

**Fig 5.**

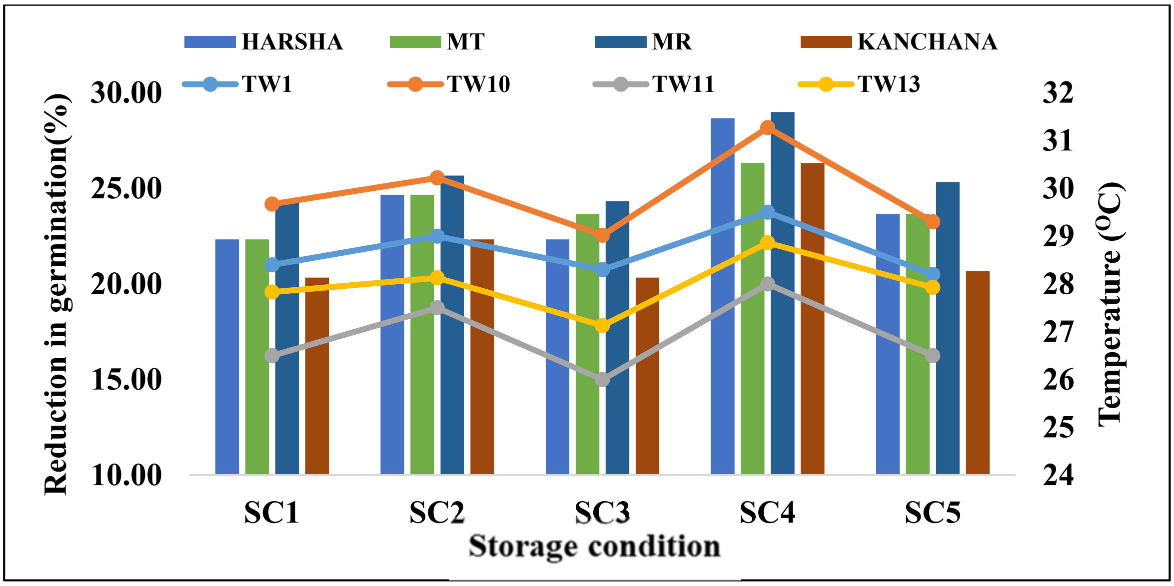



Fig 5. Storage temperature (1$^{st}$, 10$^{th}$, 11$^{th}$ and 13$^{th}$ weeks) and reduction in germination of short duration rice varieties in different storage conditions.

.

**Fig 6.**

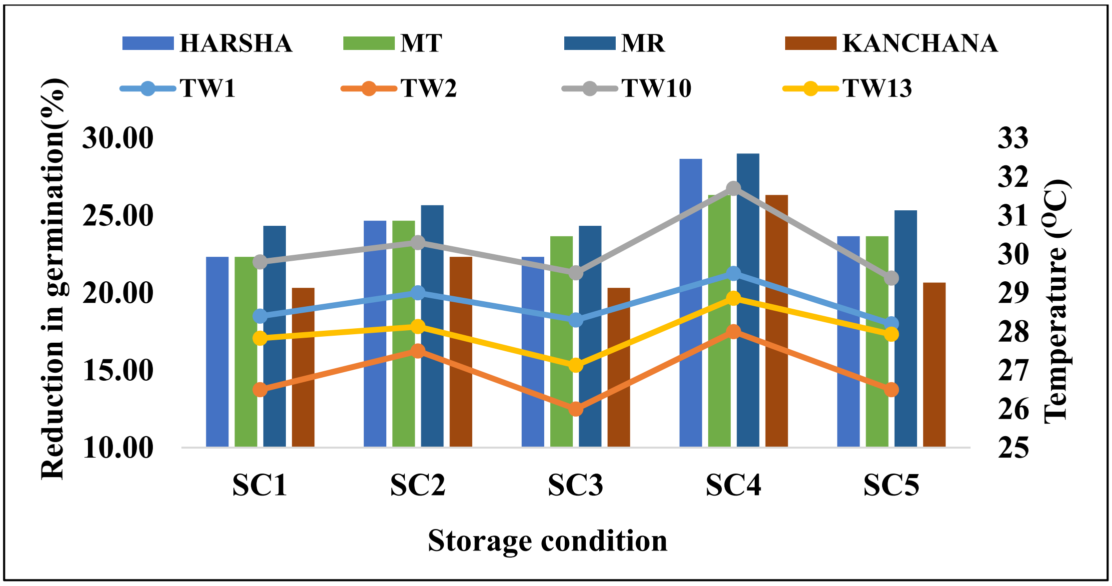



Fig 6. Storage temperature (1st, 2nd, 10th and 13th weeks) and reduction in germination of medium duration rice varieties in different storage conditions.

**5.1.2.1.4.3 Impact of relative humidity (RH) on germination (%)**

The correlation between weekly relative humidity recorded during the 38 weeks of storage period and reduction in germination per cent of different short duration and medium duration rice varieties stored various different storage condition was analyzed.

Relative humidity during 24th, 31st, 32nd, 33rd, 34th, and 36th weeks showed a significant positive correlation with reduction in germination in both short and medium duration varieties, the correlation being highly significant in case of SD variety Matta Triveni during 24th and 31st week of storage and during 31st, 32nd and 34th week of storage in case of MD variety Uma.. High Relative humidity during the storage period was found to significantly reduce germination during storage. It was evident that high RH during the 2nd half of the storage period (*i.e.,* between 24th and 36th week), proved to be detrimental to seed longevity.

As observed in case of temperature, RH (%) was found to be the highest during the crucial weeks, under R.C.C. + without ventilation (SC4) followed by Asbestos + without ventilation (SC2) and a corresponding decline in germination occurred (Fig 7), while, the RH and decline in germination during the corresponding period was lower in ventilated stores (Asbestos + ventilation: SC1, R.C.C + ventilation: SC3 and Asbestos + forced ventilation: SC5).

The result is in agreement with Miah *et al*. (2006), who assessed the effect of storage relative humidity (*viz.*, 50%, 60%, 70%, and 80%) on longevity of different varieties of wheat seed. The germination in all the varieties decreased with increase in RH. Longevity of seeds stored at 70 per cent and 80 per cent RH was six months and two months respectively, while it was the longest in seeds stored at 50 per cent RH.

Marginal variations in RH was evident between the ventilated stores, with the least estimate in Asbestos + forced ventilation (SC5). However, there was no associated improvement in seed longevity in SC5 over others (SC1 and SC3). This finding again reiterates the fact that storing seeds in godowns with provision for forced ventilation did not confer any advantage over that with natural ventilation. Incurring additional expenditure on installation, maintenance, operation of forced ventilation system does not give any additional benefit with respect to prolonging storability of stored seeds.

**Fig 7.**

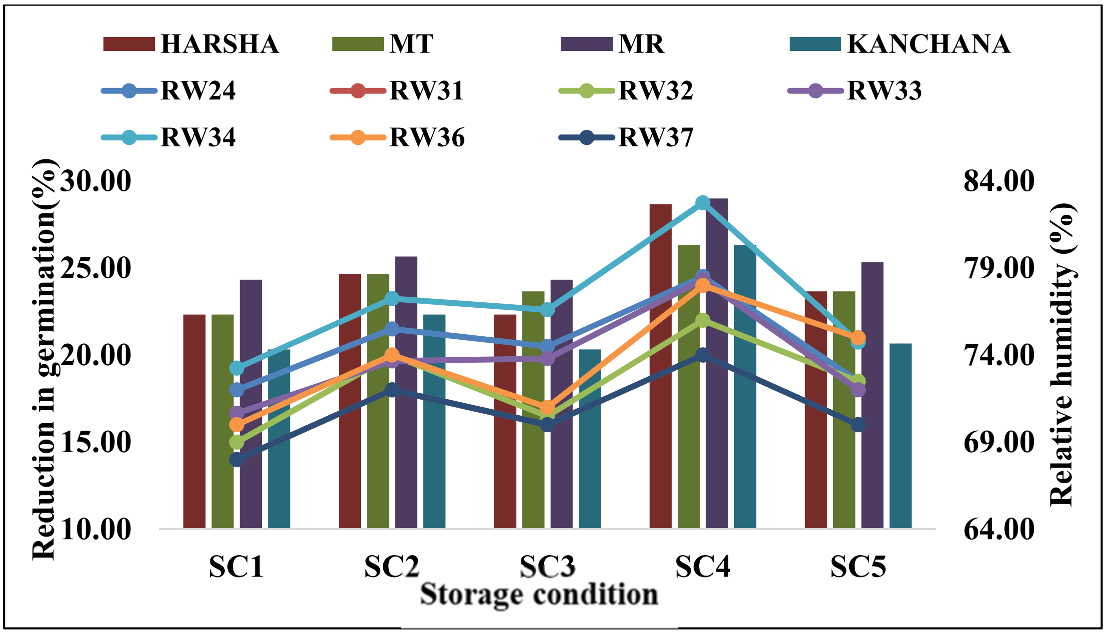



Fig 7. Relative humidity (24th, 31st, 32nd, 33rd, 34th, and 36th week) and reduction in germination of short duration rice varieties in different storage conditions.

.

**Fig 8.**

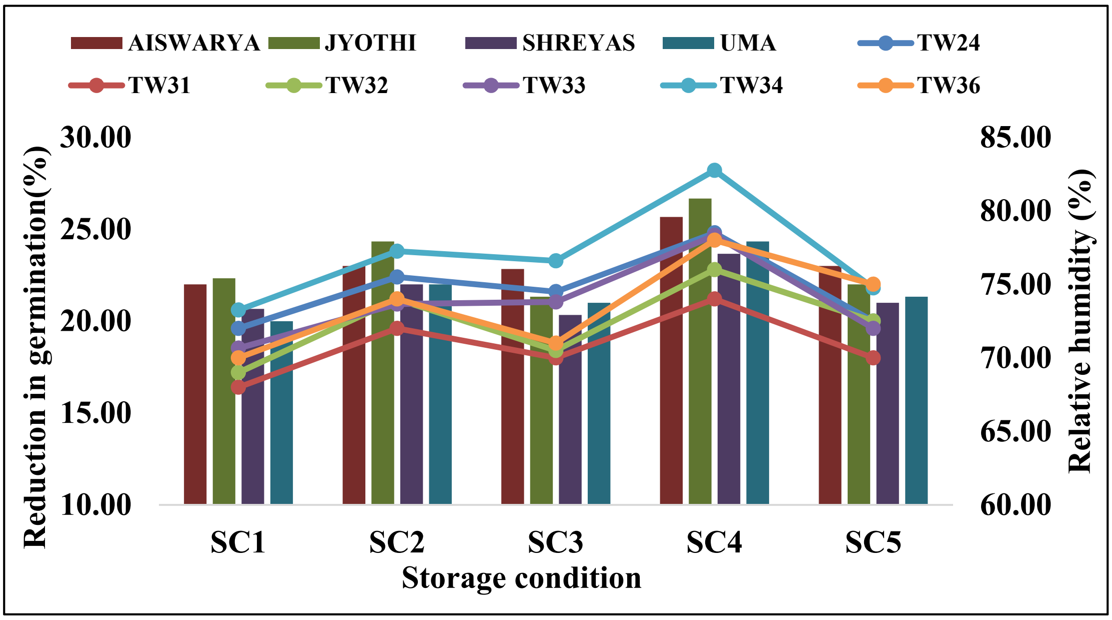



Fig 8. Relative humidity (24th, 31st, 32nd, 33rd, 34th, and 36th week) and reduction in germination of medium duration rice varieties in different storage conditions.

### 5.1.2.1.4.4 Impact of Temperature Humidity Index (THI) on germination (%)

The correlation between combined effect of weekly storage temperature and relative humidity recorded during the 38 weeks of storage and reduction in germination per cent of various short and medium duration rice varieties stored under different conditions were analyzed.

Temperature-Humidity Index (THI) during 1st, 2nd, 11th, 13th, 14th, 19th, 20th and 21st weeks, exhibited a significant positive correlation with reduction in germination in both the groups the correlation being highly significant in case of SD variety Matta Triveni, Harsha, and Kanchana during the 20th, 21st and 19th week of storage, respectively and in case of MD varieties Jyothi and Uma during 11th, 20th and 21st week of storage.

Strong negative impact of the combined influence of storage RH and temperature was evident on germination. Although, high temperature during the initial period (1st, 10th 11th and 13th week) and 2nd half of storage (24th, 31st, 32nd, 33rd, 34th and 36th week), respectively, had negatively impacted the germination, high RH in conjunction with high temperature prevalent mostly during the 1$^{st}$ half of storage period (1$^{st}$, 2$^{nd}$, 11$^{th}$, 13$^{th}$, 14$^{th}$ 19$^{th}$, 20$^{th}$ and 21$^{st}$ week), was found to impact seed germination and longevity in both short and medium duration varieties.

Sharma *et al*. (2007) reported that seed longevity was greatly influenced by storage conditions, such as relative humidity and temperature and lowering of these parameters significantly increases the storage life of seeds. Harrington, (1972) also reported that good seed storage is achieved when the per cent relative humidity in storage environment and the storage temperature in degree Fahrenheit add up to less than or equal to hundred, but the contribution from temperature should not exceed 50$^{O}$F.

Non-ventilated storage condition, R.C.C. + without ventilation (SC4) and SC2 (Asbestos + without ventilation) experienced higher THI than other ventilated storage condition (Fig 9 and Fig 10) and subsequently, resulted in higher reduction in germination under these storage structures. Similar deterioration in seed viability owing to high temperature and RH was observed by Thilakarathna *et al*., (2006) and Thakur *et al*., (2011). Harrington, (1973) proposed that high temperature and relative humidity leads to seed deterioration and loss of germination rapidly which provide suitable conditions for metabolic activity. The seed viability loss due to seed deterioration is inexorable, irreversible and inevitable. The rate of deterioration however, can be reduced when the key storage factors such as temperature and humidity during storage are well managed (Ellis & Roberts, 1981; Rindels, 1995; Adetumbi, 2009).

**Fig 9.**

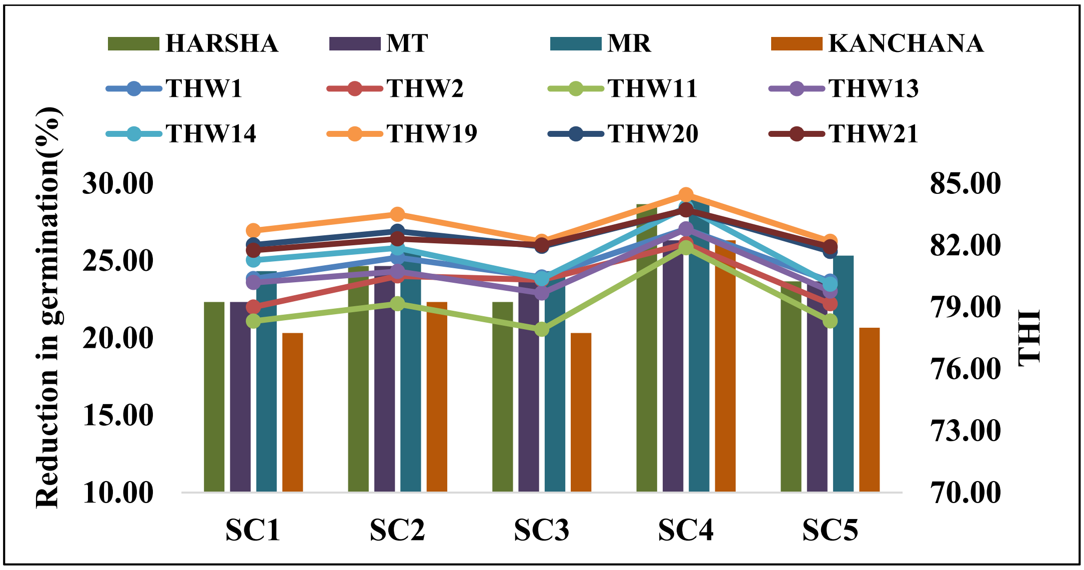



Fig 9. Temperature- Humidity Index (1st, 2nd, 11th, 13th, 14th, 19th, 20th and 21st weeks) and reduction in germination of short duration rice varieties in different storage conditions.

**Fig 10.**

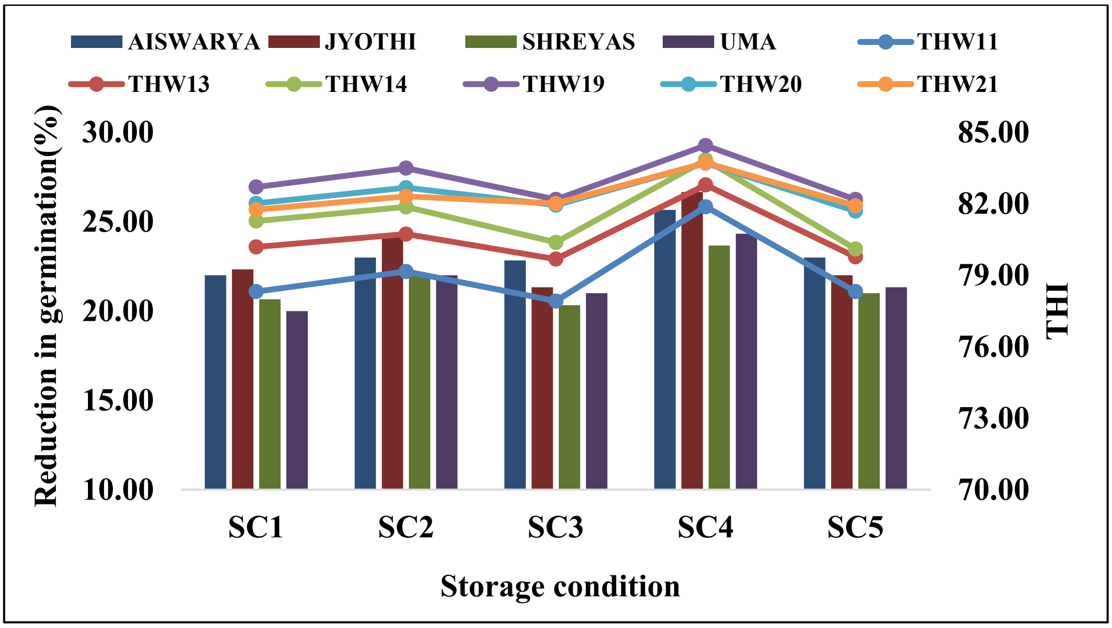



Fig 10. Temperature- Humidity Index (1st, 2nd, 11th, 13th, 14th, 19th, 20th and 21st week) and reduction in germination of medium duration rice varieties in different storage conditions.

From the above results, it can be summarised that germination of seeds during storage is strongly dependent on the variety, storage condition, the period of storage and the interaction between these factors. Germination of short duration varieties declined progressively over the storage period. Variety Matta Triveni and Harsha exhibited better storability compared to Manurathna and Kanchana.

Storing seeds in ventilated storage structures *viz.,* R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (SC5), was clearly advantageous (Fig.11 and 12) over non ventilated structures [Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4)]. Storing seeds in ventilated structures, either with asbestos roofing or with R.C.C. roofing, helped maintain viability in varieties Harsha and Matta Triveni above IMSCS by one month *i.e.,* 8 MAS compared to 7 MAS in non-ventilated structures.

**Fig 11.**

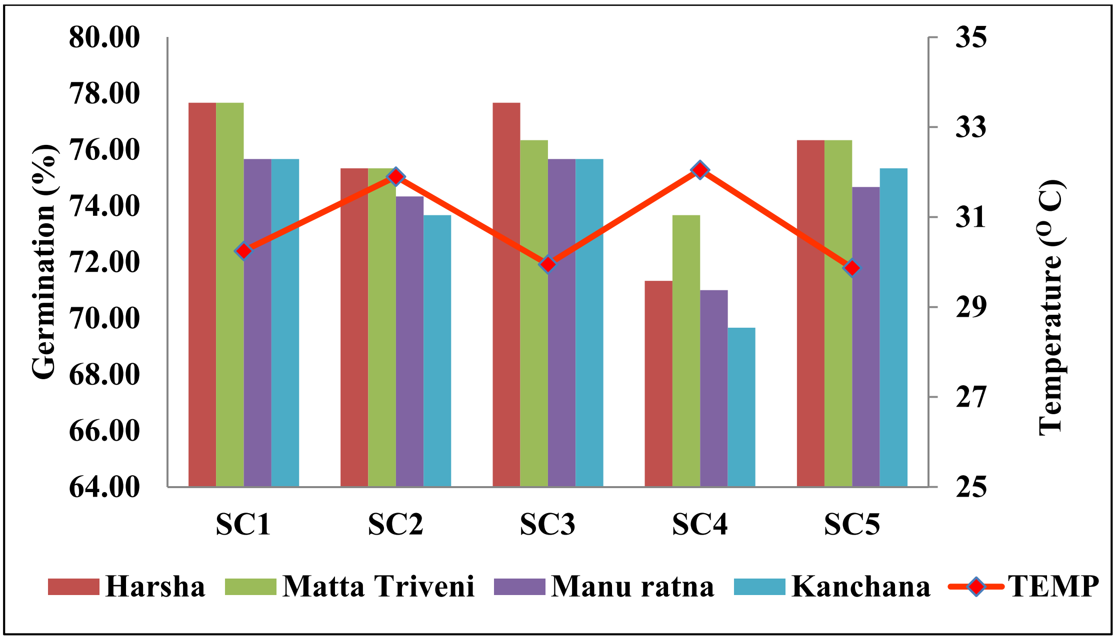



Fig.11. Influence of storage temperature on germination (%) of short duration rice varieties in different storage condition, at the end of storage (9 MAS)

**Fig 12.**

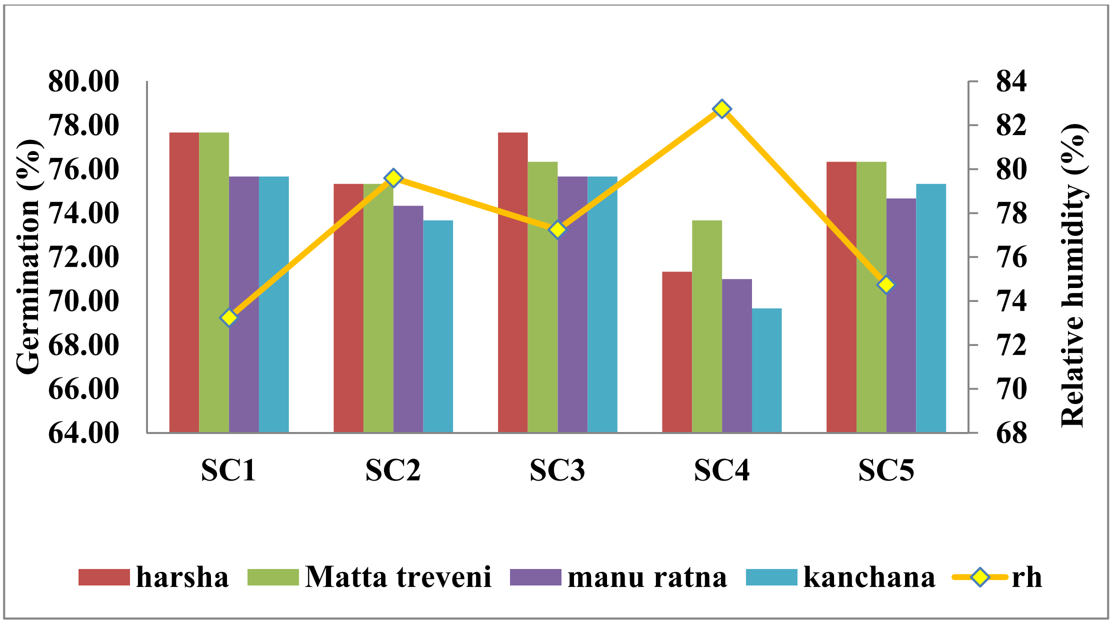



Fig 12. Influence of relative humidity on germination (%) of short duration rice varieties in different storage condition, at the end of storage (9 MAS)

From the above results, it can be summarised that germination of seeds during storage is strongly dependent on the variety, storage condition, the period of storage and the interaction between these factors. Germination of medium duration varieties declined progressively over the storage period. Variety Aiswarya and Sreyas exhibited better storability compared to Jyothi and Uma. Storing seeds in ventilated storage structures *viz.*, R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (SC5), was clearly advantageous (Fig.13 and 14) over non ventilated structures [Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4)]. Storing seeds of medium duration varieties Jyothi, Sreyas, Aiswarya and Uma, in ventilated structures, either with asbestos roofing or with R.C.C. roofing, helped maintain viability above IMSCS by one month *i.e.,* 8 MAS compared to 7 MAS in non-ventilated structures. Seed longevity of the medium duration varieties stored under asbestos + natural ventilation (SC1) asbestos + forced ventilation (SC5), or R.C.C. + natural ventilation (SC3), was the same (8 MAS), and no substantial increase in seed quality parameters was observed under SC5. Therefore, it is inferred that storing seed under ventilated structures with provision for natural ventilation would be more advantageous as it would prove to be more economic as the cost incurred on installation, recurring expenditure on operation and maintenance of the exhaust fans in godowns with forced ventilation can be pruned.

**Fig 13.**

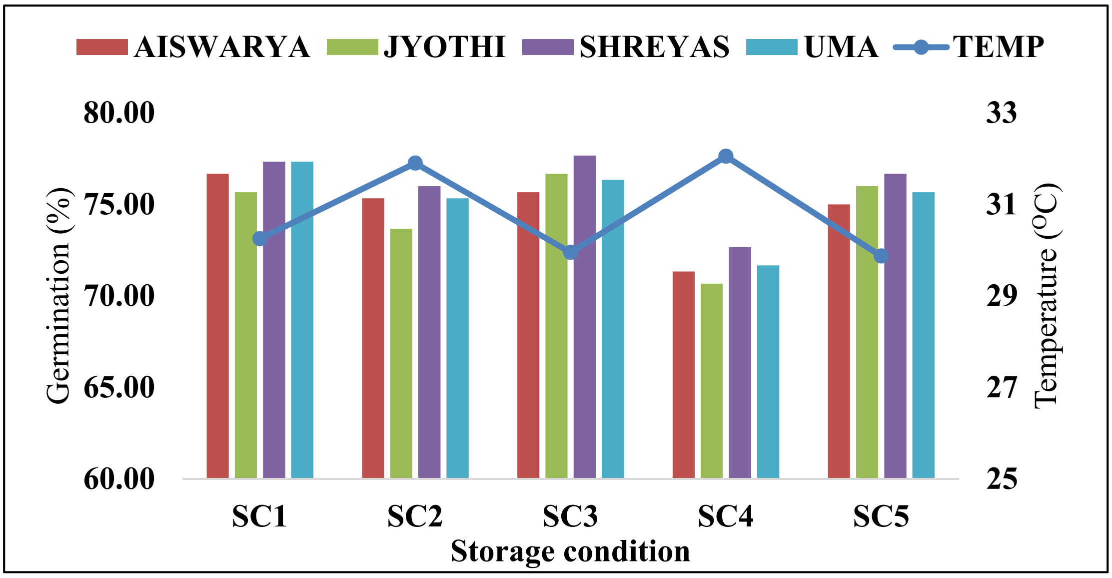



Fig.13 Influence of storage temperature on germination (%) of medium duration rice varieties in different storage conditions, at the end of storage (9 MAS)

**Fig 14.**

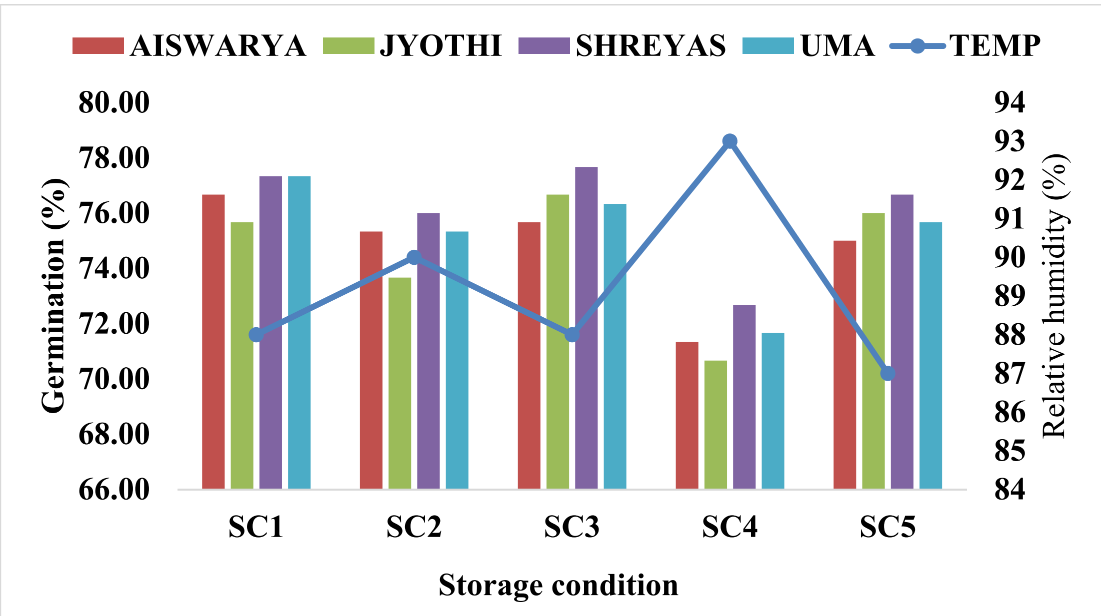



Fig 14. Influence of relative humidity on germination (%) of medium duration rice varieties in different storage conditions, at the end of storage (9 MAS)

### 5.1.2.2 VIGOUR INDEX - I

The results on vigour index - I as influenced by varieties, storage condition, the period of storage and their interactions are discussed below.

#### 5.1.2.2.1 Effect of varieties (VAR)

Irrespective of storage period and the storage conditions, both short duration and medium duration varieties varied among themselves with respect to vigour (VI-I).

Short duration varieties Matta Triveni and Kanchana were found to be the most vigourous (Fig.15a to 15e). Although Kanchana had registered the least germination per cent (86.82%) over the storage period, it was found to be on par with variety Matta Triveni in vigour, implying that seedling growth in the variety was considerably better than all other varieties.

With respect to medium duration group, variety Jyothi was found to be the most vigorous (Fig.24a to 24e). Although the variety had registered the least germination (88.74%) over the storage period, the high VI-I implied that the seedling growth in the variety was considerably better than all other varieties. Genetic potential of a variety and genetic factors such as chemical composition of seed and hard-seediness may not always be the reason for low seed vigour. The conditions during seed development, maturation, storage and aging are also crucial. Seeds with good germination, may not always be capable of continued growth and establishment in less favourable environment. Unlike germination test, vigour test reflects the ability of seed to produce normal seedlings under less optimum growing conditions. Vigour is an indicator of rate and final seedling emergence of the crop (Ellis, 1992; Matthews *et al.,* 2012).

#### 5.1.2.2.2 Effect of period of storage (MAS)

Irrespective of varieties and storage conditions, Vigour index – I was found to significantly influenced by storage duration in both short duration and medium duration groups.

It declined progressively and significantly with the advancement of storage period. The decline was significant towards the end of the storage. This may be attributed to the aging of seeds during storage. Generally, seeds start to lose vigour before they lose their ability to germinate. Therefore, vigour testing is an important practice in seed production programs. Floris (1970) reported that the ageing or deterioration of seeds is a progressive process accompanied by accumulation of such metabolites, which progressively depress germination capacity and growth of seedlings with increasing age, ultimately reducing the dry matter and vigour of seeds during storage.

**5.1.2.2.3 Effect of storage condition (SC)**

Irrespective of varieties and the storage period, Vigour index – I was found to be significantly influenced by storage condition among the short duration and medium duration varieties.

The storage conditions significantly influenced the vigour of seedlings (VI-I) over the storage period. VI-I of seeds stored in ventilated storage was significantly higher than those stored in non-ventilated stores. Seeds stored in naturally ventilated R.C.C. roofed stores registered the highest vigour (Fig. 15a to 15e).

It is to be noted that the relative humidity and temperature with the ventilated storage was lower than that within non-ventilated structures. This may have led to an increase in moisture content of the seed stored under non-ventilated structures (asbestos + without ventilation: SC2; R.C.C. + without ventilation: SC4) and subsequent reduction in vigour. Copeland and McDonald (1999) and Volenik *et al*. (2006) reported that moisture equilibration between seeds and environmental air, result in an increase in seed moisture. The deteriorative process increases within seeds and speeds up with concomitant increase in temperature, consequently leading to germination and vigour decrease. Mbofung *et al*. (2013) studied the effect of soybean seeds stored in three storage environments differing in temperature and relative humidity: a cold storage (CS: 10°C), a warm storage (WS: 25°C), and a warehouse (WH). Seed viability and vigour were evaluated using standard germination and accelerated aging tests. Viability and vigour remained high throughout the study for seeds stored in cold storage (CS: 10°C) (>92%) and moderate in the warm storage (WS: 25°C) (>78%), but decreased to almost 0 per cent after 20 months in the warehouse.

#### 5.1.2.2.4 Effect to interaction

Vigour index-I during storage was not affected by the interactions between varieties, the storage conditions and storage period in both short duration and medium duration varieties.

#### 5.1.2.2.4.1 Varieties × Storage period (VAR x MAS)

The interaction between varieties and storage period, did not significantly influence vigour index - I. This implied that the interaction between varieties and storage period caused only a marginal variation in VI-I *i.e.,* the combined influence of both varieties and period of storage on changes in VI-I was negligible.

#### 5.1.2.5.4.2 Storage condition × Storage period (SC x MAS)

The interaction between different storage conditions and storage period did not significantly influence vigour index - I, implying that the interaction between storage condition and storage period caused only a marginal variation in VI-I *i.e.,* the combined influence of both storage condition and period of storage on changes in VI-I was negligible.

#### 5.1.2.5.4.3 Varieties × Storage condition (VAR x SC)

The interaction between varieties and storage conditions did not significantly influence vigour index - I. Hence, the results revealed that, interaction between varieties and storage condition caused only a marginal variation in VI-I *i.e.,* the combined influence of both varieties and storage condition on changes in VI-I was negligible.

#### 5.1.2.5.4.4 Varieties × Storage condition × Storage period (VAR x MAS x MAS)

The interaction between the factors *viz.,* varieties, storage conditions and period of storage did not exert any significant influence on trait expression. This implied that the VI-I in different varieties under different storage conditions across the storage period were on par with each other *i.e.,* the combined influence of varieties storage condition and period of storage on changes in VI-I was negligible.

Different cultivars of the same species may differ with regard to the vigour and longevity (Timóteo and Marcos-Filho, 2013). It is inevitable that deteriorative changes that occur in seed irrespective of the genotype caused delayed germination, reduced seedling growth rates, reduced vigour decreased tolerance to adverse conditions and loss of germinability (Abdul - Baki and Anderson, 1973; Vasudevan *et al.,* 2012; Kumar *et al.,* 2017b). Adopting appropriate storage condition and ensuring optimum storage environment was found to be beneficial in slowing down the pace of the deteriorative process during storage, maintaining the seed quality and prolonging seed longevity.

To summarise, the analysis of impact of varieties, storage conditions and period of storage on VI-I, it can be inferred that the various factors independently influenced vigour of seedlings. However, the interaction between these did not significantly influence vigour of seeds. Varieties Matta Triveni and Kanchana among the short duration group and variety Jyothi among the medium duration group had recorded significantly higher vigour index-I. However, across the various varieties, including Matta Triveni, Kanchana and Jyothi a significant decline in seed vigour (SV-I) was observed in all varieties during the period of storage. Storing seeds under ventilated condition either in Asbestos + ventilation, R.C.C. + ventilation or Asbestos + forced ventilation was found to maintain superior vigour index –I over non ventilated storage conditions. This variation could be associated with the higher temperature and relative humidity prevailing in the non-ventilated condition (Fig. 15a to 15e and Fig. 16a to 16e).

**Fig.15a to15e: Mean vigour index –I of short duration rice varieties, as influenced by storage condition**

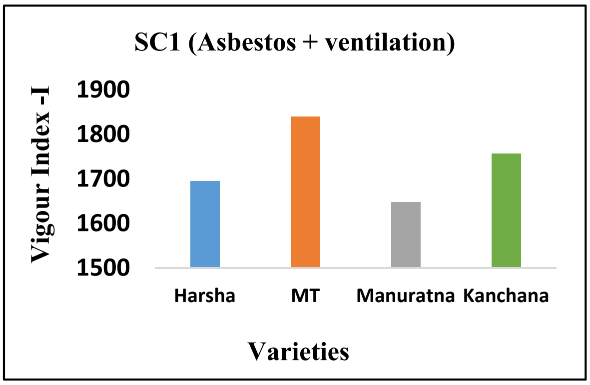



**Fig**.15a

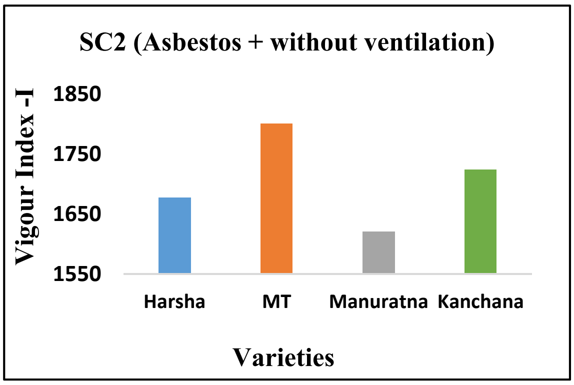



**Fig.** 15b

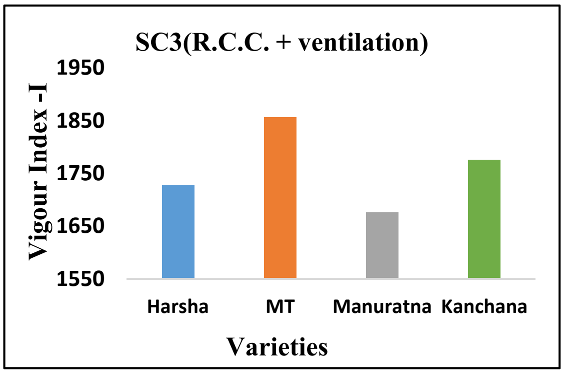



**Fig**.15c

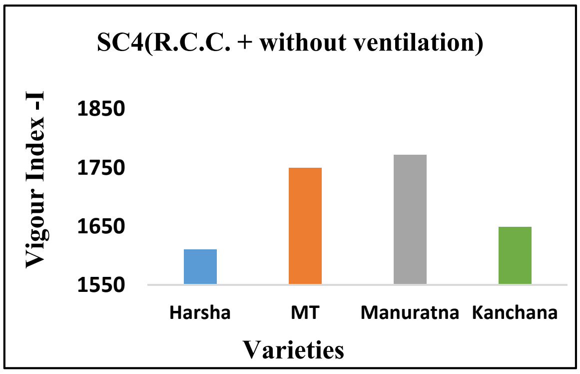



**Fig**.15d

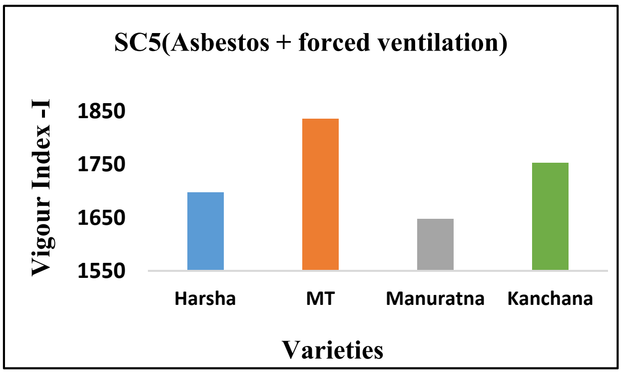



**Fig**.15e

**Fig.16a to 16e: Mean vigour index –I of medium duration varieties as influenced by storage condition**

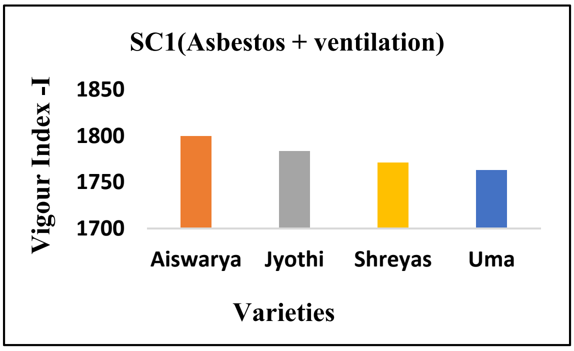



**Fig.** 16a

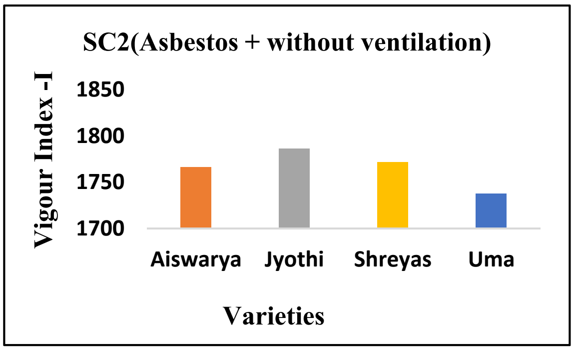



**Fig.** 16b

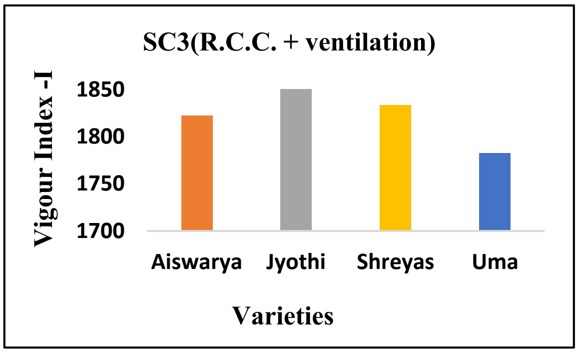



**Fig.** 16c

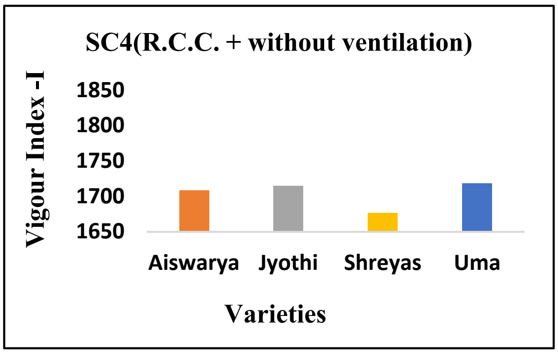



**Fig.** 16d

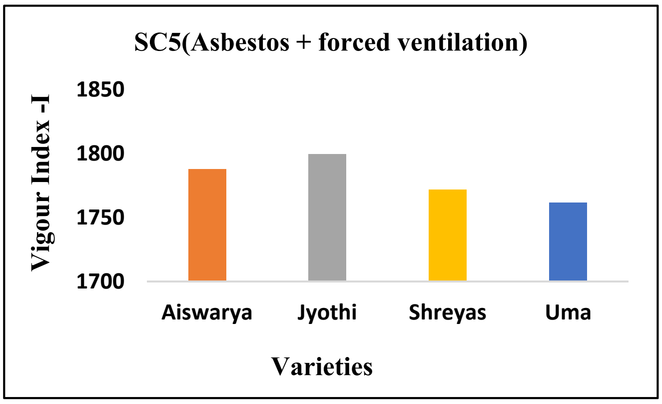



**Fig.** 16e

### 5.1.2.3 VIGOUR INDEX – II

The results on vigour index - II as influenced by varieties, storage condition, the period of storage and their interactions are discussed below.

#### 5.1.2.3.1 Effect of varieties (VAR)

Irrespective of the period of storage and storage condition, vigour (VI-II) of both short duration and medium duration varieties varied significantly over storage.

Varieties Kanchana in the short duration group and Jyothi among the medium duration group, which had registered the least germination per cent during the storage period, had produced the most vigourous seedlings (VI-II). Incidentally, Kanchana and Jyothi had also recorded significantly high VI-I. This points to the fact that the seedling growth and weight/ biomass of the seedling was high in Kanchana in comparison with the other varieties.

A germination test indicates the per cent of the seed lot that will start to grow under ideal conditions, whereas, a vigour test, on the other hand, is an indicator of how that seed will perform under less than perfect environmental conditions, taking into account the seeds' genetic constitution, size, physiological maturity, and any effects related to production and storage during previous year. Hence, it can be inferred that variety Kanchana would produce higher normal seedlings over varied or less favourable conditions of germination compared to other varieties. Timóteo and Marcos-Filho (2013) had observed considerable differences in seed vigour in different corn genotypes during storage. The storability of seeds of different genotypes could be consistently evaluated by associating germination and vigour test results with iso-enzymatic activity. Storage under controlled sub-optimal temperature and relative humidity provoked differences in intensity and speed of deterioration in corn seeds of different genotypes. According to Sharma *et al*. (2018), seed vigour depends upon the variation within the rice genotypes with respect to seed weight, shoot dry weight, shoot length as well as germination per cent.

#### 5.1.2.3.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, vigour index - II of both short duration and medium duration varieties were found to be significantly influenced by the period of storage.

Vigour of seeds decreased significantly as storage period increased. Copeland and McDonald (2001), Tekrony (2003) and ISTA, (2006) had reported that germination and vigour tests show a progressive decline during the storage period. They suggested that this can be used to make informed decisions regarding the value of different seed lots. Seed vigour is seen as the property of the seed, which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. Germination, seedling vigour and growth has been found to impact yield, field emergence and vigour / earliness of seedling emergence. These in turn, influence crop yield by influencing crop stand/density in the field (Ellis, 1992).

#### 5.1.2.3.3 Effect of storage condition (SC)

Irrespective of varieties and the storage period, storage conditions strongly influenced the vigour (SV-II) of the seeds during storage in both the short and medium duration groups.

With respect to production of vigourous seedlings (VI-II), storing seeds of both short duration and medium duration varieties in godowns with either Asbestos or R.C.C roofing and provision for either natural ventilation or forced ventilation, was advantageous over keeping them in non-ventilated stores which had asbestos nor R.C.C roofing. It is to be noted that the temperature and RH was found to be higher in non-ventilated storage than in ventilated storage. Similar results were reported by Sterlec *et al*., (2010). According to them, the influence of temperature and relative humidity on grain moisture, germination and vigour of different wheat cultivars during storage were significant. They also found that high temperature and relative humidity exerted a negative impact on seed vigour indices.

### 5.1.2.3.4 Effect to interaction

Vigour index- II of short duration varieties during storage was strongly affected by the interactions between storage period, and varieties and storage conditions while in the medium duration group it was influenced by the interaction between varieties and storage period only.

#### 5.1.2.3.4.1 Varieties × Storage period (VAR × MAS)

Irrespective of the storage conditions, vigour (VI-II) of seeds in both short and medium duration groups were significantly influenced by the interaction between varieties and storage period.

Short duration variety Kanchana produced the most vigourous seedlings throughout the storage period, followed by Matta Triveni. Manuratna registered the least estimates although the germination of this variety was comparatively higher than Kanchana during the early phases. Among the medium duration varieties, Aiswarya produced the most vigorous seedlings throughout the storage period, followed by Sreyas. The least estimates were registered by variety Uma. Uma along with variety Jyothi had registered lower germination per cent during the storage period unlike the other varieties. Results thus indicated that seedlings of variety Kanchana were not only vigourous, but also robust over the storage period. Vigour tests can help to predict the uniformity and rate of seed germination and seedling growth, its field performance and its retention capacity during storage and transport.

Naguib *et al*. (2011) reported that wheat seeds recorded high values for seed viability and vigour parameters until 12 months of storage. Seeds exhibiting a high magnitude of the parameters studied, produced strong and tall seedlings with heavier seedling dry weights.

#### 5.1.2.3.4.2 Storage condition × Storage period (SC × MAS)

Irrespective of the varieties, the interaction between storage conditions and storage period was found to exert significant influence on vigour index –II only in case of the short duration varieties. The vigour Index-II of seeds under various storage conditions declined gradually during storage. The difference was found not so prominent in the early phases of storage, gradually increased as seeds aged (Fig.17). VI-II. Seeds stored in non-ventilated stores with RC.C roofing (SC4) followed by that stored under asbestos roofing (SC2), registered the least SV-II estimates, indicating the negative impact of these storage conditions on seedling vigour during storage. The RH and temperature were higher under these non-ventilated storages compared to ventilated conditions *viz.,* Asbestos + ventilation (SCI), R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5).

A non-significant influence on vigour index – II of medium duration varieties by the interaction between different storage conditions and storage period, implied that the interaction between these factors caused only a marginal variation in VI-II *i.e.,* the combined influence of both storage condition and period of storage on changes in VI-II was negligible.

Several factors like; genetic constitution, environment and nutrition of mother plant. Maturity at harvest, seed weight and size, mechanical integrity, deterioration, ageing and pathogens are known to influence seed vigour (Stein, 1974; Perry, 1984; Timóteo and Marcos-Filho, 2013). Mettananda *et al.* (2001) opined that in orthodox seeds, vigour decreases in high-temperature environments and high relative humidity especially, with increasing water content.

**5.1.2.3.4.3 Varieties × Storage condition (VAR × SC)**

The interaction between varieties and the different storage conditions did not significantly influence Vigour index - II in both the short and medium duration groups, implying that the interaction between varieties and storage conditions resulted only in a marginal variation in VI-II *i.e.,* the combined influence of both varieties and storage condition on changes in VI-II was negligible.

**5.1.2.3.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

The interaction between the factors *viz.,* varieties, storage conditions and period of storage in short and medium duration varieties, did not exert any significant influence on VI-II. This implied that VI-II in different varieties under different storage conditions across the storage period were on par with each other *i.e.,* the combined influence of varieties, the storage condition and the period of storage, on changes in the trait expression was negligible.

Proper storage allows for the conservation of seed viability for prolonged periods. According to Stein *et al*. (1974), many factors affect the performance of seeds during storage, including genotype, the type of seed, maturation stage, treatments prior to storage, viability and initial water content of the seeds, temperature and relative humidity, oxygen pressure during storage and degree of infection by fungi and bacteria. High temperature and relative humidity during storage of seeds contribute to their deterioration by promoting degenerative changes such as destabilization in the activities of enzymes and the destruction and eventual loss of integrity of the cell membranes system, caused mainly by lipid peroxidation due to increased reactive oxygen species (ROS) (Alscher *et al.,* 2002).

The result of the study thus indicated that, vigour index –II strongly depended on the varieties, the storage condition and the period of storage and was also greatly influenced by the interaction between varieties and storage period in both short and medium duration groups. In addition, in case of short duration varieties, it was also found to be influenced by the interaction between storage conditions and storage period. However, it was not influenced by the interaction between varieties and storage conditions, as well as that between varieties, storage conditions and the storage period

Varieties Kanchana and Matta Triveni among the short duration group and medium duration varieties Jyothi and Aiswarya, produced more vigourous seedlings and irrespective of the varieties and the storage condition, vigour index – II of seeds stored under different storage conditions declined progressively and significantly over the storage period. Seeds stored in ventilated storage structures *viz.,* R.C.C. + ventilation, Asbestos + ventilation and Asbestos + forced ventilation, exhibited superior vigour index -II over those in non-ventilated structures (Asbestos + without ventilation and R.C.C. + without ventilation (Fig. 17 and Fig. 18), indicating that the storage temperature and relative humidity within the storage structures greatly influenced the vigour index –II.

**Fig.17**

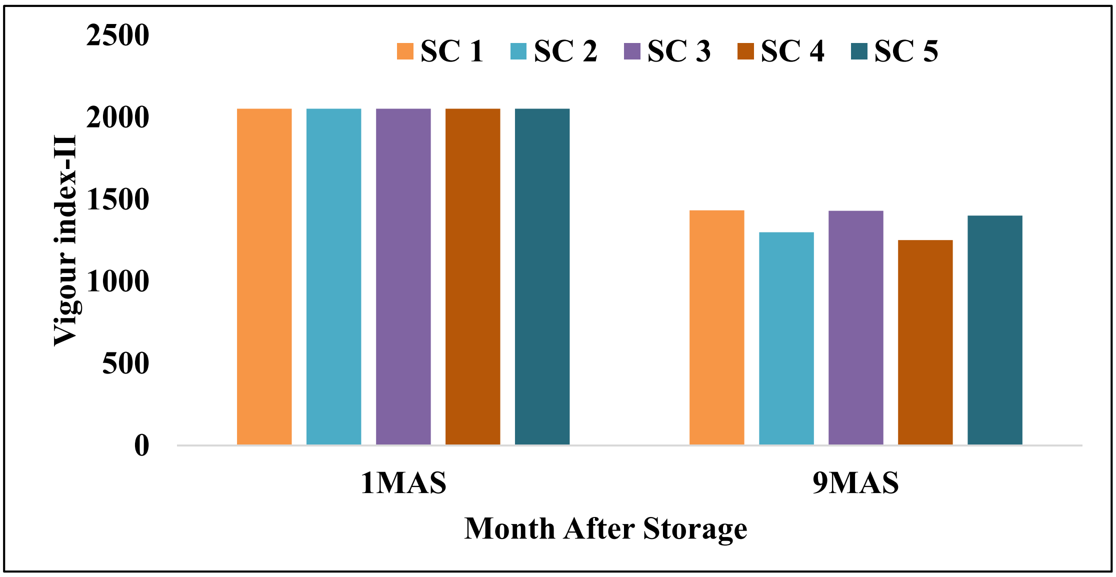



Fig 17. Vigour Index-II of seeds under various storage conditions at the start (1MAS) and end of storage (9 MAS)

**Fig.18**

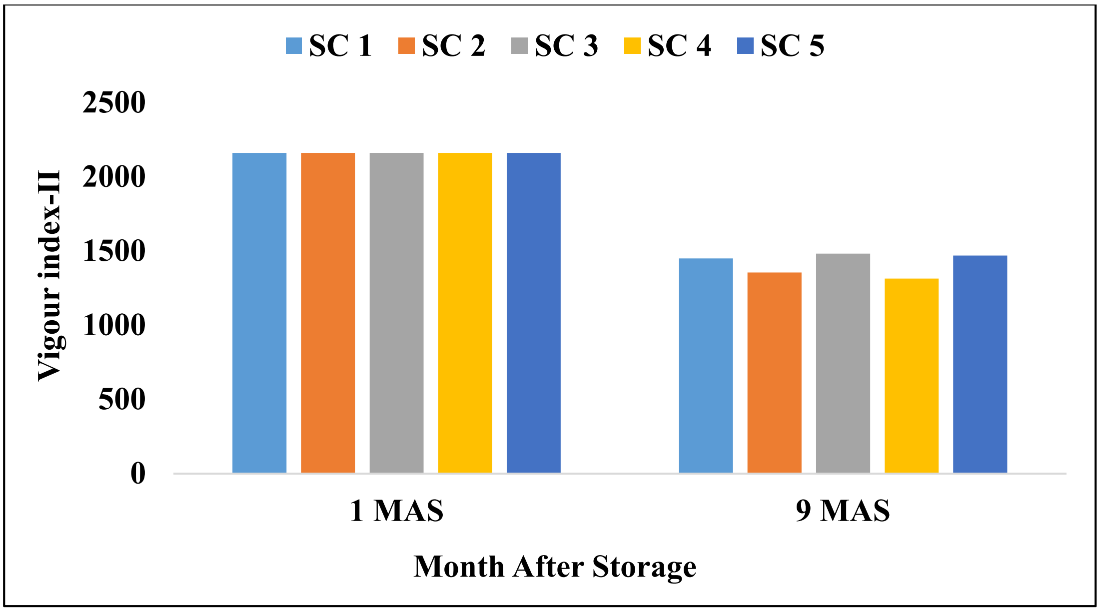



Fig 18. Vigour Index-II of seeds under various storage conditions at the start (1MAS) and end of storage (9 MAS)

### 5.1.2.4 SEED MOISTURE CONTENT (%)

The results on seed moisture content per cent as influenced by varieties, storage condition, the period of storage and their interactions are discussed below.

#### 5.1.2.4.1 Effect of varieties

Irrespective of the period of storage and storage condition, moisture content in seed of both the short and medium duration varieties varied significantly between varieties over storage.

Although the initial moisture content was the least in variety Kanchana, the average per cent gain in seed moisture content in the variety during storage was the highest (25.94%). In comparison, the gain in moisture in Harsha was 19.63 per cent, 20.28 per cent in Matta Triveni and 23.80 per cent in Manuratna. Similarly, among the medium duration varieties, although the average moisture content over the storage period was the least in variety Sreyas, the average per cent gain in seed moisture content in the variety during storage was the highest (28.16%). In comparison, the gain in moisture in Aiswarya was 22.00 per cent, 24.81 per cent in Jyothi and 26.91 per cent in Uma. There occurred a significant increase in seed moisture content across all the varieties. However, the change in moisture content was substantially different among the varieties. Seed deterioration is associated with the genotype, seed history and their physiological and chemical compositions (Copeland and McDonald, 2001).

Significant genotypic differences in seed storability have been reported by several researchers (El-Abady *et al.*, 2012; Chirchir *et al.,* 2017). Such differences have been attributed to biochemical characteristics of the genotypes, which affect the degree of seed damage and the ability of seed to resist the negative consequences of ageing (Balešević-Tubić *et al*., 2011).

#### 5.1.2.4.2 Effect of period of storage (MAS)

Irrespective of the varieties and storage condition, the moisture content of the seed increased significantly during the storage period in both short and medium duration groups.

In case of short duration varieties, moisture content was found to be below 13 per cent, the moisture level advocated for safe storage of rice seeds, only up to four months. Considering the seed moisture content at the start of storage (1 MAS), the average gain in moisture content at the end of the storage period (9 MAS) was 41.67 per cent. However, in case of medium duration varieties seed moisture content was found to be below 13 per cent only up to three months, but the average gain in moisture content at the end of the storage period was lower (38.08%) than in short duration varieties. Seed moisture is always changing owing to seeds being hygroscopic and therefore readily absorb and desorb water based on the amount of water in the surrounding (McDonald, 2007).

The seeds in the present study were packed in jute bags which is a moisture pervious container. As in our present study, Nahar *et al.* (2009) had found that storing bean seeds in jute led to an increase in moisture over five months of storage in comparison to storing them in tin and polybags, since they are more or less moisture proof. They reported that the higher moisture in the seed led to quick quality deterioration of seeds packed in gunny bags. Poonam *et al*. (2001) and Agha *et al*. (2004) reported that if seed could be packaged in moisture proof containers such that the relative humidity of the air around the seed remains low, then the seed equilibrium moisture remains low and the seed maintains its viability and vigour for a longer time.

**5.1.2.4.3 Effect of storage condition (SC)**

Irrespective of varieties and the period of storage, storage conditions strongly influenced the moisture content in the seed of both short duration and medium duration varieties, over the period of storage.

Seed moisture was found to be the least when the seeds were stored in ventilated storage with asbestos roofing (SC1) followed by seeds in other ventilated structures *viz.*, R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5). The extent of moisture gains from 1 MAS to the end of storage (9 MAS) was the highest under R.C.C. + without ventilation (SC4: 29.85%), followed by Asbestos + without ventilation (SC2: 24.11 %). The gain in MC in seeds under Asbestos + forced ventilation (SC5) was 20.72

per cent and under R.C.C. + forced ventilation (SC3), it amounted to 20.34 per cent, whereas, the gain was only 16.95 per cent in case of Asbestos + ventilation (SC1).

As observed in the case of short duration varieties, seed moisture among medium duration group was also found to be the least when the seeds were stored in ventilated storage with asbestos roofing (SC1) followed by seeds in other ventilated structures *viz.*, R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5). The extent of moisture gains from 1 MAS to the end of storage (9 MAS) was the highest under R.C.C. + without ventilation (SC4: 28.29%), followed by Asbestos + without ventilation (SC2: 24.03 %). The gain in MC in seeds under Asbestos + forced ventilation (SC5) was 20.85 per cent and under R.C.C. + forced ventilation (SC3), it amounted to 21.21 per cent, whereas, the gain was only 19.13 per cent in case of Asbestos + ventilation (SC1).

It was evident that storing seeds in non-ventilated structures resulted in increased moisture imbibition by seeds during storage. There was a strong positive correlation between gain in seed moisture and atmospheric RH (Fig. 19; Fig. 21) rather than storage temperature (Fig. 20; Fig. 22), in the present study. The average RH (SC2: 80.9%; SC4: 83.4%) and temperature (SC2: 29.7$^{O}$C; SC4: 29.9 $^{O}$C) in the non-ventilated storage environment was comparatively higher than that in ventilated conditions (SC1: 76.7%, 29.2$^{O}$C; SC3:78.8%; 29.3$^{O}$C and SC5: 74.4%; 29.5$^{O}$C). Loss of seed viability and vigour under high temperature and relative humidity conditions is a common phenomenon in may crop seeds (Balešević-Tubić *et al.,* 2010; Chirchir *et al.,* 2017). Miah *et al.* (2006) reported that after one month of storage, wheat seed moisture content (SMC) increased with increase in storage RH. At 50 per cent storage RH, the seed moisture content was seven to eight per cent, while, it reached 15-16 per cent at 80 per cent storage RH.

#### 5.1.2.3.4 Effect to interaction

Moisture content of seed (%) in short duration as well as medium duration varieties during storage were strongly affected by the interaction between varieties, storage conditions and the storage period.

**5.1.2.3.4.1 Varieties × Storage period (VAR x MAS)**

Irrespective of the storage conditions, moisture content in seed of both groups was influenced significantly by the interaction between varieties and the period of storage. Suriyong *et al.* (2015) observed that seed moisture content in cultivars of hemp that were initially dried to 7.50 – 8.60 per cent, varied during storage, owing to differences in seed moisture equilibrium between the varieties. They concluded that during storage, either high or low relative humidity affected the moisture equilibrium of seed due to its hygroscopic property. According to McPartland *et al.* (2000), the type of container was important for protecting moisture immigration during storage.

The increase in moisture over the nine-month storage period from the start of storage (0 MAS) varied between 37.96 per cent in Matta Triveni to 45.74 per cent in Kanchana in the short duration group. The gain in Harsha and Manuratna was 39.72 per cent and 43.61 per cent, respectively. The increase being the highest in variety Kanchana. It was obvious that the seed moisture content in the seeds increased beyond the safe moisture level mid-way of storage (*i.e.,* by 5 / 6 MAS).

Among the medium duration varieties, the increase in moisture over the nine-month storage period from the start of storage (0 MAS) varied between 39.73 per cent in Aiswarya to 48.64 per cent in Sreyas. The gain in Uma and Jyothi was 43.73 per cent and 40.19 per cent, respectively. The increase being the highest in variety Sreyas. It was obvious that the seed moisture content in the seeds increased beyond the safe moisture level early in storage (*i.e.,* by 3/ 4 MAS). These results, once again reiterated that the seed moisture content increased in all varieties with the increase in storage period.

Thobunluepop *et al.* (2009) revealed that seeds of rice kept in storage for 12 months under ambient conditions showed increased seed moisture content and seed water activity which affected germination rate, seedling vigour, seedling dry weight, shoot and root length. Loss in viability was due to disturbances in the cell membrane and the loss of enzymes like alpha-amylase. However, unlike in the present study, Rickman and Aquino (2007) reported a lower gain in seed moisture over storage. According to them, thegrain moisture levels in the traditional open storage systems fluctuated between two and three per cent over a 12-month storage period. Using a hermetic system reduced the variation to less than 1.5 per cent, while the moisture level in grain stored in the air-conditioned room decreased by more than two per cent over a 12-month period. The high gain in seed moisture observed in the present study may be attributed to the high RH and temperature prevailing the location of the experiment (Fig.3 and Fig.4).

**5.1.2.3.4.2 Storage condition × Storage period (SC x MAS)**

Irrespective of the varieties, the interaction between storage conditions and the period of storage significantly influenced the seed moisture content during storage in both short and medium duration varieties.

Storing seeds of short duration varieties in ventilated godowns with asbestos roofing (SC1: 35.22%) registered the least gain in moisture between 1 MAS and end of storage period *i.e.,* 9 MAS followed by SC3 (39.45 %) and R.C.C + Forced ventilation (SC5: 40.96). The gain in moisture by seeds stored in SC4 (43.69%) and Asbestos + without ventilation (SC2: 40.96%) was higher. In addition, it was observed that the moisture level in seeds reached above the safe moisture level (13%) earlier in SC4 (4 MAS) and SC2 (5 MAS) and it occurred only much later in SC1 (7 MAS). Similarly, storing seeds of medium duration varieties in ventilated godowns with asbestos roofing (SC1: 35.72%) registered the least gain in moisture between 1 MAS and end of storage period *i.e.,* 9 MAS, followed by SC5 (37.90 %) and SC3 (38.71%). The gain in moisture by seeds stored in R.C.C. + without ventilation (SC4: 44.42%) and Asbestos + without ventilation (SC2: 41.43%) was higher. In addition, it was observed that the moisture level in seeds reached above the safe moisture level (13.00%) earlier in SC4 (3 MAS) and SC2 (4 MAS) and it occurred only much later in SC1, SC2 and SC5 (5 MAS). This clearly pointed out the advantage of storing seeds in ventilated storage and specifically under ventilated storage with asbestos roofing, in high humid, high temperature environment. Under forced air ventilated condition (SC5), the air inside the storage environment is constantly refreshed by the forced suction of external air. This leads to an increase inflow of moisture laden air into the storage environment as the ambient RH prevailing outside the storage environment is higher. This may have led to an increased gain of moisture by seed stored under R.C.C + Forced ventilation (SC5).

Sawant *et al.* (2012) reported that, in godown storage method, relative humidity increased as storage period increased and resulted in high seed moisture content, while, in air tight storage method, initially relative humidity of wheat grains was higher and it gradually decreased as storage advanced. Jian *et al.*, (1998) proposed different models representing seed moisture content as a function of relative humidity and temperature. These models point to an increase in seed moisture content with an increase in relative humidity and temperature.

**5.1.2.3.4.3 Varieties × Storage condition (VAR x SC)**

Irrespective of storage period, the interaction between varieties and storage conditions significantly influenced the seed moisture condition during storage.

The moisture content in all varieties stored under R.C.C. + without ventilation (SC4) and Asbestos + without ventilation (SC2) were significantly high than those stored under SC1 (Asbestos + with ventilation), SC3 (R.C.C. + with ventilation and SC5 (Asbestos + forced ventilation). Short duration variety Manuratna and medium duration variety Uma had registered significant high seed moisture across all the storage environments. The moisture content in seeds of all varieties under SC2 and SC4, except in case of Kanchana under SC2 was above the moisture level for safe storage, whereas among the medium duration group, the moisture content in varieties Sreyas under SC1 and SC5 and variety Jyothi under SC1 was optimum for safe storage (13.00%). The moisture estimates in all other instances were above the moisture level for safe storage during storage. During storage, the seeds tend to equilibrate itself with that microclimate and RH of the environment, also termed as equilibrium relative humidity. Copeland and McDonald (1999) and Volenik *et al.* (2006) reported that moisture equilibration between seeds and environmental air result in an increase in seed moisture. The deteriorative process within seeds increases and speeds up with concomitant increase in temperature, consequently leading to decline in germination and vigour.

Variety Kanchana had registered the least moisture content across all environments, while among medium duration varieties, Sreyas had registered the least moisture content across all environments, except in SC3. These varieties had registered the lower seed moisture content before the start of the storage period (Kanchana: 10.10%; Sreyas: 10.30%; Jyothi: 10.80%). Khan *et al*. (2007) reported that seed moisture content of different crops and varieties of a crop, differ due to difference in seed composition. Wheat seed has more protein content (12%) and since protein has greater affinity for water molecule due to presence of positive and negative charges that provide site for hydrogen bonding, it had a higher moisture content. Moreover, maize seeds have more oil content (5.00%) than proteins (9.00 %) as compared to wheat seeds (oil content: 2-3%). Lipids have less affinity for the water molecule. Therefore, the elevated moisture content in wheat seeds in comparison to seeds of maize was attributed to the low oil content and higher protein in the former (Mcdonald, 2007).

In addition, the results also pointed to the advantage of storing seeds under ventilated storage. It indirectly indicated that storing seeds under high humid and hot conditions in moisture pervious containers would lead to an increase in seed moisture content, as seeds would try to attain equilibrium with the RH of the surrounding atmosphere. Siracusa (2017) reported that seed moisture content varied in different packaging materials due to varying water-vapor transmission rates.

**5.1.2.3.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

Seed moisture content was found to be significantly influenced by the interaction between varieties, storage condition and the storage period in both short duration and medium duration varieties, implying that the seed moisture content was strongly influenced by the genetic makeup of a variety, the storage environment and the storage period.

The per cent gain in moisture over storage was higher in varieties Manuratna and Kanchana compared to varieties Harsha and Manuratna. In addition, the initial moisture content in Manuratna (10.80%) was higher than in variety Kanchana (10.10%). Owing to this fact, the moisture content in Manuratna exceeded the safe level recommended for seed storage, faster than in the other varieties. This may be one of the reason for lower seed quality parameters observed in variety Manuratna during the storage period. Among the medium duration varieties, Sreyas recorded the least moisture content during storage, although the per cent gain in moisture during storage in the variety (Sreyas: 28.16%) was the highest. This may be attributed to the least moisture content observed in the variety (10.30%) before the start of storage. However, although the per cent gain in moisture over storage in varieties Uma (26.91%), Jyothi (24.91%), Aiswarya (22.00%) was lower, variety Uma registered significant high seed moisture estimates over other varieties during the corresponding periods of storage across the various storage conditions. In all instances, except under SC3, the seed moisture content of Uma exceeded the safe level recommended for seed storage, quicker than the other varieties. This may be one of the reason for lower seed quality parameters observed in variety Uma during the storage period.

The moisture content of seeds stored under different storage structures was found to be significantly variable. The moisture content of seeds stored in SC4 (R.C.C. + without ventilation) exceeded the safe level recommended for seed storage quicker than under other storage environments. This may be also have contributed to the lower seed longevity (7 MAS) observed in seeds of both short and medium duration varieties stored in this environment. Short duration varieties Matta Triveni and Manuratna under SC4, exceeded the safe level recommended for seed storage at 3 MAS, while in varieties Kanchana and Harsha it crossed 13.00 per cent at 4 MAS and 5 MAS, respectively. In case of medium duration varieties, Jyothi and Uma under SC4, exceeded the safe level recommended for seed storage at 2 MAS, while in varieties Aiswarya and Sreyas crossed 13.00 per cent at 3 MAS. In addition, it was obvious that storing seeds in ventilated storage also reduced the rate of gain in seed moisture during storage.

Seeds in both groups stored under non ventilated condition, SC2 (Asbestos + without ventilation) and SC4 (R.C.C. + without ventilation) had experienced higher temperature and relative humidity. This was found to directly influence the seed moisture content over the storage period. SC1 (Asbestos + ventilation), SC3 (R.C.C. + ventilation) and SC5 (Asbestos + forced ventilation) recorded lower temperature and humidity and hence, lower was the seed moisture content recorded. As observed in the short and medium duration groups in the present study, Khaldun and Haque (2009) had reported that seed moisture content increased with increase in temperature and relative humidity of the storage environment.

Survival of seeds in dry storage depends more on its moisture content than on any other factor. Deteriorative reactions frequently proceed in the seed more readily if the moisture content is higher and consequently, the moisture condition would constitute a threat to the longevity of survival. The rate of seed respiration increased at high seed moisture contents and heat generated by the respiring seeds is enough to kill the seeds (Duarte *et al*., 2004). Storage of maize at high moisture contents (15%) resulted into low germination per cent, dry matter losses (up to 35%) along with fungal growth (Afzal *et al*., 2017). Jyoti and Malik (2013) had also reported that seeds stored at high moisture content manifested increased respiration, heating, and fungal invasion resulting in reduced seed vigour and viability. According to Dillahunty *et al.* (2000), the respiration rate of rice decreased with decreasing moisture content and the growth of microorganisms was inhibited at a low water activity, which resulted in better storability of rice seeds.

To summarise the results considering the effect of varieties, storage condition, storage period and their interaction, it was evident that seed moisture content of both short and medium duration varieties, increased significantly over the storage period. Among the different varieties, short duration variety Manuratna and medium duration variety Uma registered significantly higher moisture content over other varieties under all storage condition, while Kanchana and Sreyas recorded the least moisture content. The results, also clearly proved that the seeds stored under non-ventilated condition accounted for higher seed moisture content during storage.

**Fig.19**

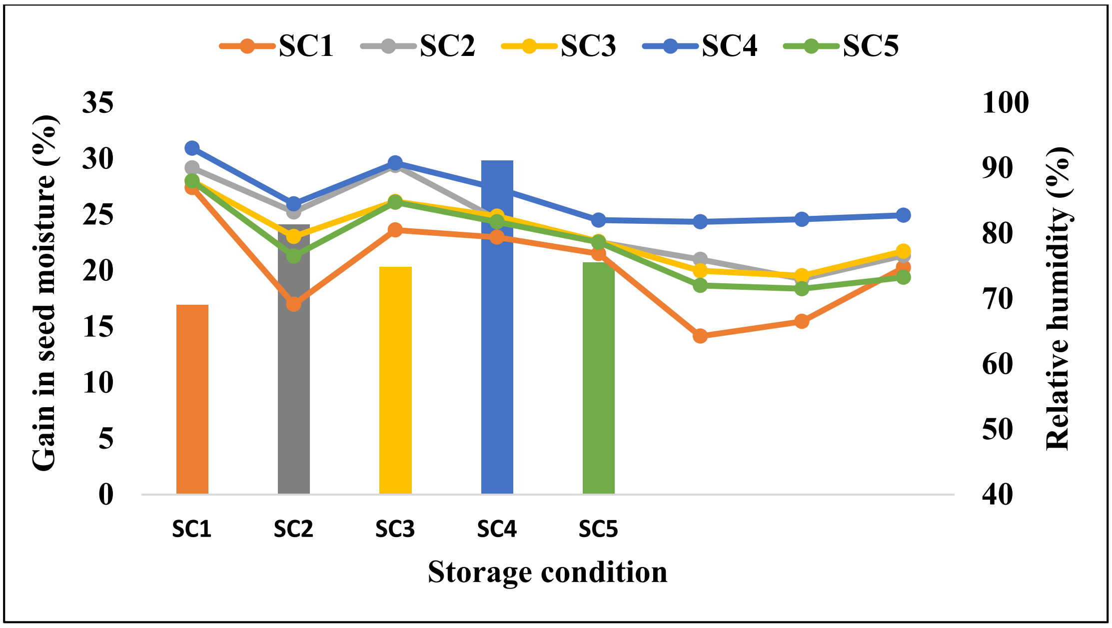



Fig.19. Gain in seed moisture content (%) over storage and change in RH (%) in the storage environments.

**Fig.20**

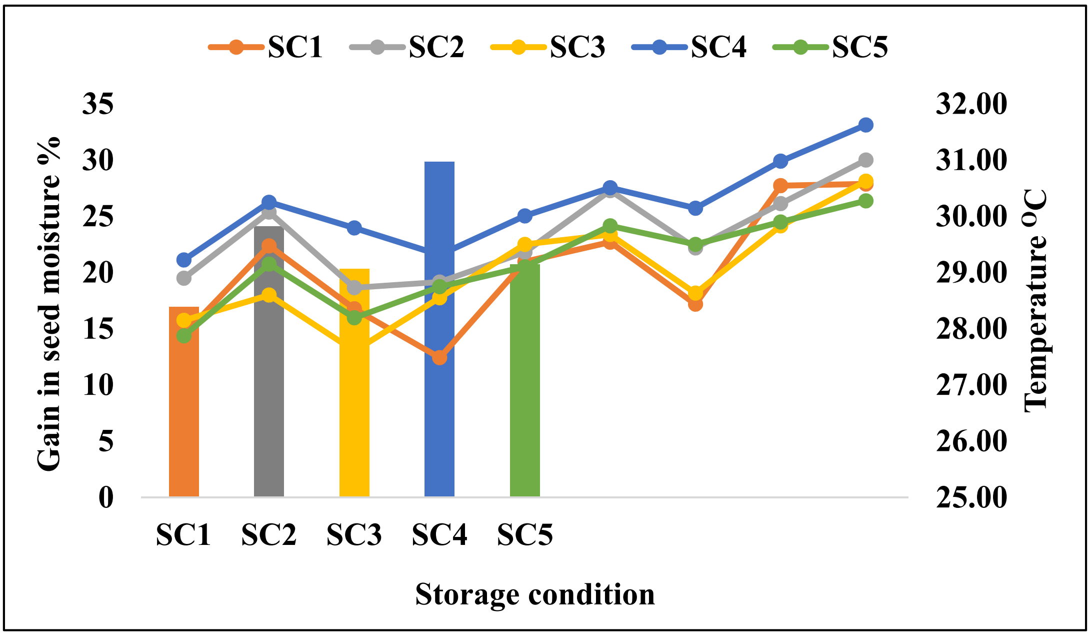



Fig.20. Gain in seed moisture content (%) and over storage and change in storage temperature ($^{O}$C) in the storage environments.

**Fig.21**

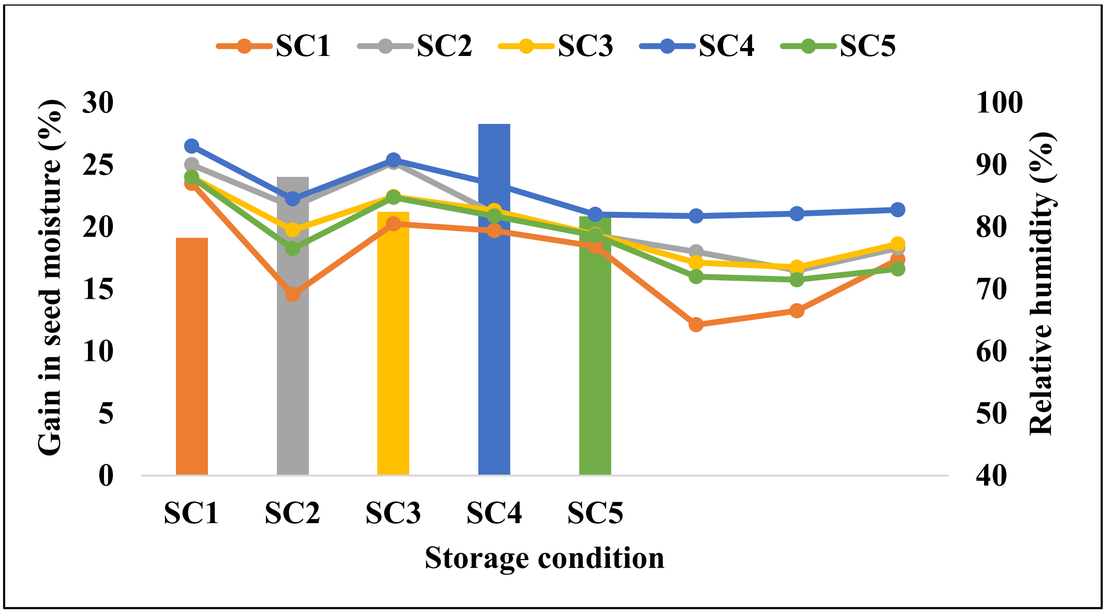



Fig.21 Gain in seed moisture content (%) over storage and change in RH (%) in the storage environments.

**Fig.22**

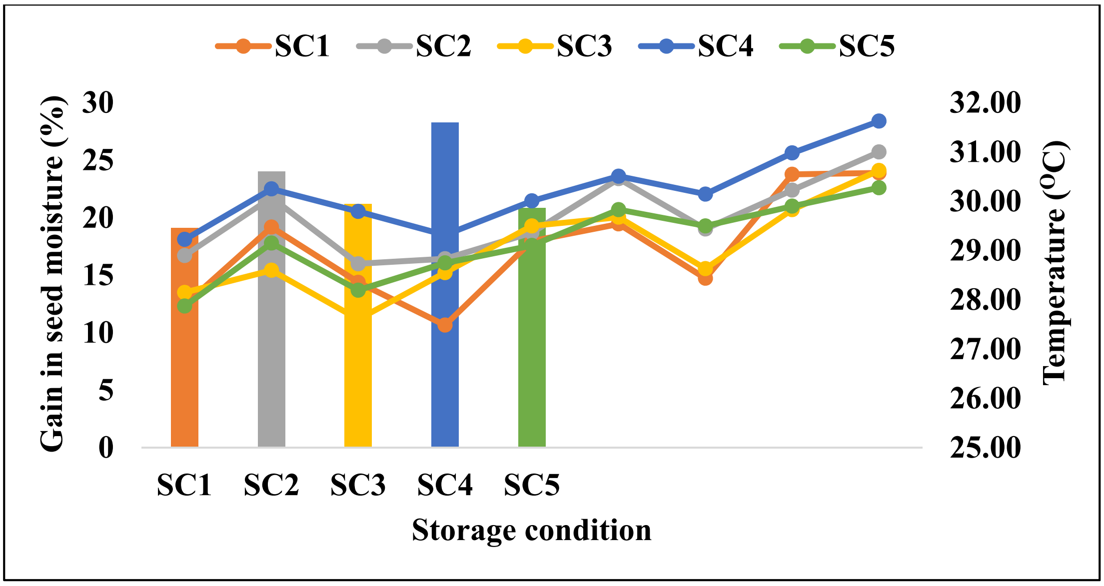



Fig.22 Gain in seed moisture content (%) and over storage and change in storage temperature ($^{O}$C) in the storage environments.

### 5.1.2.5 ELECTRICAL CONDUCTIVITY OF SEED LEACHATE (EC) (µSM$^{-1}$)

The results on electrical conductivity of seed leachate (EC) (µSm$^{-1}$) content as influenced by varieties, storage condition, the period of storage and their interactions are discussed below.

#### 5.1.2.5.1 Effect of varieties (VAR)

Irrespective of storage conditions and the period of storage, electrical conductivity of seed leachate (EC) of was found to vary significantly between the short and medium duration varieties over storage.

In the short duration group, varieties Kanchana and Harsha had registered significant low EC than Matta Triveni and Manuratna, the estimate being the highest in the latter. Medium duration varieties Sreyas and Aiswarya had registered significant low EC than Jyothi and Uma, the estimate being the highest in the latter.EC of seed leachate is an indication of the status of seed deterioration. Hence, from the result, it can be inferred that the deterioration of seeds of variety Harsha and Kanchana was comparatively lower than that of Matta Triveni; Manuratna being in the most deteriorated state. Variation in EC between cultivars have been reported earlier (Vieira *et al*., 2001; Bijanzadeh *et al*., 2016; Chirchir, 2017). Vieira *et al*. (1999) and Tajbakhsh (2000) revealed that all germination parameters in wheat crop were inversely proportional to electrical conductivity or vice- versa as storage period increases.

#### 5.1.2.5.2 Effect of period of storage (MAS)

Irrespective of varieties and the storage conditions, as the storage period increased, there was a significant increase in EC of seed leachate in both the duration groups.

As observed in the present study, Bijanzadeh *et al*. (2016) found that in seeds of rice cultivars, the initial electrical conductivity was low (50-67 µScm$^{-1}$mg$^{-1}$). After ageing, various cultivars exhibited E.C. in the range of 272 µSm$^{-1}$ to 493 µSm$^{-1}$. Govindaraj *et al*. (2017) reported that, irrespective of the treatment and varieties, the least electrical conductivity was observed in unaged seeds (60.1 µSm$^{-1}$) and EC increased gradually with increase in duration of ageing and reached the maximum at 20 days of ageing (143.7 $\mu Sm^{-1}$). An inverse relationship between germination and EC was also elucidated by Eluid *et al.* (2010) in bean seeds. They reported that germination per cent declined below the accepted level after storage of two months and to zero after nine months, while the electrical conductivity shot above the critical level after two months.

**5.1.2.5.3 Effect of storage condition (SC)**

Irrespective of varieties and period of storage, the storage conditions strongly influenced the EC of seed leachate.

In the short duration group, the EC was found to be the significantly low in Asbestos + ventilation (SC1) followed by R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5). The significant high EC observed in seeds stored under Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4), implied the advantage of storing seeds under ventilated storage (Fig.23). The EC of seed leachate in medium duration group was found to be the significantly low in Asbestos + forced ventilation (SC5) followed by Asbestos + ventilation (SC1) and R.C.C. + ventilation (SC3). The significant high EC observed in seeds stored under Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4), implied the advantage of storing seeds under ventilated storage (Fig.24). As discussed earlier, the RH and temperature in these non-ventilated storages were higher than that in the ventilated stores. Being a fragile living entity, seed storability is greatly influenced by abiotic and biotic environmental conditions. According to Bhandari *et al*., (2017), the environmental factors that are responsible for seed quality deterioration are temperature, relative humidity, atmospheric conditions of storage containers and moisture content of the seed. Adetumbi *et al*., (2009) reported that the hygroscopic nature of maize seed make storage in open container unsafe. In humid tropical region, at a temperature 25°C and above, and 65-70% relative humidity, storage of maize seed for more than 3-4 months could be detrimental for seed viability and vigour, unless proper container and moisture level is maintained (Abba and Lavato, 1999)

### 5.1.2.5.4 Effect to interaction

EC of seed leachate ($\mu Sm^{-1}$) during storage in both short and medium duration varieties was strongly affected by the interaction between varieties, storage conditions and the period of storage.

### 5.1.2.5.4.1 Varieties × Storage period (VAR × MAS)

EC of seed leachate during storage in both short and medium duration varieties was significantly influenced by the interaction between varieties and storage period. EC was found to be the significantly high in variety Manuratna throughout the storage, while it was significantly low in varieties Harsha and Kanchana. Among medium duration varieties, EC was found to be the significantly high in variety Uma and Jyothi throughout storage, while it was significantly low in varieties Aiswarya and Sreyas. Differential increase in EC with ageing of seeds in different genotypes have been reported by earlier workers (Chirchir *et al.,* 2016; Carvalho *et al.,* 2017). Generally, viability and quality of seeds gradually deteriorate after harvest (Coolbear 1995, McDonald 1999), but the deterioration in long-term storage depends on environment, biochemical, biological, and genetic factors. Mathew and Brandnock (1967) and Mathew and Whitburead (1968) reported that the electrical conductivity (EC) test is based on the concentration of solutes, namely sugar, amino acids possessing electrical charges that have leached out of the seed and can be detected by measurement of the EC. The low leakage would mean low conductivity, which is associated with seeds that emerged well with high vigour. In comparison, high leakage of electrolyte, resulting in increased EC, is expressed in seed with lowered vigour and poor emergence.

### 5.1.2.5.4.2 Storage condition × Storage period (SC × MAS)

Interaction between storage conditions and the period of storage, significantly influenced the EC of seed leachate throughout the storage period in both short and medium duration varieties.

Seeds stored in non-ventilated stores *viz.*, R.C.C. + without ventilation (SC4) and Asbestos + without ventilation (SC2) had registered significantly high EC throughout the period of storage, over storing them in ventilated stores. As lower amounts of leachates indicate high seed vigour and vice versa (Adriana *et al*., 2012; Powell, 1988), it can be concluded that storing seeds under non-ventilated structures, either for short or long term, was detrimental to seed. High EC estimates observed in these conditions are indicative of the extent of seed deterioration.

Thobunluepop *et al*. (2009) revealed that seeds of rice kept in storage for 12 months under ambient conditions showed increased seed moisture content and seed water activity which affected germination rate, seedling vigour, seedling dry weight, shoot and root length. Loss in viability was due to disturbances in the cell membrane and the loss of enzymes like alpha-amylase as evident from the increased seed leachate of aged seeds.

**5.1.2.5.4.3 Varieties × Storage condition (VAR × SC)**

In the short duration and medium duration varieties, significant influence on EC of seed leachate was evident due to the interaction between varieties and storage condition.

Variety Manuratna among the short duration varieties and Uma in the medium duration group registered high EC estimates under all the storage environments. The EC estimates of all varieties under non-ventilated structures, *i.e.,* Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4) were higher, compared to those in ventilated structures, indicating that better seed quality in all varieties can be realised, when stored under ventilation.

Vieira *et al*. (2001) reported the effect of temperature and relative humidity on electric conductivity and concluded that an increase in temperature ($20^0$C) and RH tends to increase the electrical conductivity, as the storage period increases. The storage of grains in the natural environment of tropical areas presents larger problems due to the temperature conditions and relative humidity, when compared to the areas having a cold or temperate climate (Abba and Lovato, 1999). The parameters of temperature and relative humidity during storage are decisive in the process of loss of seed viability (Alencar *et al.,* 2006).

### 5.1.2.5.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)

The interaction between varieties, storage conditions and period of storage, significantly influenced the EC of seed leachate in both duration groups. According to Mathews and Powell (2006), as a result of aging or storage period or storage environment or crop, the seed loses its viability. Consequently, it leads to degradation of membranes in seeds, which is reflected during imbibition as electrolyte leakage.

Among the short duration varieties, Manuratna recorded significantly high EC over other varieties, while Kanchana with the least under various storage environments throughout storage, indicating a lower state of deterioration in the later. In case of medium duration group, variety Uma had registered significant high EC over other varieties, while Sreyas with the least under various storage environments throughout storage, indicating a lower state of deterioration in the later. However, the EC of seed leachate increased in all varieties with increase in storage period and it was significantly high under Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4), whereas it was low in ventilated structures *viz.*, Asbestos + ventilation (SC1), R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5). Thus, it was evident that seeds stored under non-ventilated condition registered significant higher electrical conductivity as the storage period increases.

Seeds stored under non-ventilated condition, Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4), experienced higher temperature and relative humidity which indirectly influenced electrical conductivity over the storage period. The lower temperature and relative humidity was recorded under Asbestos + ventilation (SC1), R.C.C. + ventilation (SC3) and Asbestos + forced ventilation (SC5) may be attributed to lower seed leachates under these conditions during storage (Fig. 23 and Fig. 24).

The result of the present study is in concurrence with that of Smruti *et al*. (2010). It was reported that rice stored under high temperature ($45^0$C) and humidity (~100%) for 15 days showed a decrease in per cent germination and concentrations of protein and starch, however, it increased conductivity of leachate and content of sugar. An increase in temperature tends to increase the electrical conductivity, as the storage period increases.  However, the physiological and biochemical mechanisms by which this variability is expressed are still not fully understood, although it has been found to be significantly influenced by genotype, environment, management practices and their interactions (Bellaloui *et al.* 2011).

To conclude, the results of the study pointed out that, EC of seed leachate in seeds stored under different conditions increased as the storage period increased. Lower EC and subsequently a lower rate of deterioration of seed quality can be realised if seeds are stored in ventilated stores either with asbestos or RCC roofing with provision for natural ventilation, or asbestos roofing with provision for forced ventilation.

**Fig.23**

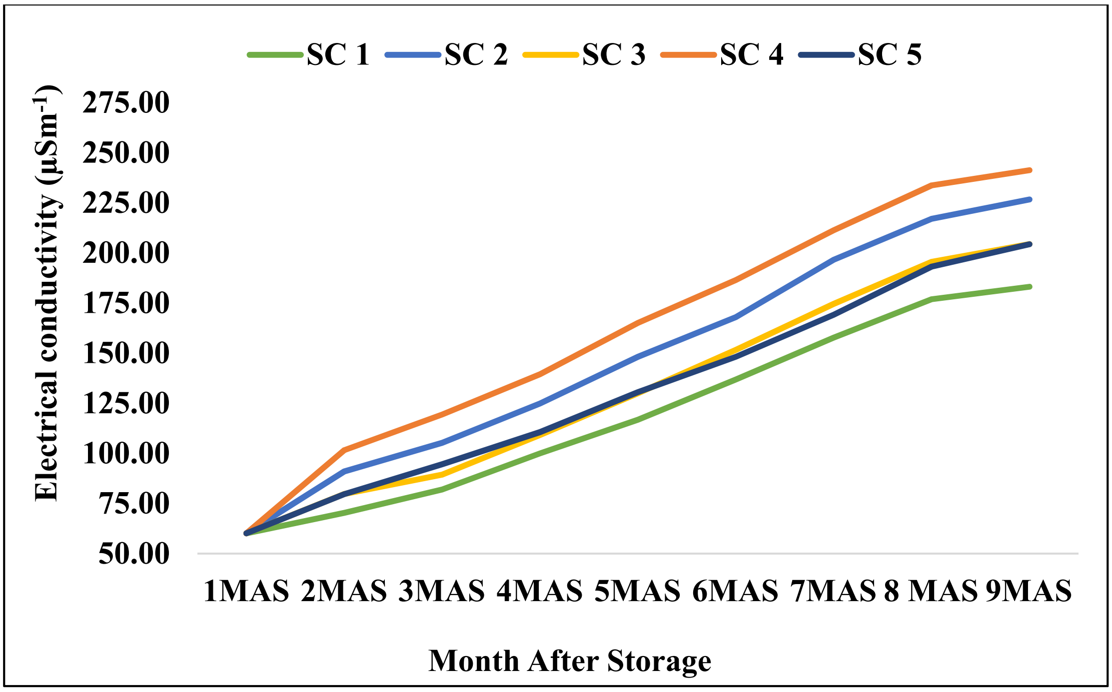



Fig.23 Electrical conductivity (µSm$^{-1}$) of seed leachate under different storage condition

**Fig.24**

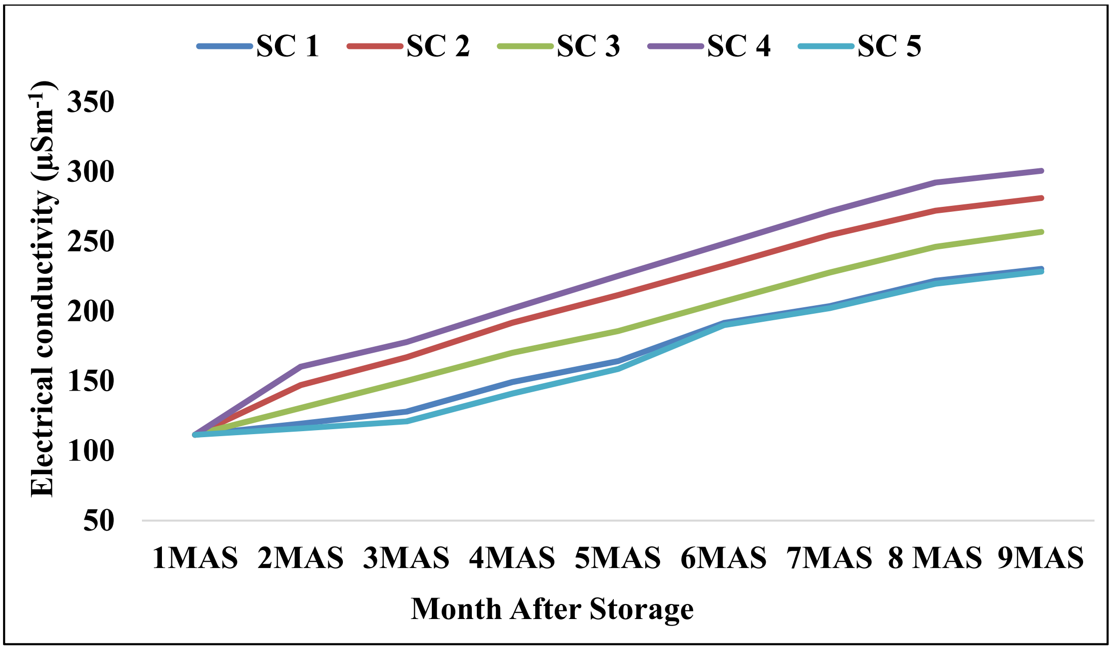



Fig.24 Electrical conductivity ($\mu Sm^{-1}$) of seed leachate in different storage conditions during storage

### 5.1.2.6 FIELD ESTABLISHMENT (%)

The results on field establishment per cent as influenced by varieties, storage condition, the period of storage and their interactions are discussed below.

#### 5.1.2.6.1 Effect of varieties (VAR)

Irrespective of storage condition and period of storage, significant varietal difference in field establishment was evident over the storage period.

Higher estimates were evident in short duration varieties Matta Triveni and Harsha. Although, initially, the FE in varieties Manuratna and Harsha was the same as in variety Matta Triveni, the varieties exhibited significant differences as storage duration increased. FE of Kanchana was the least throughout the storage period. This variety had registered high vigour indices, which is an indication of the potential of the variety to germinate under unfavourable conditions. Hence, a lower FE in Kanchana may be attributed to the lower initial germination (96.00%) observed in the variety in comparison to the others (100.00%).

Among medium duration varieties, higher estimates were evident in varieties Aiswarya and Sreyas. FE of Jyothi was the least throughout the storage period. This variety had registered high vigour indices, which is an indication of the potential of the variety to germinate under unfavourable conditions. Hence, a lower FE in Jyothi may be attributed to the lower initial germination (98.00%) observed in the variety in comparison to the others (100.00%). It was also observed that the field establishment per cent in both short duration and medium duration varieties, was lower than the germination per cent in the corresponding period.

As per ISTA (1976), the germination test for cereals is conducted under standardised optimum conditions, so that the maximum germination potential of a seed line can be realised. The relationship between laboratory germination and field emergence is generally good, when soil conditions are favourable for germination and seedling growth, but less satisfactory, when soil conditions become unfavourable (Matthews and Collins 1973; Perry 1977; Stormonth and Doling, 1979). Many researchers have reported significant positive correlation coefficients between laboratory evaluations of physiological potential (standard germination and vigour tests) and field emergence (TeKrony and Egli, 1977; Yaklich and Kulik, 1979; Egli and TeKrony, 1996).

**5.1.2.6.2 Effect of period of storage (MAS)**

Irrespective of storage condition and period of storage, significant varietal difference in field establishment was evident over the storage period in both the short and medium duration groups.

As observed in germination, FE remained high initially and gradually declined to less than 90.00 per cent (at 6 MAS), whereas, the decline to below 80.00 per cent was quick (occurring at 8 MAS). As in the present study, ageing of seeds has been reported to be associated with decreased emergence (Egli and TeKrony, 1996). Tekrony *et al*. (2005), revealed that the germination, field emergence and vigour in seed lots that registered high germination (87–99%) before storage, declined to 50–80 per cent, after eight months of storage in the 'uncontrolled' warehouse. Considering the above, it can be inferred that understanding the effects of storage duration on seed quality in the laboratory and its emergence in the field is crucial for good crop establishment.

**5.1.2.6.3 Effect of storage condition (SC)**

Irrespective of varieties and period of storage, significant variations in field establishment was evident in the short duration and medium duration varieties, over the storage period

As in most other seed quality parameters, especially, germination and vigour, seeds stored in ventilated storage exhibited significant high FE compared to those in non-ventilated structures. The higher FE in seeds stored in ventilated stores may be attributed to the comparatively lower temperature and RH within these storage conditions. It is to be noted that among the three ventilated structures, these atmospheric parameters were higher in the store with Asbestos roofing and forced ventilation (SC5). The fact that the seeds in godowns with either R.C.C. or asbestos roofing and provision for natural ventilation had registered significantly high FE compared to those stored within the ventilated structure with provision for forced ventilation (Asbestos + Forced ventilation: SC5), also pointed out that, storing seeds in godowns with either R.C.C. or asbestos roofing and provision for natural ventilation, was sufficient to realise higher F.E.

Temperature of the storage environment has a large impact on seed emergence, with warmer temperatures having a negative effect on seed emergence (Balesevic-Tubic *et al*., 2010; Vertucci and Roos, 1990; Vieira *et al*., 2001). Heatherly and Elmore (2004) reported that irrespective of the initial seed quality, unfavourable storage conditions, particularly the air temperature and relative humidity, contribute to accelerating seed deterioration which resulted in poor field emergence.

**5.1.2.6.4 Effect to interaction**

The interaction between varieties, storage conditions and the period of storage significantly influenced field establishment (%) in both short and medium duration varieties.

**5.1.2.6.4.1 Varieties × Storage period (VAR × MAS)**

Irrespective of the storage condition, field establishment in both the short and medium varieties declined significantly as storage period increased.

A steep decline in FE occurred in all varieties, beyond 90.00 per cent, while the decline from 100.00 per cent was gradual, taking place within a period six month in varieties MT, Harsha and Manuratna. In variety Kanchana, it was retained above 90.00 per cent for 3 MAS only. In all the medium duration varieties also a steep decline in FE occurred beyond 90.00 per cent, while the decline from 100.00 per cent had been gradual, taking place within a period six months, indicating the difference in response to ageing between the varieties. Studies by Hendry *et al*. (1994) revealed that, the rates of ageing and potential life spans of seeds vary among species. Even within species, various accessions often exhibit differences in their storage properties and field performance. Andric *et al*. (2007) reported that significant cultivar differences in seed vigour preservation during storage, implicated the possibility for usage of genotypes with higher seed vigour potential in soybean, to achieve higher crop establishment even in suboptimal environmental conditions.

**5.1.2.6.4.2 Storage condition × Storage period (SC × MAS)**

Irrespective of the varieties, field establishment was found to be significantly influenced by the interaction between storage condition and the period of storage in both short and medium duration groups.

FE in all varieties decreased as seeds aged, the decline being sharp beyond 90.00 per cent. Seeds stored under ventilated stores as well as those in non-ventilated stores with asbestos roofing, registered significantly high FE compared to those in non-ventilated storage with RCC roofing, up to 6 MAS. However, as storage period increased, the advantage of storing seeds in ventilated stores became clearly evident. Stores with natural ventilation proved better than that with forced ventilation, at the end of storage season. As discussed earlier, among the three ventilated structures, the RH and temperature was higher under store with forced ventilation. The RH and temperature inside the non-ventilated structures were higher than in ventilated stores.

High RH and moisture content, especially when combined with high temperature, have a negative impact on seed emergence during storage (Balesevic-Tubic *et al.,* 2010) During the storage of soybean seed viability, vigour and field performance often declined with increasing duration in storage, particularly when storage conditions are not favourable (Egli and TeKrony, 1996; Vieira *et al*., 2001).

**5.1.2.6.4.3 Varieties × Storage condition (VAR × SC)**

Irrespective of storage period, significant influence on field establishment per cent (FE) was exerted by the interaction between varieties and storage condition in both duration groups.

FE of short duration variety Matta Triveni was significantly high compared to other varieties under all the five storage conditions indicating the superior potential of MT. The FE in variety Kanchana was the least and differed significantly from other varieties stored in any given condition. FE of variety Manuratna was low compared to MT and Harsha, but significantly higher than Kanchana in the various environments. Variety Manuratna stored under treatments (SC1, SC2 & SC4) and variety Kanchana stored under all the treatments registered a FE below 90 per cent.

Among the medium duration varieties, FE of Aiswarya and Sreyas was significantly high compared to other varieties under all the five storage conditions indicating the superior potential of these varieties. The FE in variety Jyothi was the least and differed significantly from other varieties stored in any given condition. FE of variety Uma was low compared to Aiswarya and Sreyas, but significantly higher than Jyothi in the various environments. Variety Aiswarya stored under treatments (SC1, SC2, SC3 and SC5) and variety Uma and Sreyas stored under SC3 registered a FE above 90 per cent. It was evident that the varieties responded differentially under different storage environments. Wein and Kueneman, (1981) also reported that germinability and emergence of cultivars varied with the storage conditions.

Seeds of short duration varieties stored in ventilated store with R.C.C. roofing (SC3) registered a higher FE over other storage environments, while it was the least in those stored under R.C.C. + without ventilation (SC4) (Fig 25and Fig 26). In case of medium duration varieties, seeds stored in ventilated store with Asbestos roofing (SC1) registered a higher FE over other storage environments, while it was the least in those stored under R.C.C. + without ventilation (SC4) (Fig 27 and Fig 28). The FE of a given variety when stored under the ventilated structures, were found to be on par with each other but differed significantly with that stored in non-ventilated stores, implying the superiority of ventilated storage over non-ventilated store. Considering the RH and temperature differences within the storage conditions, the negative impact of high estimates of these parameters on FE is deduced. Kumar (2009) reported that all the physiological parameters like seed germination, vigour index, root length, shoot length, seed establishment and speed of germination were adversely affected by high relative humidity (75 %) and temperature conditions. Hamman *et al*. (2002) had reported that reduced soybean field emergence was associated with lower vigour, and that all these factors are more negatively affected by challenging planting environments than higher vigour seed.

**5.1.2.6.4.4 Varieties × Storage condition × Storage period (VAR × SC × MAS)**

The interaction between varieties, storage condition and the storage period was found to significantly influence field establishment per cent of stored seeds in both short and medium duration groups.

Field establishment of all both short duration and medium duration varieties declined progressively over the storage period. Short duration varieties Matta Triveni and Harsha registered significant high field establishment compared to Manuratna and Kanchana, under different storage conditions during storage. Among the medium duration varieties Aiswarya and Sreyas registered significant high field establishment compared to Jyothi and Uma under different storage conditions during storage. As the seeds aged, it was observed that there was a differential response in FE in different varieties stored under varying storage conditions. Sisman, (2005) also reported that storing seed beyond the optimum storage period might result in reduced germination potential, seedling establishment and final seed production. In general, high vigour seed do have increased field emergence (Zorrilla *et al*., 1994; Roy and Ratnayake, 1997). Low vigour seed are associated with difficulties in field emergence (Cho and Scott, 2000), as low vigour seed are more affected by challenging planting environments than higher vigour seed. Hamman *et al*. (2002) however, had reported that in addition to seed vigour, the planting environment is also known to affect emergence. Conditions in the planting environment that affect emergence include seedbed conditions, temperatures at planting, and soil moisture.

In both short and medium duration groups, field establishment of seeds stored under different storage structures was found to be significantly varied. Ventilated storage structures *viz.*, R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (SC5) registered superior field establishment per cent over non- ventilated structures [Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4)].

Influence of storage temperature and relative humidity on field establishment under different conditions during 9 MAS are detailed in Fig.25 to Fig. 28. Seeds of both short and medium duration varieties stored under Asbestos + without ventilation (SC2) and R.C.C. + without ventilation (SC4) were exposed to higher temperature and relative humidity, which resulted in reduced field establishment. Storage conditions R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilated (SC5) recorded lower storage temperature and humidity. Significant high field establishment was observed under these storage conditions. Hence, it can be inferred that storing seed under ventilated structures was advantageous especially, as when the period of storage prolongs. Conversely, storing seeds in non-ventilated structures, either asbestos roofed or R.C.C., negatively impacted field establishment in all varieties during storage. Seed deterioration leading to loss of germination and establishment progressed very rapidly at higher humidity and temperature (Barton, 1941; Bass *et al.*, 1963; Alscher *et al.*, 2002; Timóteo and Julio Filho, 2013). Kumar (2009) reported that all the physiological parameters like seed germination, vigour index, root length, shoot length, seed establishment and speed of germination were adversely affected by high relative humidity (75.00 %) and temperature conditions.

**Fig 25.**

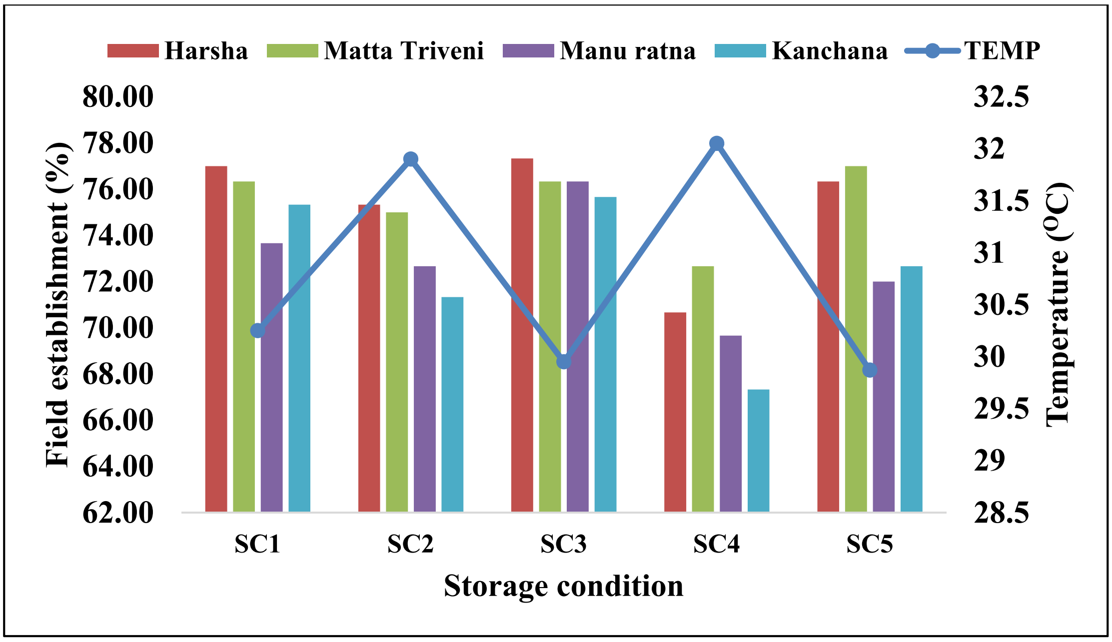



Fig 25. Influence of storage temperature in different storage conditions on field establishment (%) of varieties, at end of storage (9 MAS)

**Fig 26.**

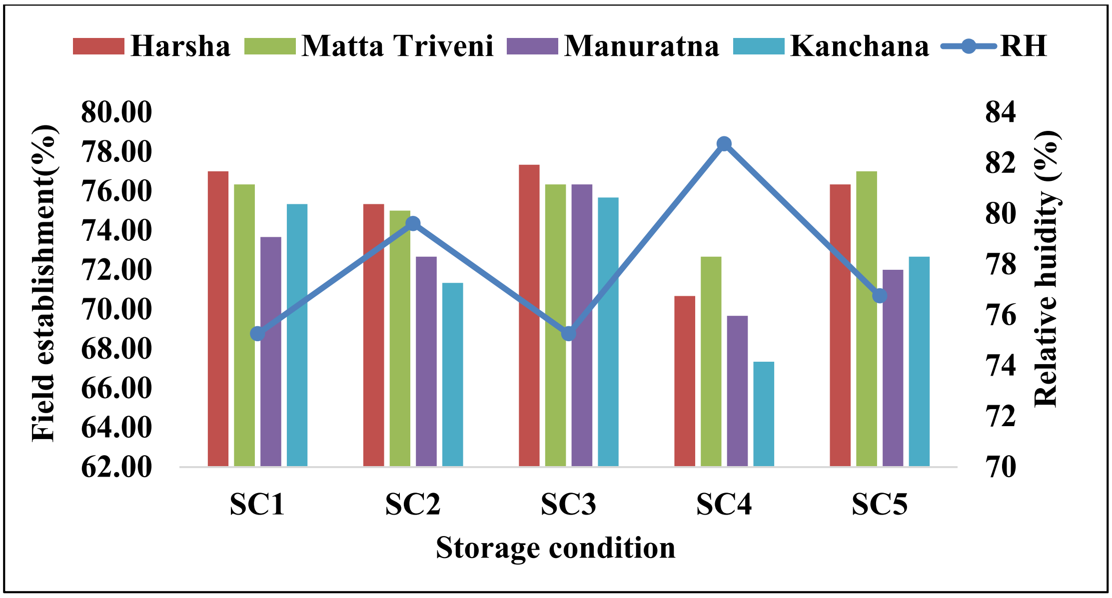



Fig 26. Influence of relative humidity in different storage conditions on field establishment (%) of varieties, at end of storage (9 MAS)

**Fig.27**

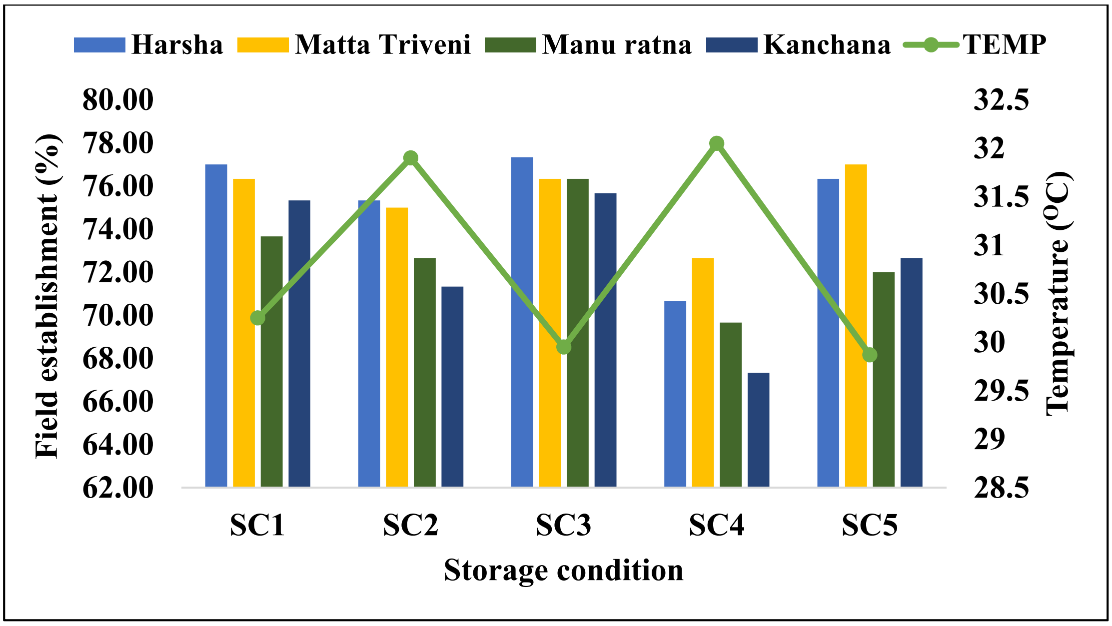



Fig.27. Influence of storage temperature in different storage conditions on field establishment (%) of short duration varieties, at end of storage (9 MAS)

**Fig.28**

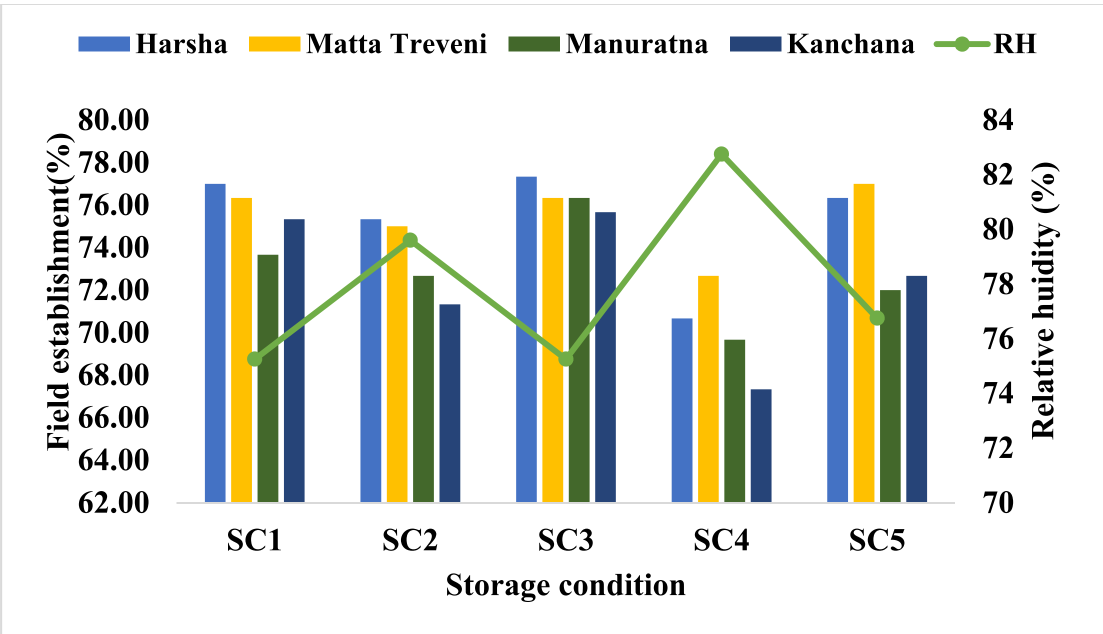



Fig.28. Influence of relative humidity in different storage conditions on field establishment (%) of medium duration varieties, at end of storage (9 MAS)

### 5.1.2.7 SEED MICROFLORA (%)

Varieties and the storage conditions were found to influence per cent occurrence of microflora in seed, at the end of seed storage.

#### 5.1.2.7.1 Effect of varieties (VAR)

Irrespective of the storage condition, at the end of the storage period, in both the short and medium duration varieties, seed microflora (%) was found to vary significantly between the varieties.

The per cent seed microflora at the end of storage was found to be the least in variety Matta Triveni, while the highest estimate was recorded in variety Kanchana. Among medium duration varieties, seed infection at the end of storage was found to be the least in variety Uma, while the highest estimate was recorded in variety Jyothi.

The seed microflora that infected the seed were *Aspergillus niger*, *Aspergillus flavus* and *Pencillium sp.* Although these species have not been reported to cause any seed-borne disease in rice, the storage fungi cause considerable damage and are responsible for deterioration and reduction in storage potential of seed (Pedireddi *et al.,* 2018). Roberts (1972) reported that the viability and vigour of the stored seeds is mainly reduced due to storage fungi.

Seeds harbour a great variety of micro flora, especially fungi. During storage viability and vigour are lost due to many biotic factors such as microflora. Christensen (1972) reported that fungi not only cause qualitative and quantitative loss of seed, but also increased the moisture content of the seeds in storage, bring biochemical changes leading to decreased membrane integrity, decrease food reserves in seed and cause rapid death of seeds within a short period of time.

Trung *et al*. (2001) reported that the most common micro-organism that were found to infect the seed were fungi belonging to the genus *Aspergillus*, *Fusarium* and *Penicillium.* Monajjem *et al*. (2014) also reported that among seed-borne fungi, *Aspergillus niger* and *Aspergillus flavus* was the most prevalent microbe in rice seed storage compared to other fungi. Seed borne fungi, not only reduce the germination and vigour of seedlings but also act as a source of inoculum for the development of the disease in the field.

**5.1.2.7.2 Effect of storage condition (SC)**

Irrespective of the varieties storage condition, at the end of the storage period, seed microflora (%) was found to vary significantly between the storage conditions in both short and medium duration groups.

No seed infection was recorded during the start of storage. At the end of the storage period, in both short and medium varieties, per cent seed microflora was found to be the least in seeds stored in R.C.C. + ventilation (SC3). It was observed to be high in seeds stored under non ventilated conditions *viz.,* R.C.C + without ventilation (SC4) and Asbestoses + without ventilation (SC2). In comparison to the storage environment in ventilated conditions [R.C.C. + ventilation (SC3), Asbestos + forced ventilation (SC5) and Asbestos + ventilation (SC1)], the environment in non-ventilated storage was more conducive for fungal growth and multiplication. According to Begum *et al*. (2013), the tropical climate with high temperature and RH, along with unscientific storage conditions, adversely affect preservation of cereals, oilseed and other crops which leads to total loss of seed quality. Decline in seed quality on account of microbial infection under various storage conditions and packing have been studied earlier (Butt *et al.,* 2011; Monajjem *et al*., 2014)

Seeds harbour a great variety of micro flora, especially fungi. During storage viability and vigour are lost due to many biotic factors such as microflora. It is assumed that as the production environment and storage conditions changes the spectrum and type of infection by the pathogens tend to change which ultimately causes severe losses during storage and also reduces the seed quality (Pedireddi *et al.,* 2018).

**5.1.2.7.3 Effect of interaction (VAR x SC)**

The interaction between varieties and storage condition among the short and well as medium duration varieties, did not exert significant influence on seed microflora (%).

This implied that the interaction between varieties and storage condition caused only a marginal variation in seed microflora *i.e.,* the combined influence of both varieties and period of storage on changes in seed microflora was negligible.

To summarise the results, considering the effect of varieties and storage condition and their interaction, it was evident that seed microflora in both short duration and medium duration short duration varieties varied significantly between varieties and the storage conditions. However, no obvious effect on occurrence of seed microflora was evident, owing to the interaction between these factors. The per cent of seed microflora was high and significant in short duration variety Kanchana and medium duration Jyothi under all storage conditions, while the least was recorded in variety Matta Triveni and Uma from the short duration and medium duration groups, respectively. The results, also clearly indicated that the seeds stored under non-ventilated condition accounted for higher seed microflora per cent at the end of storage.

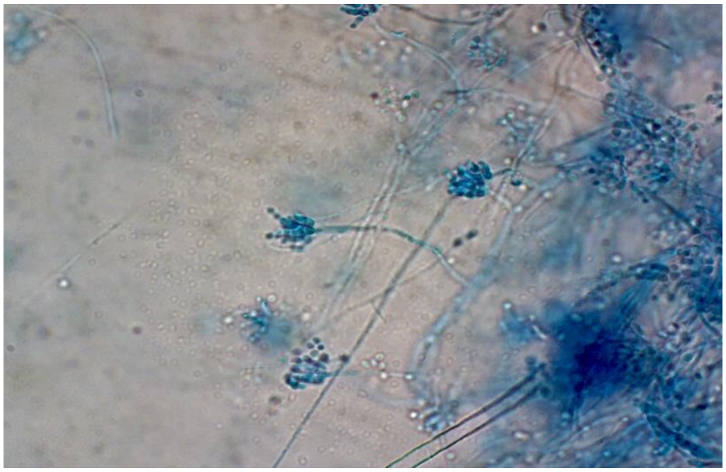
In general, the results of storage studies revealed that among the short duration varieties, Matta Triveni and Harsha showed better longevity, *i.e.* until 8 MAS, while it was only up to 7 MAS in varieties Manuratna and Kanchana. However, seed of all the medium duration varieties registered the same longevity, *i.e.* until 8 MAS. Irrespective of the varieties, germination, field establishment and vigour indices I and II, decreased progressively over the storage period. However, there was an increase in seed moisture content and electrical conductivity of seed leachate towards the end of storage period. Storing seeds in non-ventilated storage conditions; either in R.C.C + without ventilation (SC4) or Asbestoses + without ventilation (SC2), had a greater negative influence on seed viability and longevity, moisture content and electrical conductivity. However, storing seeds under ventilated conditions Asbestoses + ventilation (SC1), R.C.C + ventilation (SC3) and Asbestoses + forced ventilation (SC5) was advantageous in maintaining the germination, field establishment, vigour of seedlings (VI-II), lowering the rate of increase in EC of seed leachate and seed moisture content, for a longer period during storage.

Existence of a strong influence of the interaction between varieties, storage condition and storage period on seed longevity of stored seeds was also discerned.

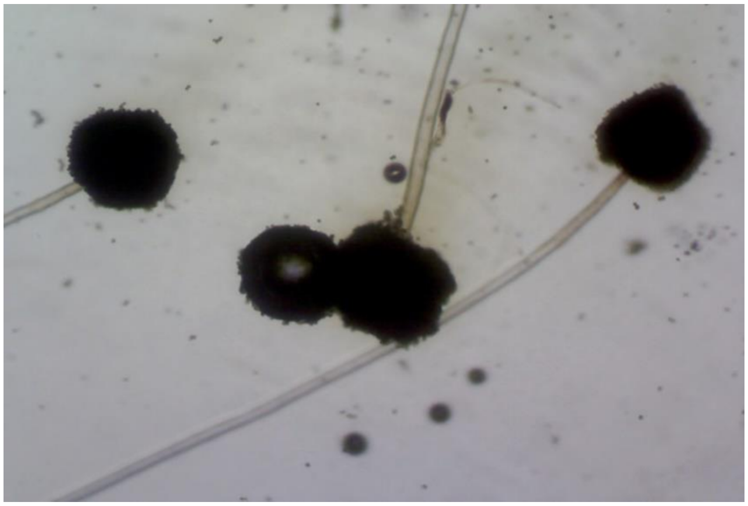
Among the various storage conditions, it would be best to store seeds in ventilated condition [Asbestoses + ventilation (SC1), R.C.C + ventilation (SC3) and Asbestoses + forced ventilation (SC5)], as this prolonged seed longevity the farthest *i.e.,* until eight months after storage (8 MAS). However, the seeds if stored in Asbestoses + without ventilation (SC2) and R.C.C + without ventilation (SC4) had retained viability above the minimum standards of seed certification (IMSCS) for 7MAS only. In addition, the interaction between varieties, storage condition and storage period had exerted a significant influence on seed quality parameters as well. Seeds of various varieties stored under SC1 (Asbestoses + ventilation), SC3 (R.C.C + ventilation) and SC5 (Asbestoses + forced ventilation) was found to register significant high germination, vigour (VI-I and VI-II), field establishment and lower EC of seed leachate, seed moisture and seed microflora during storage.

To conclude, under hot and humid conditions, it would be most advantageous to store seeds under ventilated conditions in order to delay the rate of quality deterioration during storage. In addition, as there was no associated improvement in seed longevity and most quality parameters by storing seeds under Asbestos + Forced ventilation (SC5) over other ventilated conditions [Asbestoses + ventilation (SC1) and R.C.C + ventilation (SC3)], it can be inferred that storing seeds in godowns with provision for forced ventilation did not confer any advantage over that with natural ventilation. Incurring additional expenditure on installation, maintenance, operation of forced ventilation system, does not confer any additional benefit with respect to prolonging storability of stored seeds.

*Aspergillus flavus*



*Pencillium sp*



*Aspergillus niger*

**Plate 4. Seed microflora**

# Summary

# 6. SUMMARY

The study ’Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),’ was carried out in the Department of Seed Science and Technology, College of Horticulture, Vellanikkara, Kerala Agricultural University (KAU), Thrissur, during the year 2019 - 2020. The results obtained are summarized below.

**Experiment I: Impact of storage structure on seed longevity of short duration rice varieties.**

**I (a). Seed quality before storage**

1. The seed used for the study was of good quality. Although, the quality parameters varied marginally between varieties (Harsha, Matta Triveni, Manuratna and Kanchana), they were above the minimum standards required for seed certification in rice crop.

2. Germination and field establishment ranged from 96.00 per cent (Kanchana) to 100.00 per cent (Harsha, Matta Triveni and Manuratna). Vigour indices (VI-I: 2100.00 and VI-II: 2170.00) was the highest in variety Matta Triveni and the least in variety Manuratna (VI-I: 1870 and VI-II: 1700).

3. Moisture content in seeds was below the safe level (<13.00%) in all the varieties. The seed moisture content and was the least in Kanchana (10.10%), while it was 10.80 per cent in the other varieties, while the electrical conductivity (EC) of seed leachate ranged from 39.02 $\mu Sm^{-1}$ (Kanchana) to 102.20 $\mu Sm^{-1}$ (Manuratna).

**I (b) Seed quality during storage**

**A. Seed quality and longevity of short duration rice seeds as influenced by varieties**

1 Irrespective of the storage condition and storage period, significant variation in germination (%), seed vigour indices, seed moisture content, electrical conductivity of seed leachate, field establishment (%) and seed microflora (%) was found to exist between varieties *i.e.,* significant genotypic differences was evident in seed quality parameters over storage.

2 Variety Matta Triveni exhibited superior quality parameters over other varieties. The variety registered significant high germination (%) and vigour (indices VI-I and VI-II), high field establishment (%) and low seed moisture content (%), electrical conductivity of seed leachate and seed microflora.

3 Variety Manuratna registered significant low seed quality parameters.

4 Vigorous seedlings, coupled with low seed moisture (%) and electrical conductivity of seed leachate was observed in Kanchana. However, the variety had registered the highest per cent seed microflora and the least estimate for germination (%) and field establishment.

**B. Seed quality and longevity of short duration rice seeds as influenced by storage condition**

1. Irrespective of the varieties and storage period, storage condition exerted significant influence on germination (%), seed vigour indices, seed moisture content, electrical conductivity of seed leachate, field establishment (%), and seed microflora (%).

2. Quality of seeds stored under ventilated conditions *viz.,* R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (S5) was significantly superior to those stored in non-ventilated conditions [Asbestos + without ventilation (SC2), R.C.C. + without ventilation (SC4)].

**C. Seed quality and longevity of short duration rice seeds as influenced by storage period**

1. Irrespective of the varieties and storage conditions, the period of storage caused significant variation in germination (%), seed vigour indices, seed moisture content, electrical conductivity of seed leachate, field establishment (%), and seed microflora (%).

2. Germination, vigour indices I and II and field establishment of seeds decreased progressively and significantly over the storage period, while a

significant increase in seed moisture content, electrical conductivity of seed leachate, and seed infection (%) was evident. towards the end of storage period.

3. Seed longevity was higher (8 months each) in varieties Harsha and Matta Triveni compared to varieties Manurathna and Kanchana (7 months each).

**D. Seed quality and longevity of short duration rice seeds as influenced by interaction between varieties, storage condition and storage period**

1. Results indicated existence of wide variability in the impact of interaction between varieties, storage condition and storage period on germination (%), seed moisture content, electrical conductivity of seed leachate, field establishment (%), and seed microflora (%). However, the impact of interaction between varieties with storage condition and the storage period, did not cause any significant variation in seed vigour indices I and II.

2. The interaction between varieties and storage period on germination and other seed indices, indicated that germination, vigour indices and field establishment increased significantly over the storage period. Performance of variety Matta Triveni was superior over other varieties, while that of Manuratna was low. Although, germination and field establishment of variety Kanchana was poor, it was found superior with respect to other quality parameters *viz.,* vigour (VI-I and VI-II), seed moisture and EC of seed leachate). The longevity of varieties Matta Triveni and Harsha was higher (8 MAS), compared to varieties Manuratna and Kanchana (7 MAS).

3. Interaction between varieties and storage condition on seed quality indicated that storing seeds under ventilated conditions [R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (S5)] was advantageous over storing them under non-ventilated conditions. Seed longevity under ventilated condition was higher (8 months), while it was for 7 months in non-ventilated conditions.

4. As observed in the interaction between varieties and storage condition on seed quality, the interaction between storage condition and the period of storage also indicated that storing seeds under ventilated conditions was advantageous over storing them under non-ventilated conditions. Seed longevity under ventilated condition was higher (8 months), while it was for 7 months in non-ventilated conditions.

5. The interaction between varieties, storage condition and the period of storage, indicated that storing seeds under ventilated condition would be most advantageous. The interaction however, revealed that longevity of variety Matta Triveni and Harsha was influenced strongly by the storage condition. The longevity of seeds of these varieties was higher by a period one month *i.e.,* 8 MAS, when stored under ventilated environments conditions *viz.,* R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (SC5) as against 7 MAS under non-ventilated storage [Asbestos + without ventilation (SC2), R.C.C. + without ventilation (SC4)]

6. As the quality parameters and seed longevity varied only marginally among the various ventilated storage conditions, it can be concluded that storing seeds in structures with natural ventilation under the prevailing hot and high humid condition, would be more economic and less cumbersome.

**Experiment 2: Impact of storage structure on seed longevity of medium duration rice varieties.**

**1 (a). Seed quality before storage**

1. The seed used for the study was of good quality. Although, the quality parameters varied marginally between varieties (Aiswarya, Jyothi, Sreyas and Uma), they were above the minimum standards required for seed certification in rice crop.

2. Germination and field establishment ranged from 98.00 per cent (Jyothi and Uma) to 100.00 per cent (Aiswarya and Sreyas). Vigour indices (VI-I: 2100.00 and VI-II: 2528.00) was the highest in variety Jyothi and the least in variety

Uma (VI-I: 2029.00 and VI-II: 1793.00).

3. Moisture content in seeds was below the safe level (<13.00%) in all the varieties. The seed moisture content and was the least in Sreyas (10.30%), while it was 10.80 per cent in Jyothi and 11.00 per cent each in Uma and Aiswarya. The electrical conductivity (EC) of seed leachate ranged from 81.20 $\mu Sm^{-1}$ (Aiswarya) to 146.50 $\mu Sm^{-1}$ (Uma).

**1 (b) Seed quality during storage**

**A. Seed quality and longevity of medium duration rice seeds as influenced by varieties**

1. Irrespective of the storage condition and storage period, significant variation in germination (%), seed vigour indices, seed moisture content, electrical conductivity of seed leachate, field establishment (%), and seed microflora (%) was found to exist between varieties *i.e.,* significant genotypic differences was evident in seed quality parameters over storage.

2. High significant seed quality parameters were evident in variety Aiswarya. The variety registered high significant germination (%), vigour index-II and field establishment (%) and relatively low seed moisture content (%), electrical conductivity of seed leachate and seed microflora.

3. Variety Uma registered significant low seed quality parameters.

4. Vigorous seedlings were observed in Jyothi while, variety Sreyas exhibited high significant low moisture content (%) and electrical conductivity of seed leachate.

**B. Seed quality and longevity of medium duration rice seeds as influenced by storage condition**

1. Irrespective of the varieties and storage period, storage condition exerted significant influence on germination (%), seed vigour indices, seed moisture content, electrical conductivity of seed leachate, field establishment (%), and seed microflora (%).

2. Quality of seeds stored under ventilated conditions *viz.,* R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (S5) was significantly superior to those stored in non-ventilated conditions [Asbestos + without ventilation (SC2), R.C.C. + without ventilation (SC4)].

**B. Seed quality and longevity of short duration rice seeds as influenced by storage period**

1. Irrespective of the varieties and storage conditions, the period of storage caused significant variation in germination (%), seed vigour indices, seed moisture content, electrical conductivity of seed leachate, field establishment (%), and seed microflora (%).

2. Germination, vigour indices I and II and field establishment of seeds decreased progressively and significantly over the storage period, while a significant increase in seed moisture content, electrical conductivity of seed leachate, and seed infection (%) was evident. towards the end of storage period.
3. Seed longevity was found to equal in all the of the medium duration varieties (8 months each).

**C. Seed quality and longevity of medium duration rice seeds as influenced by interaction between varieties, storage condition and storage period**

1. Results indicated existence of wide variability in the impact of interaction between varieties, storage condition and storage period on germination (%), seed moisture content, electrical conductivity of seed leachate, field establishment (%), and seed microflora (%). However, the impact of interaction between varieties, storage condition and storage period did not cause any variation in seed vigour indices (VI-I and VI-II).

2. The interaction between varieties and storage period on germination and other seed indices, indicated that germination, vigour indices and field

establishment increased significantly over the storage period. Performance of variety Aiswarya was superior over other varieties, while that of Uma was low. Although, germination and field establishment of variety Jyothi was poor, it produced the most vigorous (VI-I and VI-II) seedlings. The longevity all the medium duration varieties was found to be 8 months.

3. Interaction between varieties and storage condition on seed quality indicated that storing seeds under ventilated conditions [R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (S5)] was advantageous over storing them under non-ventilated conditions. Seed longevity of all varieties under ventilated condition was higher (8 MAS), while it was for 7 MAS in non-ventilated conditions.

4. As observed in the interaction between varieties and storage condition on seed quality, the interaction between storage condition and the period of storage also indicated that storing seeds under ventilated conditions was advantageous over storing them under non-ventilated conditions. Seed longevity under ventilated condition was higher (8 MAS), while it was for 7 MAS in non-ventilated conditions.

5. The interaction between varieties, storage condition and the period of storage, indicated that storing seeds under ventilated condition would be most advantageous. The interaction however, revealed that longevity of medium duration varieties was influenced strongly by the storage condition. The longevity of seeds of the varieties was 8 MAS, when stored under ventilated environments conditions *viz.,* R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (S5) as against 7 MAS under non-ventilated storage [Asbestos + without ventilation (SC2), R.C.C. + without ventilation (SC4)].

6. As the quality parameters and seed longevity varied only marginally among the various ventilated storage conditions, it can be concluded that storing seeds in structures with natural ventilation under the prevailing hot and high

humid condition, would be more economic and less cumbersome.

**2. Storage environment and seed quality**

1. Higher temperature and relative humidity was recorded under non-ventilated storage conditions resulting in higher seed deterioration under these storage structures compared to those in ventilated storages.
2. Marginal variations in storage temperature and RH was evident between the ventilated stores, with the least estimate in Asbestos + forced ventilation (SC5). However, there was no associated improvement in seed longevity in SC5 over others (SC1: Asbestos + with ventilation and SC3: R.C.C. + with ventilation). This again reiterated the fact that storing seeds in godowns with provision for forced ventilation did not confer any advantage over that with natural ventilation. Incurring additional expenditure on installation, maintenance, operation of forced ventilation system does not give any additional benefit with respect to prolonging storability of stored seeds.
3. High temperature and relative humidity within the storage environment strongly influenced germination and seed longevity. The decline in germination was found to be more pronounced when the seed was exposed to high temperatures in the early period of storage *i.e.,* between 1 and 13$^{th}$ week, while high RH during the 2$^{nd}$ half of the storage period (*i.e.,* between 24$^{th}$ and 36$^{th}$ week), proved to be detrimental to seed longevity

# References

## REFERENCE

Abba, E. J. and Lovato, A. 1999. Effect of seed storage temperature and relative humidity on maize (*Zea mays* L.) seed viability and vigour. *Seed Sci. Technol*. 27(1): 101-114.

Abdul-Baki, A. A. and Anderson, J. D. 1970. Viability and leaching of sugars from germinating barley. *Crop Sci*. 10(1): 31-34.

Abdul-Baki, A. A. and Anderson, J. D. 1973. Vigor determination in soybean seed by multiple criteria. *Crop Sci*. 13(6): 630-633.

Abdullah, N., Nawai, A., and Othman, I. 2000. Fungal spoilage of starch based foods in relation to its water activity (aw). *J. Stored Products Res.* 36: 47-54.

Adetumbi, A., Odiyi, A. C., Olakojo, S., and Adebisi, M. 2009. Effect of storage materials and environments on drying and germination quality of maize (*Zea mays* L.) seed. *Elec. J. Env. Agric. Food Chem*. 8: 1140-1149.

Adhikarinayake, T. B., Palipane, K., and Muller, J. 2006. Quality change and mass loss of paddy during airtight storage in a ferro-cement bin in Sri Lanka. *J. Stored Products Res*. 42. 377-390.

Adriana, L., Tassi, W., Santos, J. F. D., and Panizzi, R. D. C. 2012. Seed-borne pathogens and electrical conductivity of soybean seeds. *Sci. Agric*. 69: 19-25.

Afzal, I., Bakhtavar, M. A., Ishfaq, M., Sagheer, M., and Baributsa, D. 2017. Maintaining dryness during storage contributes to higher maize seed quality. *J. Stored Prod. Res*. 72: 49–53.

Agha, S. K., Malik, Z. H., Hatam, M., and Jamro, G. H. 2004. Emergence of healthy seedlings of soybeans as influenced by seed storage containers. *Pakist. J. Biol. Sci*. 7(1): 42-44.

Ahmed, M., Hossain, M., Hassan, K., and Dash, C. K. 2013. Efficacy of different plant extract on reducing seed borne infection and increasing germination of collected rice seed sample. *Uni. J. Plant Sci*. 1(3): 66-73

Akter, N., Haque, M. M., Islam, M. R., and Alam, K. M. 2014. Seed quality of stored soybean (*Glycine max* L.) as influenced by storage containers and storage periods. *The Agric*. 12(1): 85-95.

Alam, M., Islam, M. O., and Hasanuzzaman, M. 2009. Performance of alternate storage devices on seed quality of Boro rice. *Middle-East J. Sci. Res.* 4(2): 78-83.

Alencar, E. R., Erturk, N., and Health, L. S. 2002. Role of superoxide dismutase's in controlling oxidative stress in plants. *J. Exp. Bot.* 53 (372): 1331-1341.

Alencar, E. R., Faroni, L. R. D., Filho, A. F., Ferreira, L. G., and Meneghitti, M. R. 2006. Influence of different storage conditions on soybean grain quality. *J. Exp. Bot.* 7(1): 42-44.

Alhamdan, A. M., Alsadon, A. A., Khalil, S. O., Wahb-Allah, M. A., Nagar, M. E., and Ibrahim, A. A. 2011. Influence of storage conditions on seed quality and longevity of four vegetable crops. *Am. -Eurasian J. Agric. Environ. Sci.* 11(3): 353-359.

Ali, M. R., Rahman, M. M., and Ahammad, K. U. 2014. Effect of thickness of polythene bag on seed quality of soybean. *Bangladesh J. Agric. Res.* 39(4): 709-716.

Alscher, R. G., Erturk, N., and Health, L. S. 2002. Role of superoxide dismutase's (sods) in controlling oxidative stress in plants. *J. Exp. Bot.* 53 (372): 1331-1341.

Al-yahya, S. A. 2001. Effect of storage conditions on germination in wheat. *J. Agron. Crop Sci*. 186(4): 273-279.

Andric, L., Teklic, T., Vrataric, M., Dudaric, A., and Duvnjak, V. 2007. Soybean seed vigour and field emergence under influence of cultivar, seed age and planting date. *Cer. Res. Comm*. 35: 177-180.

Antony, L. 2016. Effect of seed protectants against pulse beetle on viability, vigour and health of cowpea seeds. MSc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 89p.

AOSA [Association of Official Seed Analysts]. 1983. *Seed Vigour Testing Handbook*. East Laring, 235-238.

Assefa, F. and Srinivasan, K. 2016. Effect of relative humidity and temperature on shelf life of sorghum, lentil and niger seeds. *Int. J. Appl. Agric*. 2(6): 83-91.

Bailly, C. 2004. Active oxygen species and antioxidants in seed biology. *Seed Sci. Res*. 14: 93-107.

Bahuguna, V. K., Rawat, M. M. S., and Naithani, K. C. 1989. Viability of *Syzygium cumini* and *Pongamia pinnata* seeds in storage. *J. Trop. For*. 3: 3l8-323.

Bakhtavar, M. A., Afzal, I., and Basra, S. M. A. 2019. Moisture adsorption isotherms and quality of seeds stored in conventional packaging materials and hermetic super bag. *Plos One* 14(2): 207-569.

Balesevic-Tubic, M., Tatic, V., Dorđevic, Z., Nikolic, J., and Subic Dukic, V. 2010. Effects of accelerated ageing on germination and biochemistry of eight rice cultivars. *J. Plant Nutr.* 40(2): 156-164.

Balesevic-Tubic, M., Tatic, V., Dorđevic, Z., Nikolic, J., and Subic Dukic, V. 2011. Changes in soybean seeds as affected by accelerated and natural aging. *Rom. Biotechnol. Lett.* 6(6): 6740–6747.

Barret, M., Guimbaud, J. F., Darrasse, A., and Jacques, M. A. 2015. The effect of low temperature pre-sowing treatment on the germination performance and membrane integrity of artificially aged tomato seeds. *J. Exp. Bot*. 35: 1609-1617.

Barret, M., Guimbaud, J. F., Darrasse, A., and Jacques, M. A. 2016. Plant microbiota affects seed transmission of phytopathogenic microorganisms. *Mol. Plant Pathol.* 17: 791–795.

Barton, L. V. 1941. Seed dormancy: General survey of dormancy types in seeds, and dormancy imposed by external agents. *J. Exp. Bot*. 35: 1609-1617.

Bass, L. N., Gunn, C. R., and Hesterman, O. B. 1963. Seed physiology, seedling performance, and seed sprouting. *J. Agric. Eng. Today*, 5(3): 9-18.

Begum, M. A. J., Venudevan, B., and Jayanthi, M. 2013. Storage fungi in groundnut and the associate seed quality deterioration- a review. *J. Plant Pathol*. 12(3): 127-134.

Bellaloui, N., Krishna, N. R., Bruns, H. A., Gillen, A. M., Mengistu, A., Zobiole, L. H. S., Fisher, D. K., Abbas, H. K., Zablotowicz, R. M., and Kremer, R. J. 2011. Soybean seed composition and quality: interactions of environment, genotype, and management practices. In: Maxwell, J. E. (ed) Soybeans: Cultivation, Uses and Nutrition. Nova Science Publishers, pp. 1–42.

Bewley, J. D. and Black, M. 1982. Physiology and biochemistry or seeds in relation to germination, viability, dormancy and environmental control. *Seed Sci*. *Res. 35*: 24-26.

Bewley, J. D. and Black, M. 1985. *Seeds: Physiology of Development and Germination* ($1^{st}$ Ed.). Plenum Press, New York, pp. 54-63.

Bewley, J. D. and Black, M. 1994. *Seed Physiology of Development and Germination* ($2^{nd}$ Ed.). Plenum Press, New York. pp. 88-95

Bhandari, G., Ghimire, T. B., Kaduwal, S., Shrestha, J., and Acharya, R. 2017. Effects of storage structures and moisture contents on seed quality attributes of quality protein maize. *J. Maize Res. Dev*. 3(1): 77-85.

Bijanzadeh, E., Naderi, R., Nosrati, K., and Egan, T. P. 2016. Effects of accelerated ageing on germination and biochemistry of eight rice cultivars. *J. Plant Nutr.* 40(2): 156-164.

Birewar, B. R. 1981. Appropriate technology for food grain storage under Indian conditions. *J. Agric. Eng. Today*, 5(3): 9-18.

Bortey, H. M., Sadia, A. O., and Asibuo, J. W. 2016. Influence of seed storage techniques on germinability and storability of cowpea (*Vigna unguiculata* (L) Walp), *J. Agril. Sci*. 8 (10): 25-33.

Carpenter, W. J. and Boucher, J. F. 1992. Temperature requirement for the storage and germination of *Delphinium cultorum* seed. *Hortic. Sci*. 27: 989-992.

Carvalho, C. F., Uarrota, V. G., Souza, C. A., and Coelho, C. M. M. 2017. Physiological quality of soybean seed cultivars (*Glycine max* (L.) Merr.) with different maturity groups. *Res. J. of Seed Sci.* 10: 59-72.

Chirchir, G. J., Mwangi, M., Nyamongo, D. O., and Gweyi-Onyango, J. P. 2017. Effects of genotype and agro-ecological conditions on storability of soybean seed (*Glycine max* (L.) Merr.]. *Trop. Plant Res*. 4(1): 126–133.

Cho, Y. and Scott, R. A. 2000. Combining ability of seed vigor and seed yield in soybean. *Euphytica.* 112: 145-150.

Christensen, C. M. 1967. Germinability of seeds free of and invaded by storage fungi. *Assoc. Off. Seed Anal. Proc*. 57: 141-143.

Christensen, C. M. and Kaufman, H. H. 1969. *Grain Storage: The Role of Fungi in Quality Loss*. University of Minnesota Press, Minneapolis, pp. 32-51.

Christensen, C. M. 1972. Microflora and seed deterioration. In: Roberts, E. H. (5th Ed.). Viability of Seeds. Syracuse University Press, Syracuse, New York, pp. 59-149.

Christensen, C.M. 1973. Loss of viability in storage: Microflora. *Seed Sci. Technol*. 1: 547-562.

Coolbear, P., Francis, A., and Grierson, D. 1984. The effect of low temperature pre-sowing treatment on the germination performance and membrane integrity of artificially aged tomato seeds. *J. Exp. Bot*. 35: 1609-1617.

Coolbear, P. 1995. Mechanisms of seed deterioration. In: Basra, A.S. (2nd Ed.), Seed quality, Basic mechanisms and agricultural implications. Food Product press, London, pp. 223–277.

Copeland, L. O. and McDonald, M. B. 1999. *Principles of Seed Science and Technology*. Kluwer Academic Publishers Group, Dordrecht, pp. 64-108.

Copeland, L. O. and McDonald, M. B. 2001. *Principles of Seed Science and Technology*, (4th Ed.). Kluwer Academic Publishers, Massachusetts, pp. 46-97.

Copeland, L. O. and McDonald, M. B. 2005. *Principles of Seed Science and Technology*, (4th Ed.). Springer Publication, New Delhi: 467 P.

Cromarty, A. S., Ellis, R. H., and Roberts, E. H. 1985. The design of seed storage facilities for genetic conservation Rome, IBPGR, pp. 124-218.

Dejene, M., Jonathan, Y., and Sigvald, R. 2004. Effects of storage methods, storage time and different agro-ecological zones on chemical components of stored sorghum grain in Hararghe. *Ethiop. J. Stored Prod. Res*. 42 (4): 445-456.

Delouche, J. C., Matthes, R. K., Dougherty, G. M., and Boyd, A. H. 1973. Storage of seed in subtropical and tropical regions. *Seed Sci. Technol*. 1: 671-700.

Devereau, A. D., Myhara, R. and Anderson, C. 2000. Seed and seedling vigour in relation to crop growth and yield: *Seed Sci. and Technol*. 1: 43-65.

Devereau, A. D., Myhara, R. and Anderson, C. 2002. Physical factors in post-harvest quality, Crop Post-Harvest: *Seed Sci. and Technol*. 1: 62-92.

Dillahunty, A. L., Siebenmorgen, T, J., Buescher, R. W., Smith, D. E., and Mauromoustakos, A. 2000. Effect of moisture content and temperature on the respiration rate of rice. *Cereal Chem.* 77(5): 541-543.

Doijode, S. D. 1993. Changes in viability, vigour and certain biochemical aspects during ambient storage of bell pepper seeds. *Haryana J. Hortic. Sci.* 22: 48-51.

Doijode, S. D. 1988. Effect of storage environment on brinjal (*Solanum melongena*) seed viability. *Progress. Hortic.* 20: 292-293.

Duarte, C. R, Neto, J. L. V., Lisboa, M. H., Santana, R. C., Barrozo, M. A. S., and Murata, V. V. 2004. Experimental study and simulation of mass distribution of the covering layer of soybean seeds coated in a spouted bed. *Braz. J. Chem. Eng*. 21: 59–67.

Egli, D. B. and TeKrony, D. M. 1996. Seedbed conditions and prediction of field emergence of soybean seed. *J. Prod. Agric*. 9: 365-370.

El-Abady, M. I., El-Emam, A. A. M., Seadh, S. E., and Yousof, F. I. 2012. Soybean seed quality as affected by cultivars, threshing methods and storage periods. *Res. J. Seed Sci.* 5: 115–125.

Ellis, R. H. and Roberts, E. H. 1981. . Effect of physical seed treatment on yield and quality of crops. *J. Exp. Bot.* 41: 1245-1236.

Ellis, R. H., Hong, T. D., and Roberts, E. H. 1990. An intermediated category of seed storage behaviour in coffee. *J. Exp. Bot.* 41: 1167-1174.

Ellis, R. H. 1992. Seed and seedling vigour in relation to crop growth and yield. *Plant Growth Reg*. 11: 249-255.

Eliud, R., Muasya, R., and Gohole, L. 2010. Longevity of bean (*Phaseolus vulgaris*) seeds stored at locations varying in temperature and relative humidity. *J. Pure Appl. Sci. Technol.* 5: 60-70.

Fakir, G. A. 1983. Teaching, research and training activities on seed pathology in Bangladesh. *Seed Sci. Technol*. 11: 1345-1352.

FAO [Food and Agriculture Organization] 1992. Report of the expert consultation on gene bank standard. Rome, International board for Plant Genetic Resources.

FAO [Food and Agriculture Organization] 1994. Report of the expert consultation on gene bank standard. Rome, Italy, International board for Plant Genetic Resources.

FAO [Food and Agriculture Organization] 2017. FAOSTAT: Crop production data [online]. Available: http://www.fao.org/faostat/en/#data/QC.

Floris. 1970. An evaluation on the viability on the post-harvested stored wheat grains. *Int. J. Pharm. Biol. Sci*. 1(4): 192-198.

Fonseka, H. H. and Fonseka, R. M. 2009. Studies on deterioration and germination of bitter gourd seed (*Momordica charantia* L.) during storage. *Acta Hortic*. 898: 31-38.

Fontana, E. 2007. Effects of storage temperature and relative humidity on viability and vigor of treated soybean seeds. *Crop Sci*. 53(3): 1086–1095.

Fukai, S., M., Albert, A., Bhaskaran, M., and Khunthasuvon, S. 1999. Genotypic variation in rice grown in low fertile soils and drought-prone, rainfed lowland environments. *Field Crops Res*. 64: 121–130.

Fukai, S., Inthapanya, P., Blamey, F. P. C., and Khunthasuvon, S. 2003. Effect of moisture content and temperature on the respiration rate of rice. *Field Crops Res*. 64: 48–73.

Genchev, D. 1997. Seed coat as a factor for breaking of common bean seed (*Phaseolus vulgaris*). In: H.F Schwartz (3rd Ed.), Bean improvement Cooperative, pp. 46–47.

Gopalakrishnan, C., Kamalakannan, A., and Valluvaparidasan, V. 2010. Survey of seed-borne fungi associated with rice seeds in Tamil Nadu, India. *Libyan Agric. Res. center J. Inter*. 1: 307-309.

Gomez, K. A and Gomez, A. A. 1976. Statistical procedure for agricultural research, (2nd Ed.). pp. 451-536.

Govindaraj, M., Poomaruthai, M., Albert, A., and Bhaskaran, M. 2017. Effect of physical seed treatment on yield and quality of crops: A review. *Agric. Rev*. 10: 73-104.

Guenha, R., Salvador, B. V., Rickman, J., Goulao, L. F., Muocha, I. M., and Carvalho, M. O., 2014. Hermetic storage with plastic sealing to reduce insect infestation and secure paddy seed quality: A powerful strategy for rice farmers in Mozambique. *J. Stored Products Res*. 59: 275–281.

Hampton, J. G. and Tekrony, D. M. 1995. *Handbook of Vigour Test Methods* (3rd Ed.). International Seed Testing Association, Zurich.

Hamman, B., Egli, D. B., and Koning, G. 2002. Seed vigor, soil borne pathogens, preemergent growth, and soybean seedling emergence. *Crop Sci*. 42: 451-457.

Harrington, J. F. 1972. Seed storage longevity. In: Kerzlorski, T. T. (3rd Ed.). *Seed Biol.* 3: 145-240.

Harrington, J. F. 1973. Problems of seed storage. In: Seed Ecology (2nd Ed.): W. Heydecker Butterworths, London, UK, pp. 251-264.

Hare, M. D., Tatsapong, P., and Phengphet, S. 2008. Effect of storage duration, storage room and bag type on seed germination of Brachiaria Hybrid Cv. Mulato. *Tropi. Grasslands* 42: 224–228.

Heatherly, L. G. and Elmore, R. W. 2004. Managing inputs for peak production. In. H. R. Boerma, & J. E. Specht (Eds.), Soybeans: Improvement, Production and Uses (3rd Ed.). pp. 451-536.

Hedimbi, M., Natalia K., and Ananias M. K. 2012. Effects of storage conditions on viability, germination and sugar content of Pearl Millet (*Pennisetum glaucum*) grains. J. of Rese in Agriculture 1 (1): 088-092

Hendry, G. A., Thompson, F. K., Moss, C. J., and Edwards, P. C. 1994. Seed persistence: a correlation between seed longevity in the soil and ortho-dihydroxyphenol concentration. *Funct. Ecol.* 8: 658-664.

Hong, T. D., Linington, S., and Ellis, R. H. 1996. *Seed Storage Behaviour: A Compendium*. Handbook of gene banks No. 4, International Plant Genetic Resource Institute, Rome, pp. 74-128.

Hussain, S., Zheng, M., Khan, F., Khaliq, A., Fahad, S., and Peng, S. 2015. Benefits of rice seed priming are offset permanently by prolonged storage and the storage conditions. *Sci. Rep*. 5: 81-101.

IBPGR [International Bureau of Plant Genetic Resources] 1989. *Annual Report,* **(**1988) International Bureau of Plant Genetic Resources, Rome, Italy.

IBPGR [International Bureau of Plant Genetic Resources] 1992. *Annual Report,* **(**1991) International Bureau of Plant Genetic Resources, Rome, Italy.

ISTA [International Seed Testing Association] 1965. International rules for seed testing. *Seed Sci. Technol*. 13: 300-513.

ISTA [International Seed Testing Association] 1976. International rules for seed testing. *Seed Sci. Technol*. 13: 456-508.

ISTA [International Seed Testing Association] 1985. International rules for seed testing. *Seed Sci. Technol*. 13: 299-355.

ISTA [International Seed Testing Association] 1993. International rules for seed testing. *Seed Sci. Technol*. 21: 288.

ISTA [International Seed Testing Association] 1995. International rules for seed testing. *Seed Sci. Technol*. 11: 354 - 513.

ISTA [International Seed Testing Association] 1999. International rules for seed testing. *Seed Sci. Technol*. 27: 1-340.

ISTA [International Seed Testing Association] 2001. Rules Amendments 2001. *Seed Sci. Technol. Suppl*. 29:1-131.

ISTA [International Seed Testing Association] 2006. International rules for seed testing. *Seed Sci. Technol*. 32: 43-236.

Jackson, J. F. 2007. Seed moisture and the equilibrium seed moisture content curve. *Seed Sci. Technol.* 29(1): 7–18.

Javaid, M. S., Wahid, A., Idrees, M., Gill, M. A., and Saleem, A. 2002. Seed microflora studies in rice. *Pakistan J. Phyto pathol*. 14: 132-134.

Jian, F., Moore, F., Roos, E., and Walters, C. 1998. Three dimensional models to represent seed moisture content as a function of relative humidity and temperature. *Hortic. Sci.* 33: 1207-1209.

Jyothi. and Malik, C. P. 2013. Seed deterioration: a review. *Int. J. Life Sci. Biotechnol. Pharma. Res.* 2(3): 374-385.

Justice, O. L. and Bass, L. N. 1978. *Principle and Practices of Seed Storage.* Agricultural handbook no. 506. U.S. Government Printing Office, Washington, DC.

Karim, M. R., Rahim, M. A., and Fakir, G. A. 2005. Effect of storage containers on seed quality of onion. *Bangladesh J. Seed Sci. Technol*. 9 (1 and 2): 27-31.

Karami, S., Soroush, S., Zarea, L., and Hashemi, F. S. H. 2012. Effect of seed born fungi, *Fusarium* spp and *Bipolaris oryzae* on rice seed germination. *Plant Path.* 17: 42-56.

Kapoor, N., Arya, A., Siddiqui, M. A., Hirdesh, K., and Amir, A. 2011. Physiological and biochemical changes during seed deterioration in aged seeds of rice (*Oryza sativa* L.). *Am. J. Plant Physiol*. 6: 28-35.

Khidrapure, G., Doddagoudar, S. R., Vasudevan, S. N., Maruti, K. and Korishettar, P. 2016. Assesment of storage potential of Proso Millet (*Panicum miliaceum* L.) genotypes through accelerated aging technique. *The Ecoscan*. 6: 435-439.

Khaldun, B. M. and Haque, M. E. 2009. Seed quality deterioration due to temporal variation of biotic and a biotic factors in cucumber. *Bangladesh J. Agric. Res.* 34(3): 457-463.

Khan, I. and Zeb, A. 2007. Nutritional composition of Pakistani wheat varieties. *J. Zhejiang Univ. Sci.* 8(8): 555–559.

Kishore, A., Kumar, A., and Chaurasia, A. L. 2014. Effect of packaging material on seed viability and vigour of stored field pea genotypes. *Annals of Agric Bio Res.* 27(2): 181-186.

Kumar, S. 2009. Germination and seed storage behaviour in *Pongamia pinnata* L. *Curr. Sci*. 93: 910-911.

Kumar, V. A., Uchida, T. and Mizuki, T. 2016. Effect of relative humidity on germination and vigour of soybean seed. *Inter. J. Eng. Technol*. 3(1): 17-24.

Marcos-Filho, J. 1998. New approaches to seed vigor testing. *Sci. Agric*. 55: 27-33.

Mathew S. 2010. An evaluation on the viability on the post-harvested stored wheat grains. *Int. J. Pharm. Biol. Sci*. 1(4): 192-198.

Mathews, S. and Bradnock, W. T. 1965. Relationship between seed exudation and field emergence in Pea and French bean. *Hortic. Res.* 8: 89-93.

Mathews, S. and Bradnock, W. T. 1967. The longevity of crop seeds stored under ambient conditions. *Seed Sci. Res*. 20: 1-12.

Mathews, S. and Whitbread, R. 1968. Factors affecting pre-emergency mortality in peas: An association between seed excavates and the incidence of pre-emergency mortality in wrinkles peas. *Plant Path.* 17: 11-17.

Mathews, S. and Powell, A. 2006. Electrical conductivity vigour test: physiological basis and use. *Seed Sci. Technol.* 3: 33-35.

Matthews, S. and Collins, M. T. 1973. Laboratory measurement of field emergence potential in barley. *Seed Sci. Technol.* 3: 863-70.

Mbofung, G. C., Goggi, A. S., Leandro, L. F., and Mullen, R. E. 2013. Effects of storage temperature and relative humidity on viability and vigor of treated soybean seeds. *Crop Sci*. 53(3): 1086–1095.

McGee, D. C. 1995. Epidemiological approach to disease management through seed technology. *Annu. Rev. Phytopathol*. 33(1): 445-466.

McCormack, J. H. 2004. Seed Processing and Storage. Principles and practices of seed harvesting, processing and storage: An organic seed production manual for seed growers in the Mid-Atlantic and Southern U.S. 280 pp.

McDonald, M. B. 1999. Seed deterioration: physiology, repair and assessment. *Seed Sci. Technol*. 27(1): 177–237.

McDonald, M. B. 2007. Seed moisture and the equilibrium seed moisture content curve. *Seed Sci. Technol*. 29(1): 7–18.

McPartland, J. M., Clarke R. C., and Watson D. P. 2000. *Hemp Diseases Pests: Management and Biological Control*. Cromwell Press. UK. 251 pp.

Meints, P. and Smith, C. A. 2003. Kenaf seed storage duration on germination, emergence, and yield. *Indus. Crops.Products*. 17: 9-14.

Mettananda, K. A., Weerasena S. L, Dan, Y., and Liyanage. 2001. Effect of storage environment, packing material and seed moisture content on storability of maize (*Zea mays* L.) seeds. *An. Sri Lanka Dep. Agric.* 3: 131-142.

Miah, M. A. B., Rahman, M. M., and Haque, M. M. 2006. Effect of relative humidity on germination and vigour of soybean seed. *Inter. J. Eng. Technol*. 3(1): 17-24.

Mohammadi, G. R. 2011. The effect of seed priming on plant traits of late-spring seeded soybean (*Glycine max* L.). *Am.-Eurasian J. Agric. Environ. Sci.* 5(3): 322-326.

Monira, U. S., Amin, M. H. A., Aktar, M. M., and Mamun, M. A. A. 2012. Effect of containers on seed quality of storage soybean seed. *Bangladesh Res. Publ. J.* 7: 421-427.

Monajjerm, K. S., Das, T., and Vaish, C. P. 2014. Effect of storage period in seed and seedling vigour of *Entada pursaetha* D. C., An endangered gigantic medicinal liana. *Seed Sci. Technol.* 36(2): 475-480.

Moreno-Martinez, E., Rivera, A., and Badillo, M. V .1998. Effect of fungi and fungicides on the preservation of wheat seed stored with high and low moisture content. *J. Stored Products Res*. 34: 231–236.

Mortal, K. J. Katiyar, P. K., Das, T., and Vaish, C. P. 2017. Effects of storage temperature and relative humidity on viability and vigor of treated soybean seeds. *Crop Sci*. 53(3): 1086–1095.

Murdock, L. L. White, N. D. G., and Kavitha-Abirami, C. V. 2013. Storage studies on pinto beans under different moisture contents and temperature regimes. *J. Stored Products Res*. 52: 78–85.

Nagel, M. and Borner, A. 2010. The longevity of crop seeds stored under ambient conditions. *Seed Sci. Res*. 20: 1-12.

Nahar, K., Ali, M. H., Ruhul, A. K. M., and Hasanuzzaman, M. 2009. Moisture content and germination of bean (*Phaseolus vulgaris* L.) under different storage conditions. *Acad. J. Plant Sci*. 2(4): 237-241.

Nagendra, M. S., Bastian, D., Francies, R. M., and Rajendra, A. A. 2017. Effect of sowing time on fruit and seed yield in oriental pickling melon (*Cucumis melo var. conomon*). *Int. J. Chem. Stud*. 5(4): 1910-1912.

Naguib, N. A., Mohamed, E. A., and El-Aidy, N. A. 2011. Effect of storage period and packaging material on wheat (*Triticum aestivum* L.) seed viability and quality. *Egypt. J. Agric. Res*. 89(4): 1481-1497.

Navya, P. 2016. Halogenation for improvement of storage life of chilli (*Capsicum annuum* L.) seeds. MSc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 91p.

Neergaard, P. 1977. *Seed Pathology*. Vol II. John Wiley, New York. 650p.

Neergaard, P. 1979. *Seed Pathology*: Vol 1. The Macmillan Press Ltd. London, 746p.

Nishidha, C. T. 2018. Impact of foliar application of nutrients and growth promoters on seed yield and quality of okra. MSc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 124p.

Oyekale, K., Daniel, O. I. O., Ajala, M. O., and Sanni, L. O. 2012. Potential longevity of maize seeds under storage in humid tropical seed stores. *Nature Sci.* 10(8) 114 – 124.

Padma, V. and Reddy, M. B. 2000. The effect of seed moisture and packaging material on onion seed longevity. *Seed Res.* 28: 171-175.

Perry, B. A. 1977. Report on the vigour test committee 1975-76. *Seed Sci. Technol*. 12: 174-196.

Perry, B. A. 1984. Report on the vigour test committee 1980-83. *Seed Sci. Technol*. 12: 287-299.

Poonam, S., Tewari, N., Katiyar, P. K., Das, T., and Vaish, C. P. 2001. Storability of soybean (*Glycine max* Merr.) seeds in different containers under ambient conditions. *Prog. Agric*. 1(1): 9093.

Powell, A. A., Oliveira, M. A., and Matthews, S. 1988. Seed vigour in cultivars of dwarf French bean (*Phaseolus vulgaris*) in relation to the colour of the testa. *J. Agric. Sci.*109: 419-425.

Prabhakar, B. S. and Mukherjee, R. K. 1977. Effect of storage conditions on viability of rice seeds. *The Harvestor*, 19: 4-6.

Prasantha, B. D. R., Wafeel, R. F., Wimalasiri, K. M. S., and Pathirana, U. P. D. 2014: End-use quality characteristics of hermetically stored paddy. *J. Stored Products Res.* 59: 158-166

Priestley, D. A. 1986. *Seed Ageing: Implication for Seed Storage and Persistence in the Soil.* Cornell University Press, Ithaca, New York.

Priya, S. V. and Rao, J. V. S. 2008. Effect of storage period in seed and seedling vigour of *Entada pursaetha* D. C., An endangered gigantic medicinal liana. *Seed Sci. Technol.* 36(2): 475-480.

Rahman, A. H. M. M., Anisuzzaman, M., Ahmed, F., Islam, A. K. M. R., and Naderuzzaman, A. T. M. 2008. Study of nutritive value and medicinal uses of cultivated cucurbits. *J. Appl. Sci. Res.* 4: 555-558.

Rajjou, L. and Debeaujon, I. 2008. Seed longevity: survival and maintenance of high germination ability of dry seeds. *J. Agric. Sci.* 331: 796–805.

Rani, R., Chelladurai, V., Jayas, D. S., White, N. D. G., and Kavitha-Abirami, C. V. 2013. Storage studies on pinto beans under different moisture contents and temperature regimes. *J. Stored Products Res.* 52: 78–85.

Reddy, K. R. N., Reddy, C. S., and Muralidharan, K. 2004. Appropriate technology for maintaining grain quality in small-scale storage. *Amer. J. Pl. Physiol.* 2(3): 258–293.

Reddy, K. R. N., Reddy, C. S., and Muralidharan, K. 2007. Exploration of ochratoxin a contamination and its management in rice. *Amer. J. Pl. Physiol.* 2(3): 206–213.

Reshma, R. 2016. Seed quality enhancement in okra and oriental pickling melon with film coat. MSc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 102p.

Rehman, Z. U. 2006. Storage effects on nutritional quality of commonly consumed cereals, *Food Chem*. 95: 53–57.

Rickman, J. F. and Aquino, E. 2007 Appropriate technology for maintaining grain quality in small-scale storage. *J. Stored Products Res*. 27: 59–93.

Rindels, S. 1995. Seed Viability: survival and maintenance of high germination ability of dry seeds. *J. Agric. Sci.* 331: 796–805.

Roberts, E. H. 1973. Predicting the storage life of seeds. *Seed Sci. Technol.,* 1: 499-545.

Roberts, E. H. 1972. Loss of viability and crop yields, viability Seeds. *Springer.* Dordrecht, pp. 307-320.

Roberts, E. H. and Ellis, R. H. 1989. Water and seed survival. *Ann. Bot*. 63: 36-52.

Rockland, L. B. 1969. Water activity and storage stability. *Food Technol.* 23: 1241-1251.

Rokich, D. M., Katiyar, P. K., Das, T., and Vaish, C. P. 2000. Storability of soybean (*Glycine max* Merr.) seeds in different containers under ambient conditions. *Prog. Agric*. 1(1): 9093.

Roy, K. W., and Ratnayake, S. 1997. Frequency of occurrence of *Fusarium pallidoroseum*, effects on seeds and seedlings, and associations with other fungi in soybean seeds and pods. Can. *J. Plant Pathol*. 19:188-192.

Sawant, S. D. 1994. Seed longevity: survival and maintenance of high germination ability of dry seeds. *Agric. Eng. Today.* 2(1): 67-85.

Sawant, S. D. 2012. Modern grain storage for reducing storage losses. *Agric. Eng. Today.* 4(1): 12-20.

Sandhya, R. 2016. Seed treatment with botanicals to enhance seedling vigour in chilli (*Capsicum annuum L*.). MSc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 119p.

Sharma, R., Pandey, S., Verma, O., Srivastava, R., and Guru, S. 2007. Physiological seedling vigour parameters of wheat as influenced by different seed invigoration techniques. *Int. J. Chem. Stud*. 8(4): 1549-1552.

Shobha, R. 2016. Seed invigoration to overcome dormancy in ash gourd (*Benincasa hispida* (Thund.) Cong.). MSc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 106p.

Simic, B., Popoviae, R., Sudaric, A., Rozman, V., Kalinovic, I., and Cosic, J. 2007. Influence of storage condition on seed oil content of maize, soybean and sunflower. *Agric. Conspectus Sci.* 72(3): 211-213.

Sinclair, J. B. 1999. Bacillus seed decay. Compendium of soybean diseases. (4$^{th}$ Ed.). American Phytopathological Society Press. St. Paul, M. N. pp 8-9.

Siracusa, V. 2012. Food packaging permeability behaviour: a report. *Int. J. Polym. Sci*. 4: 12-20.

Sisman, C. 2005. Quality losses in temporary sunflower stores and influences of storage conditions on quality losses during storage. *J. Cent. Eur. Agric*. 6: 143-150.

Sisman, C. B. and Albut, S. 2010. Grain storage management. Proceedings of 3rd Annual International Symposium on Agriculture Research, Athens, Greece, pp: 1-71.

Smitha, R. M. 1975. Influence of storage conditions on change of hemp seed quality. *Agric. Sci. Proce*. 5:170 – 176.

Smruti, D., Monalisa, N., Patra, B. C., Ramakrishnan, B., and Krishnan P. 2010. Characterization of seeds of selected wild species of rice (*Oryza sativa*) stored under high temperature and humidity conditions. *Indian J. Biochem. Bio*. 147(3): 178-184.

Snedecor, G. and Cochran, E. G. 1967. *Statistical Methods*. Oxford and IBH Publishing Company, Bombay. 593p.

Solberg, S. O., Yndgaard, F., Andreasen, C., von Bothmer, R, Loskutov, I. G., and Asdal,

A. 2020. Long-term storage and longevity of orthodox seeds: a systematic review. *Front. Plant Sci.* 11:1007.

Stein, W. L., Slabauch, P. E., and Plumer, A. P. 1974. Harvesting, processing, and storage of fruits seeds. In: Seeds of woody plants in the United States, Agricultural Handbook. Forest Service, USDA, Washington D. C. pp. 98-125.

Strelec, I., Ruza, P., Ilonka, I., Vlatka, J., Zorica, J., and Zaneta U dan Mirjana, S. 2010. Influence of temperature and relative humidity on grain moisture, germination and vigor of three wheat cultivars during one year storage. Poljoprivreda 16 (2): 20-24.

Stormonth, D. A. and Doling, D. A. 1979. The significance of seed vigour in cereals. *Arable farming* 6(2): 42-46.

Sun, Q. J., Wang, A., and Sun, B. 2007. Advances on seed vigor physiology and genetic mechanisms. *Agric. Sci.* 6:1060-1066.

Suriyonga, S., Krittigamasa, N., Pinmaneeb, S., Punyalueb, A., and Vearasilpc, S. 2015. Influence of storage conditions on change of hemp seed quality. *Agric. Sci. Proce*. 5:170 – 176.

Tango, J. S., Nakamura, I. M., Leito, M. F. F., and Jardao, B. A. 1977. Effect of relative humidity on the storage stability of peanut seed. *Trop. Oil Seed Abs*. 2 (4): 73.

Tatipata, A. 2009. Effect of seed moisture content packaging and storage period on mitochondria inner membrane of soybean seed. *J. Agric. Technol*. 5(1): 51-54.

Tajbakhsh, M. 2000. Relationships between electrical conductivity of imbibed seeds leachate and subsequent seedling growth (viabiliy and vigour) in omid wheat. *Agr. Set. Tech.* 2: 67-72.

TeKrony, D. M. 2003. Accelerated aging test: principles and procedures. *Seed Technol.* 27(1): 135-146.

TeKrony, D. M. Mathad, R. C., and Macha, S. I. 2005. Electrical conductivity of soybean seeds after storage in several environments. *Seed Technol.* 29(1): 196-229.

TeKrony, D. M., and Egli, D. B. 1977. Relationship between laboratory indices of soybean seed vigor and field emergence. *Crop Sci*. 17: 573-577.

Timoteo, T. S. and Marcos-Filho, J. 2013. Seed performance of different corn genotypes during storage. *J. Seed Sci*. 35(2): 207-215

Thakur, A., Thakur, P. S., Dutt, V., and Thakur, C. L. 2011. Conservation of *Podophyllum hexandrum* through seeds. *Indian J. Plant Physiol.* l5(2): 110-116.

Thilakarathna, B. A., Palipane, K. B., and Muller, J. 2006. Quality change and mass loss of paddy during airtight storage in a Ferro-cement bin in Sri Lanka. *J. Stored Prod. Res.* 42 (3): 377-390.

Thobunluepop, Pitipong, Pawelzik, Elke, and Vearasilp, S. 2009. Possibility of sweet corn synthetic seed production. *Pak. J. Bio Sci*. 12: 108-392.

Trung, H., Rozman, V., Kalinovic, I., Liska, A., and Simic, B. 2001. Effect of relative humidity on the storage stability of peanut seed. *Trop. Oil Seed Abs*. 2 (4): 73.

Tung, K.,and Seranno, R. L. 2011. . Loss of viability and crop yields, viability Seeds. *Springer.* Dordrecht, pp. 307-320.

Vanangamudi, K., Karivaratharaju, T. V., and Ramakrishnan, V. 1986. Seed storage studies in field bean (*Lablab purpurens* L.). Sweet variety. *New sp. Assoc. Off. Seed Anal*. 60: 78-85.

Vasudevan, S. N., Shakuntala, N. M., Doddagoudar, S. R., Mathad, R. C., and Macha, S. I. 2012. Biochemical and molecular changes in aged peanut (*Arachis hypogaea* L.) seeds. *The Ecoscan: Special* 1: 347–352.

Vertucci, C. W. and Roos, E. E. 1990. Theoretical basis of protocols for seed storage. *Plant Physiol.* 94: 1019-1023.

Vieira, R. D., Paiva-aguero, J. A., Perecin, D., and Bittencourt, S. R. M. 1999. Correlation of electrical conductivity and other vigour tests with field emergence of soybean seedlings. *Seed Sci. Technol.* 27: 67-75.

Vieira, R. D., TeKrony, D. M., Egli, D. B., and Rucker, M. 2001. Conservation of *Podophyllum hexandrum* through seeds. *Indian J. Plant Physiol.* l5 (2): 110-116.

Vieira, R. D., TeKrony, D. M., Egli, D. B., and Rucker, M. 2004. Electrical conductivity of soybean seeds after storage in several environments. *Seed Sci. Technol.* 29(3): 599-608.

Volenik, M., Rozman, V., Kalinovic, I., Liska, A., and Simic, B. 2006. Influence of relative humidity and temperature on changes in grain moisture in stored wheat and sunflower, Proceedings of the 9th International Working Conference on Stored Product Protection, Campinas, Brazil. pp. 24-29.

Yaklich, R. W. and Kulik, M. M. 1979. Evaluation of vigour test in soybean seeds. *Field Crop Res*. 4: 123-132.

Walters, C., Wheeler, L., and Stanwood, P. C. 2004. Longevity of cryogenically stored seeds. *Cryobiolgy*. 48: 229–244.

Walters, C., Wheeler, L., and Stanwood, P. C. 2010. Advances on seed vigor physiology and genetic mechanisms. *Agric. Sci.* 6:1060-1066.

Wang, W. Q., Liu, S. J., Song, S. Q., and Moller, I. M. 2018. Proteomics of seed development, desiccation tolerance, germination and vigor. *Plant Physiol. Biochem.* 86: 1 - 15.

Wein, H. C. and Kueneman, E. A. 1981. Soybean seed deterioration in the tropics II: Varietal differences and techniques for screening. *Field Crop Res*. 4: 123-132.

Zorrilla, G., Knapp, A. D., and McGee, D. C. 1994. Severity of Phomopsis seed decay, seed quality evaluation, and field performance of soybean. *Crop Sci*. 43: 172-177.

# Appendices

# APPENDICES

## (i) Correlation between THI and reduction in germination (%) of medium duration varieties.

| | | ASWATHY | JYOTHI | SHREYAS | UMA | TH1 | TH2 | TH3 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | 1 | .849 | .905* | .977** | .909* | .896* | .842 |
| | Sig. (2-tailed) | | .069 | .035 | .004 | .032 | .040 | .074 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .849 | 1 | .988** | .898* | .975** | .827 | .816 |
| | Sig. (2-tailed) | .069 | | .002 | .038 | .005 | .084 | .092 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .905* | .988** | 1 | .946* | .971** | .838 | .809 |
| | Sig. (2-tailed) | .035 | .002 | | .015 | .006 | .076 | .097 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .977** | .898* | .946* | 1 | .941* | .916* | .870 |
| | Sig. (2-tailed) | .004 | .038 | .015 | | .017 | .029 | .055 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH4 | TH5 | TH6 | TH7 | TH8 | TH9 | TH10 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .684 | .496 | .544 | .900* | .816 | .728 | .774 |
| | Sig. (2-tailed) | .203 | .396 | .343 | .038 | .092 | .164 | .124 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .891* | .832 | .880* | .865 | .868 | .866 | .900* |
| | Sig. (2-tailed) | .042 | .081 | .049 | .058 | .056 | .058 | .037 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .857 | .771 | .846 | .859 | .835 | .809 | .854 |
| | Sig. (2-tailed) | .064 | .127 | .071 | .062 | .079 | .097 | .066 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .802 | .643 | .667 | .883* | .809 | .735 | .794 |
| | Sig. (2-tailed) | .103 | .242 | .218 | .047 | .097 | .157 | .109 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH11 | TH12 | TH13 | TH14 | TH15 | TH16 | TH17 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .938* | .786 | .899* | .808 | .494 | .746 | .909* |
| | Sig. (2-tailed) | .018 | .115 | .038 | .098 | .397 | .148 | .033 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .967** | .875 | .973** | .966** | .200 | .461 | .665 |
| | Sig. (2-tailed) | .007 | .052 | .005 | .008 | .748 | .434 | .220 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .978** | .904* | .967** | .930* | .306 | .553 | .740 |
| | Sig. (2-tailed) | .004 | .035 | .007 | .022 | .616 | .334 | .153 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .937* | .793 | .900* | .823 | .558 | .781 | .916* |
| | Sig. (2-tailed) | .019 | .109 | .037 | .087 | .328 | .119 | .029 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH18 | TH19 | TH20 | TH21 | TH22 | TH23 | TH24 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .663 | .798 | .874 | .978** | .635 | .140 | .693 |
| | Sig. (2-tailed) | .223 | .106 | .053 | .004 | .250 | .822 | .195 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .719 | .989** | .973** | .922* | .789 | .370 | .676 |
| | Sig. (2-tailed) | .171 | .001 | .005 | .026 | .112 | .540 | .210 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .667 | .956* | .955* | .947* | .826 | .399 | .759 |
| | Sig. (2-tailed) | .218 | .011 | .011 | .015 | .085 | .506 | .137 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .591 | .848 | .902* | .968** | .722 | .234 | .768 |
| | Sig. (2-tailed) | .294 | .070 | .036 | .007 | .169 | .704 | .130 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH25 | TH26 | TH27 | TH28 | TH29 | TH30 | TH31 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .474 | .230 | .339 | .453 | .501 | .439 | .302 |
| | Sig. (2-tailed) | .419 | .710 | .577 | .443 | .390 | .459 | .622 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .618 | .486 | .271 | .387 | .753 | .826 | .733 |
| | Sig. (2-tailed) | .266 | .406 | .660 | .519 | .142 | .085 | .159 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .669 | .509 | .346 | .479 | .759 | .730 | .669 |
| | Sig. (2-tailed) | .217 | .381 | .568 | .415 | .137 | .162 | .216 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .585 | .359 | .268 | .432 | .575 | .520 | .405 |
| | Sig. (2-tailed) | .300 | .553 | .663 | .468 | .311 | .369 | .499 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH32 | TH33 | TH34 | TH35 | TH36 | TH37 | TH38 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .024 | .479 | .841 | .849 | .510 | -.550 | .309 |
| | Sig. (2-tailed) | .970 | .414 | .074 | .069 | .380 | .337 | .613 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .407 | .507 | .852 | .770 | .756 | -.056 | .449 |
| | Sig. (2-tailed) | .496 | .383 | .067 | .128 | .139 | .929 | .448 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .310 | .437 | .830 | .763 | .744 | -.170 | .351 |
| | Sig. (2-tailed) | .611 | .462 | .082 | .134 | .149 | .785 | .562 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .007 | .402 | .794 | .821 | .681 | -.386 | .316 |
| | Sig. (2-tailed) | .991 | .502 | .109 | .088 | .205 | .521 | .605 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

**(ii) Correlation between THI and reduction in germination (%) of short duration varieties.**

| | | HARSHA | MT | MR | KANCHANA | TH1 | TH2 | TH3 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | 1 | .938* | .996** | .988** | .957* | .855 | .811 |
| | Sig. (2-tailed) | | .018 | .000 | .002 | .011 | .065 | .095 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .938* | 1 | .922* | .928* | .924* | .935* | .897* |
| | Sig. (2-tailed) | .018 | | .026 | .023 | .025 | .020 | .039 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .996** | .922* | 1 | .983** | .942* | .844 | .795 |
| | Sig. (2-tailed) | .000 | .026 | | .003 | .017 | .072 | .108 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .988** | .928* | .983** | 1 | .987** | .899* | .871 |
| | Sig. (2-tailed) N | .002 | .023 | .003 | | .002 | .038 | .055 |
| | | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH4 | TH5 | TH6 | TH7 | TH8 | TH9 | TH10 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .793 | .672 | .758 | .871 | .820 | .769 | .817 |
| | Sig. (2-tailed) | .109 | .214 | .137 | .055 | .089 | .128 | .091 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .845 | .687 | .658 | .866 | .793 | .719 | .785 |
| | Sig. (2-tailed) | .072 | .200 | .227 | .058 | .109 | .171 | .116 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .741 | .607 | .708 | .873 | .815 | .756 | .801 |
| | Sig. (2-tailed) | .152 | .278 | .181 | .053 | .093 | .139 | .103 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .827 | .704 | .745 | .931* | .898* | .858 | .895* |
| | Sig. (2-tailed) | .084 | .185 | .148 | .022 | .038 | .063 | .040 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH11 | TH12 | TH13 | TH14 | TH15 | TH16 | TH17 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .982$^{**}$ | .899$^{*}$ | .956$^{*}$ | .892$^{*}$ | .384 | .630 | .809 |
| | Sig. (2-tailed) | .003 | .038 | .011 | .042 | .523 | .255 | .097 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .887$^{*}$ | .711 | .850 | .782 | .640 | .839 | .939$^{*}$ |
| | Sig. (2-tailed) | .045 | .179 | .068 | .118 | .245 | .076 | .018 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .982$^{**}$ | .902$^{*}$ | .954$^{*}$ | .881$^{*}$ | .368 | .622 | .811 |
| | Sig. (2-tailed) | .003 | .036 | .012 | .049 | .542 | .263 | .096 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .994$^{**}$ | .857 | .984$^{**}$ | .942$^{*}$ | .317 | .596 | .798 |
| | Sig. (2-tailed) | .001 | .063 | .002 | .017 | .603 | .289 | .106 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH18 | TH19 | TH20 | TH21 | TH22 | TH23 | TH24 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .656 | .908$^{*}$ | .931$^{*}$ | .971$^{**}$ | .799 | .353 | .779 |
| | Sig. (2-tailed) | .229 | .033 | .022 | .006 | .105 | .560 | .120 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .527 | .823 | .883$^{*}$ | .935$^{*}$ | .685 | .189 | .749 |
| | Sig. (2-tailed) | .361 | .087 | .047 | .020 | .202 | .761 | .145 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .675 | .884$^{*}$ | .916$^{*}$ | .975$^{**}$ | .773 | .326 | .761 |
| | Sig. (2-tailed) | .211 | .047 | .029 | .005 | .126 | .592 | .135 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .754 | .944$^{*}$ | .973$^{**}$ | .989$^{**}$ | .721 | .243 | .677 |
| | Sig. (2-tailed) | .141 | .016 | .005 | .001 | .169 | .694 | .210 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH25 | TH26 | TH27 | TH28 | TH29 | TH30 | TH31 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .644 | .451 | .395 | .525 | .707 | .620 | .558 |
| | Sig. (2-tailed) | .241 | .446 | .510 | .364 | .182 | .265 | .328 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .566 | .341 | .140 | .335 | .514 | .510 | .366 |
| | Sig. (2-tailed) | .320 | .574 | .822 | .581 | .376 | .380 | .545 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .610 | .408 | .437 | .548 | .683 | .577 | .515 |
| | Sig. (2-tailed) | .274 | .495 | .462 | .339 | .204 | .308 | .375 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .539 | .350 | .295 | .405 | .644 | .692 | .553 |
| | Sig. (2-tailed) | .348 | .564 | .630 | .499 | .241 | .196 | .334 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TH32 | TH33 | TH34 | TH35 | TH36 | TH37 | TH38 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .215 | .424 | .832 | .783 | .671 | -.322 | .296 |
| | Sig. (2-tailed) | .729 | .477 | .080 | .117 | .215 | .597 | .629 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | -.091 | .372 | .743 | .816 | .741 | -.319 | .350 |
| | Sig. (2-tailed) | .884 | .538 | .151 | .092 | .152 | .601 | .563 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .214 | .442 | .845 | .788 | .603 | -.397 | .277 |
| | Sig. (2-tailed) | .730 | .456 | .071 | .113 | .282 | .509 | .652 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .263 | .554 | .902* | .857 | .650 | -.292 | .438 |
| | Sig. (2-tailed) | .669 | .332 | .036 | .063 | .235 | .634 | .461 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed

**(iii) Correlation between relative humidity and reduction in germination (%) of short duration varieties.**

| | | HARSHA | MT | MR | KANCHANA | RW1 | RW2 | RW3 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | 1 | .938* | .996** | .988** | .824 | .632 | .605 |
| | Sig. (2-tailed) | | .018 | .000 | .002 | .086 | .253 | .280 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .938* | 1 | .922* | .928* | .832 | .711 | .707 |
| | Sig. (2-tailed) | .018 | | .026 | .023 | .081 | .178 | .181 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .996** | .922* | 1 | .983** | .860 | .661 | .613 |
| | Sig. (2-tailed) | .000 | .026 | | .003 | .062 | .224 | .272 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .988** | .928* | .983** | 1 | .820 | .693 | .694 |
| | Sig. (2-tailed) N | .002 | .023 | .003 | | .089 | .195 | .194 |
| | | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | RW4 | RW5 | RW6 | RW7 | RW8 | RW9 | RW10 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .610 | .692 | .734 | .422 | .604 | .435 | .420 |
| | Sig. (2-tailed) | .275 | .196 | .158 | .479 | .281 | .465 | .481 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .656 | .747 | .743 | .593 | .728 | .557 | .533 |
| | Sig. (2-tailed) | .229 | .147 | .151 | .292 | .163 | .330 | .355 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .631 | .710 | .759 | .423 | .605 | .428 | .411 |
| | Sig. (2-tailed) | .253 | .179 | .136 | .478 | .280 | .472 | .491 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .701 | .769 | .804 | .520 | .691 | .552 | .543 |
| | Sig. (2-tailed) | .187 | .129 | .101 | .369 | .196 | .334 | .345 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | RW11 | RW12 | RW13 | RW14 | RW15 | RW16 | RW17 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation Sig. | .537 | .779 | .442 | .390 | .477 | .820 | .872 |
| | (2-tailed) | .350 | .120 | .457 | .516 | .417 | .089 | .054 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .574 | .627 | .533 | .493 | .273 | .752 | .743 |
| | Sig. (2-tailed) | .311 | .258 | .356 | .399 | .656 | .143 | .150 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .545 | .768 | .454 | .405 | .449 | .839 | .881* |
| | Sig. (2-tailed) | .342 | .129 | .443 | .499 | .448 | .076 | .048 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .654 | .847 | .556 | .505 | .549 | .888* | .928* |
| | Sig. (2-tailed) | .231 | .070 | .331 | .386 | .338 | .044 | .023 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | RW18 | RW19 | RW20 | RW21 | RW22 | RW23 | RW24 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation Sig. | .820 | .578 | .510 | .560 | .809 | .845 | .880* |
| | (2-tailed) | .089 | .307 | .380 | .326 | .097 | .072 | .049 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation Sig. | .785 | .334 | .324 | .312 | .749 | .923* | .954* |
| | (2-tailed) | .116 | .582 | .594 | .609 | .145 | .026 | .012 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .819 | .551 | .463 | .535 | .816 | .831 | .864 |
| | Sig. (2-tailed) | .090 | .335 | .433 | .353 | .092 | .081 | .059 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .898* | .578 | .504 | .526 | .888* | .895* | .917* |
| | Sig. (2-tailed) | .038 | .308 | .386 | .363 | .044 | .040 | .028 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | RW25 | RW26 | RW27 | RW28 | RW29 | RW30 | RW31 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .714 | .602 | .360 | .526 | .758 | .796 | .931* |
| | Sig. (2-tailed) | .175 | .283 | .552 | .362 | .137 | .107 | .021 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .767 | .644 | .395 | .615 | .762 | .777 | .954* |
| | Sig. (2-tailed) | .130 | .241 | .510 | .270 | .135 | .122 | .012 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .710 | .596 | .323 | .504 | .753 | .795 | .943* |
| | Sig. (2-tailed) | .179 | .288 | .596 | .387 | .141 | .108 | .016 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .805 | .714 | .490 | .642 | .848 | .879* | .921* |
| | Sig. (2-tailed) | .101 | .175 | .402 | .243 | .069 | .049 | .026 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | RW32 | RW33 | RW34 | RW35 | RW36 | RW37 | RW38 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .949* | .893* | .920* | .855 | .914* | .931* | .669 |
| | Sig. (2-tailed) | .014 | .041 | .027 | .065 | .030 | .021 | .217 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .943* | .953* | .967** | .841 | .889* | .954* | .673 |
| | Sig. (2-tailed) | .016 | .012 | .007 | .074 | .043 | .012 | .213 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .951* | .895* | .917* | .844 | .911* | .943* | .668 |
| | Sig. (2-tailed) | .013 | .040 | .029 | .072 | .031 | .016 | .218 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .900* | .917* | .942* | .924* | .842 | .921* | .774 |
| | Sig. (2-tailed) | .037 | .028 | .017 | .025 | .073 | .026 | .125 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

**(iv) Correlation between relative humidity and reduction in germination (%) of medium duration varieties.**

| | | ASWATHY | JYOTHI | SHREYAS | UMA | W1 | W2 | W3 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | 1 | .849 | .905* | .977** | .950* | .799 | .727 |
| | Sig. (2-tailed) | | .069 | .035 | .004 | .013 | .105 | .164 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .849 | 1 | .988** | .898* | .652 | .524 | .577 |
| | Sig. (2-tailed) | .069 | | .002 | .038 | .233 | .365 | .309 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .905* | .988** | 1 | .946* | .730 | .556 | .570 |
| | Sig. (2-tailed) | .035 | .002 | | .015 | .161 | .330 | .315 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .977** | .898* | .946* | 1 | .874 | .718 | .688 |
| | Sig. (2-tailed) | .004 | .038 | .015 | | .053 | .172 | .199 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | W4 | W5 | W6 | W7 | W8 | W9 | W10 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .737 | .811 | .846 | .565 | .718 | .528 | .500 |
| | Sig. (2-tailed) | .155 | .095 | .071 | .321 | .172 | .360 | .391 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .575 | .641 | .675 | .405 | .584 | .482 | .486 |
| | Sig. (2-tailed) | .311 | .244 | .211 | .499 | .301 | .411 | .407 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .568 | .647 | .684 | .392 | .576 | .436 | .431 |
| | Sig. (2-tailed) | .318 | .238 | .202 | .515 | .310 | .463 | .469 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .665 | .753 | .770 | .541 | .696 | .514 | .491 |
| | Sig. (2-tailed) | .221 | .142 | .128 | .346 | .191 | .375 | .401 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | W11 | W12 | W13 | W14 | W15 | W16 | W17 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .620 | .669 | .572 | .535 | .279 | .861 | .840 |
| | Sig. (2-tailed) | .264 | .217 | .314 | .353 | .650 | .061 | .075 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .578 | .902* | .448 | .388 | .699 | .811 | .904* |
| | Sig. (2-tailed) | .307 | .036 | .450 | .519 | .189 | .096 | .035 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .534 | .839 | .417 | .360 | .591 | .801 | .881* |
| | Sig. (2-tailed) | .354 | .076 | .485 | .551 | .294 | .104 | .048 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .572 | .678 | .515 | .472 | .322 | .801 | .805 |
| | Sig. (2-tailed) | .313 | .208 | .375 | .422 | .597 | .104 | .100 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | W18 | W19 | W20 | W21 | W22 | W23 | W24 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .823 | .341 | .245 | .320 | .819 | .878* | .900* |
| | Sig. (2-tailed) | .087 | .574 | .691 | .599 | .090 | .050 | .037 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .860 | .735 | .695 | .677 | .843 | .832 | .860 |
| | Sig. (2-tailed) | .061 | .158 | .193 | .210 | .073 | .081 | .061 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .829 | .675 | .627 | .643 | .813 | .835 | .871 |
| | Sig. (2-tailed) | .082 | .211 | .257 | .242 | .094 | .078 | .055 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .807 | .403 | .357 | .386 | .785 | .902* | .934* |
| | Sig. (2-tailed) | .099 | .501 | .555 | .522 | .116 | .037 | .020 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | W25 | W26 | W27 | W28 | W29 | W30 | W31 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .768 | .646 | .303 | .548 | .776 | .809 | .993** |
| | Sig. (2-tailed) | .130 | .239 | .621 | .339 | .123 | .097 | .001 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .739 | .669 | .557 | .628 | .808 | .837 | .806 |
| | Sig. (2-tailed) | .153 | .217 | .330 | .257 | .098 | .077 | .100 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .712 | .617 | .447 | .562 | .771 | .805 | .870 |
| | Sig. (2-tailed) | .177 | .268 | .451 | .324 | .127 | .100 | .055 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .756 | .632 | .355 | .573 | .767 | .793 | .975** |
| | Sig. (2-tailed) | .139 | .253 | .558 | .313 | .131 | .109 | .005 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | W32 | W33 | W34 | W35 | W36 | W37 | W38 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .957* | .957* | .960** | .840 | .886* | .993** | .703 |
| | Sig. (2-tailed) | .011 | .011 | .010 | .075 | .045 | .001 | .185 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .819 | .814 | .858 | .900* | .789 | .806 | .728 |
| | Sig. (2-tailed) | .090 | .093 | .063 | .037 | .113 | .100 | .163 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .897* | .851 | .888* | .872 | .872 | .870 | .681 |
| | Sig. (2-tailed) | .039 | .068 | .044 | .054 | .054 | .055 | .206 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .969** | .952* | .967** | .850 | .918* | .975** | .678 |
| | Sig. (2-tailed) | .006 | .012 | .007 | .068 | .028 | .005 | .208 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

**(v). Correlation between storage temperature and reduction in germination (%) of medium duration varieties.**

| | | ASWATHY | JYOTHI | SHREYAS | UMA | TW1 | TW2 | TW3 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | 1 | .849 | .905* | .977** | .824 | .863 | .840 |
| | Sig. (2-tailed) | | .069 | .035 | .004 | .087 | .059 | .075 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .849 | 1 | .988** | .898* | .983** | .879* | .874 |
| | Sig. (2-tailed) | .069 | | .002 | .038 | .003 | .050 | .053 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .905* | .988** | 1 | .946* | .957* | .880* | .866 |
| | Sig. (2-tailed) | .035 | .002 | | .015 | .011 | .049 | .057 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .977** | .898* | .946* | 1 | .883* | .922* | .899* |
| | Sig. (2-tailed) | .004 | .038 | .015 | | .047 | .026 | .038 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW4 | TW5 | TW6 | TW7 | TW8 | TW9 | TW10 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .569 | .310 | .329 | .723 | .676 | .694 | .788 |
| | Sig. (2-tailed) | .317 | .611 | .589 | .167 | .210 | .194 | .114 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .841 | .717 | .724 | .868 | .917* | .931* | .981** |
| | Sig. (2-tailed) | .074 | .173 | .167 | .056 | .029 | .021 | .003 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .804 | .650 | .685 | .876 | .859 | .874 | .944* |
| | Sig. (2-tailed) | .101 | .235 | .202 | .051 | .062 | .053 | .016 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .719 | .485 | .478 | .726 | .688 | .715 | .823 |
| | Sig. (2-tailed) | .171 | .408 | .416 | .165 | .199 | .175 | .087 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW11 | TW12 | TW13 | TW14 | TW15 | TW16 | TW17 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .848 | .716 | .768 | .695 | .429 | .648 | .802 |
| | Sig. (2-tailed) | .070 | .174 | .129 | .192 | .471 | .237 | .103 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .905* | .746 | .926* | .951* | .104 | .355 | .506 |
| | Sig. (2-tailed) | .035 | .147 | .024 | .013 | .867 | .558 | .384 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .944* | .805 | .935* | .920* | .217 | .453 | .598 |
| | Sig. (2-tailed) | .016 | .100 | .020 | .027 | .726 | .443 | .287 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .872 | .724 | .801 | .744 | .484 | .696 | .821 |
| | Sig. (2-tailed) | .054 | .167 | .103 | .149 | .409 | .191 | .089 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW18 | TW19 | TW20 | TW21 | TW22 | TW23 | TW24 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | .439 | .855 | .887* | .950* | .317 | -.273 | .315 |
| | Sig. (2-tailed) | .460 | .065 | .045 | .013 | .604 | .656 | .606 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .511 | .779 | .711 | .765 | .469 | -.067 | .315 |
| | Sig. (2-tailed) | .379 | .120 | .179 | .132 | .426 | .915 | .605 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .445 | .784 | .732 | .804 | .522 | -.043 | .407 |
| | Sig. (2-tailed) | .452 | .117 | .160 | .101 | .367 | .946 | .497 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .328 | .872 | .847 | .918* | .424 | -.208 | .384 |
| | Sig. (2-tailed) | .589 | .054 | .070 | .028 | .477 | .737 | .523 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW25 | TW26 | TW27 | TW28 | TW29 | TW30 | TW31 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | -.047 | -.195 | .025 | -.061 | -.353 | -.344 | -.243 |
| | Sig. (2-tailed) | .940 | .754 | .968 | .922 | .561 | .570 | .693 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | .076 | -.048 | -.156 | -.152 | -.223 | .188 | .274 |
| | Sig. (2-tailed) | .903 | .939 | .802 | .807 | .719 | .763 | .655 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | .135 | .000 | -.050 | -.059 | -.181 | .086 | .179 |
| | Sig. (2-tailed) | .829 | 1.000 | .936 | .925 | .771 | .891 | .774 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | .047 | -.103 | -.043 | -.089 | -.297 | -.208 | -.135 |
| | Sig. (2-tailed) | .941 | .869 | .946 | .887 | .628 | .737 | .829 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW32 | TW33 | TW34 | TW35 | TW36 | TW37 | TW38 |
|---|---|---|---|---|---|---|---|---|
| ASWATHY | Pearson Correlation | -.572 | -.374 | -.207 | .798 | .203 | -.855 | -.681 |
| | Sig. (2-tailed) | .314 | .535 | .739 | .105 | .743 | .065 | .206 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| JYOTHI | Pearson Correlation | -.200 | -.197 | .009 | .622 | .558 | -.459 | -.421 |
| | Sig. (2-tailed) | .747 | .751 | .988 | .263 | .328 | .437 | .480 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| SHREYAS | Pearson Correlation | -.320 | -.317 | -.092 | .628 | .503 | -.562 | -.543 |
| | Sig. (2-tailed) | .599 | .604 | .883 | .257 | .388 | .324 | .345 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| UMA | Pearson Correlation | -.593 | -.459 | -.310 | .744 | .402 | -.748 | -.618 |
| | Sig. (2-tailed) | .292 | .436 | .611 | .149 | .502 | .146 | .266 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

**(vi). Correlation between storage temperature and reduction in germination (%) of short duration varieties.**

| | | HARSHA | MT | MR | KANCHANA | TW1 | TW2 | TW3 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | 1 | .849 | .905* | .977** | .824 | .863 | .840 |
| | Sig. (2-tailed) | | .069 | .035 | .004 | .087 | .059 | .075 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .849 | 1 | .988** | .898* | .983** | .879* | .874 |
| | Sig. (2-tailed) | .069 | | .002 | .038 | .003 | .050 | .053 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .905* | .988** | 1 | .946* | .957* | .880* | .866 |
| | Sig. (2-tailed) | .035 | .002 | | .015 | .011 | .049 | .057 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .977** | .898* | .946* | 1 | .883* | .922* | .899* |
| | Sig. (2-tailed) | .004 | .038 | .015 | | .047 | .026 | .038 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW4 | TW5 | TW6 | TW7 | TW8 | TW9 | TW10 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .569 | .310 | .329 | .723 | .676 | .694 | .788 |
| | Sig. (2-tailed) | .317 | .611 | .589 | .167 | .210 | .194 | .114 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .841 | .717 | .724 | .868 | .917* | .931* | .981** |
| | Sig. (2-tailed) | .074 | .173 | .167 | .056 | .029 | .021 | .003 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .804 | .650 | .685 | .876 | .859 | .874 | .944* |
| | Sig. (2-tailed) | .101 | .235 | .202 | .051 | .062 | .053 | .016 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .719 | .485 | .478 | .726 | .688 | .715 | .823 |
| | Sig. (2-tailed) | .171 | .408 | .416 | .165 | .199 | .175 | .087 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW11 | TW12 | TW13 | TW14 | TW15 | TW16 | TW17 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .848 | .716 | .768 | .695 | .429 | .648 | .802 |
| | Sig. (2-tailed) | .070 | .174 | .129 | .192 | .471 | .237 | .103 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .905* | .746 | .926* | .951* | .104 | .355 | .506 |
| | Sig. (2-tailed) | .035 | .147 | .024 | .013 | .867 | .558 | .384 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .944* | .805 | .935* | .920* | .217 | .453 | .598 |
| | Sig. (2-tailed) | .016 | .100 | .020 | .027 | .726 | .443 | .287 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .872 | .724 | .801 | .744 | .484 | .696 | .821 |
| | Sig. (2-tailed) | .054 | .167 | .103 | .149 | .409 | .191 | .089 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW18 | TW19 | TW20 | TW21 | TW22 | TW23 | TW24 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | .439 | .855 | .887* | .950* | .317 | -.273 | .315 |
| | Sig. (2-tailed) | .460 | .065 | .045 | .013 | .604 | .656 | .606 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .511 | .779 | .711 | .765 | .469 | -.067 | .315 |
| | Sig. (2-tailed) | .379 | .120 | .179 | .132 | .426 | .915 | .605 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .445 | .784 | .732 | .804 | .522 | -.043 | .407 |
| | Sig. (2-tailed) | .452 | .117 | .160 | .101 | .367 | .946 | .497 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .328 | .872 | .847 | .918* | .424 | -.208 | .384 |
| | Sig. (2-tailed) | .589 | .054 | .070 | .028 | .477 | .737 | .523 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW25 | TW26 | TW27 | TW28 | TW29 | TW30 | TW31 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | -.047 | -.195 | .025 | -.061 | -.353 | -.344 | -.243 |
| | Sig. (2-tailed) | .940 | .754 | .968 | .922 | .561 | .570 | .693 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | .076 | -.048 | -.156 | -.152 | -.223 | .188 | .274 |
| | Sig. (2-tailed) | .903 | .939 | .802 | .807 | .719 | .763 | .655 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | .135 | .000 | -.050 | -.059 | -.181 | .086 | .179 |
| | Sig. (2-tailed) | .829 | 1.000 | .936 | .925 | .771 | .891 | .774 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | .047 | -.103 | -.043 | -.089 | -.297 | -.208 | -.135 |
| | Sig. (2-tailed) | .941 | .869 | .946 | .887 | .628 | .737 | .829 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | TW32 | TW33 | TW34 | TW35 | TW36 | TW37 | TW38 |
|---|---|---|---|---|---|---|---|---|
| HARSHA | Pearson Correlation | -.572 | -.374 | -.207 | .798 | .203 | -.855 | -.681 |
| | Sig. (2-tailed) | .314 | .535 | .739 | .105 | .743 | .065 | .206 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MT | Pearson Correlation | -.200 | -.197 | .009 | .622 | .558 | -.459 | -.421 |
| | Sig. (2-tailed) | .747 | .751 | .988 | .263 | .328 | .437 | .480 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| MR | Pearson Correlation | -.320 | -.317 | -.092 | .628 | .503 | -.562 | -.543 |
| | Sig. (2-tailed) | .599 | .604 | .883 | .257 | .388 | .324 | .345 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| KANCHANA | Pearson Correlation | -.593 | -.459 | -.310 | .744 | .402 | -.748 | -.618 |
| | Sig. (2-tailed) | .292 | .436 | .611 | .149 | .502 | .146 | .266 |
| | N | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

# INFLUENCE OF STORAGE STRUCTURE ON SEED LONGEVITY IN RICE (*Oryza sativa* L.)


**By**

**JYOTHISH BABU E.**

**(2018-11-156)**


## ABSTRACT OF THE THESIS

**Submitted in partial fulfilment of the requirement for the degree of**

**Master of Science in Agriculture**


**Faculty of Agriculture**

**Kerala Agricultural University**

**DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY**

**COLLEGE OF HORTICULTURE**

**VELLANIKKARA, THRISSUR -680656**

**KERALA, INDIA**


**2020**

**KERALA AGRICULTURAL UNIVERSITY**
**COLLEGE OF HORTICULTURE, VELLANIKKARA**
**Department of Seed Science and Technology**

**'Influence of storage structure on seed longevity in rice (*Oryza sativa* L.),'**

## Abstract

Ageing of seeds is an inevitable natural deteriorative phenomenon, eventually resulting in loss of vigour and viability. Adopting appropriate storage, ensuring optimum storage environment have been advocated to slow down the pace of the deteriorative process during storage, maintain the seed quality and prolonging seed longevity. Considering the above, a study to elucidate the effect of different storage structure on seed longevity and quality of short duration rice varieties (Experiment 1) and medium rice varieties (Experiment 2) was conducted at College of Horticulture, Vellanikkara, Thrissur, during 2019 - 2020.

The storage experiments were conducted following a completely randomized design with four varieties replicated thrice under five storage conditions (SC1 to SC5), each varying from the other with respect to the type of roofing and provision of ventilation. The short duration varieties used in Experiment 1 were Harsha, Matta Triveni, Manurathna and Kanchana, while, the medium durations varieties in Experiment 2 were, Aiswarya, Sreyas, Jyothi and Uma. The quality parameters of seeds stored in SC1 (Asbestos + ventilation), SC2 (Asbestos + without ventilation), SC3 (R.C.C. + ventilation), SC4 (R.C.C. + without ventilation) and SC5 (Asbestos + forced ventilation) were recorded at the start of storage and subsequently at monthly intervals for a period of nine months. The temperature and relative humidity in each storage condition were recorded at weekly intervals.

Varieties, storage conditions, the period of storage and their interactions were found to exert significant influence on seed quality and longevity in both short duration

and medium duration varieties. Irrespective of the varieties and the storage conditions, the seed quality parameters *viz.*, germination (%), vigour indices (VI-I and VI-II) and field establishment (%), declined over the storage period, whereas an increase in seed moisture content (%), electrical conductivity of seed leachate ($dSm^{-1}$) and seed microflora, was observed.

Germination and longevity of varieties Matta Triveni and Harsha was higher than that of varieties Manurathna and Kanchana. Seed longevity was higher (8 months each) in varieties Harsha and Matta Triveni compared to varieties Manurathna and Kanchana (7 months each).

The seed vigour indices (VI-I and VI-II), field establishment (%) of Matta Triveni were significantly high, while the estimates of seed moisture (%) and EC of seed leachate were significantly low in Kanchana. In case of medium duration varieties, although germination was higher in varieties Aiswarya and Shreyas compared to Jyothi and Uma, the longevity of seeds in all varieties was retained for eight months. Germination, vigour (VI-II) and field establishment (%) was significantly high in Aiswarya, while the seed moisture and EC of seed leachate was found to be significantly low in Sreyas. Variety Uma registered significant low seed quality parameters.

In both short and medium duration varieties, the quality of seeds stored under ventilated conditions (SC1, SC3 and SC5) was found to be the significantly superior to those stored in non-ventilated structures (SC2 and SC4). Irrespective of the type of roofing (Asbestos or R.C.C), seed longevity in ventilated godowns were found to be retained above IMSCS, one month longer (8 MAS) than when stored under non-ventilated environment (7 MAS).

The interaction between varieties, storage condition and the period of storage, indicated that seed longevity in all medium duration varieties stored under ventilated storage and non-ventilated storages was eight and seven months respectively. Unlike in the medium duration group, the longevity of all the longevity of short duration varieties Matta Triveni and Harsha was higher by a period one month *i.e.*, 8 MAS, when stored under ventilated environments conditions *viz.*, R.C.C. + ventilation (SC3), Asbestos + ventilation (SC1) and Asbestos + forced ventilation (SC5) as against 7 MAS under non-ventilated storage [Asbestos + without ventilation (SC2), R.C.C. + without ventilation (SC4)]

High temperature and relative humidity within the storage environment strongly influenced germination and seed longevity. The decline in germination was found to be more pronounced when the seed was exposed to high temperatures in the early period of storage *i.e.*, between 1 and 13$^{th}$ week, while high RH during the 2$^{nd}$ half of the storage period (*i.e.*, between 24$^{th}$ and 36$^{th}$ week), proved to be detrimental to seed longevity. Among the storage structures, the temperature and RH inside ventilated storage (SC3, SC1 and SC5) was relatively lower than that in non-ventilated structure (SC4 and SC4). Marginal variations in temperature and RH was evident between the ventilated stores, with the least estimate in Asbestos + forced ventilation (SC5). However, most quality parameters and longevity of seeds in these conditions were on par with each other.

From the above results, it can be summarized that storing seeds in ventilated storage structures, was clearly advantageous over storing them under non-ventilated conditions. Only marginal variations in seed quality parameters was observed between the ventilated conditions. Neither did storing seed in godowns with provision for forced ventilation improve the longevity of stored seeds over those with provision for natural ventilation. Incurring additional expenditure on installation, maintenance and operation of forced ventilation system did not to confer any additional benefits. Considering all the above, it would be more advantageous to store seeds under ventilated conditions with provision for natural ventilation.