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Influence of Maturity Stage, Seed Treatment, and Storage Containers on the Storability of Combine-Harvested Rice (*Oryza sativa* L. cv. CO (R) 50)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The current research aimed to investigate the impact of different maturity stages on the moisture content and storability of the combine-harvested rice variety CO (R) 50. Seeds were harvested at various stages of maturity - physiological maturity, two days after, four days after, and six days after physiological maturity. The seeds were treated with water-soluble polymer at a rate of 4 ml + 12 ml water per kg of seed, as well as vithai amirtham at 25 ml per kg of seed, and compared to untreated

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control seeds. The treated seeds were stored in both super grain and gunny bag containers under ambient conditions, along with the control. Quality parameters were initially assessed and then monitored at monthly intervals for 12 months to evaluate seed storability. Results showed that seeds harvested at physiological maturity exhibited the highest germination (88%), longer root(21.8cm) and shoot lengths(12.5cm), increased dry matter production (0.144g/10 seedling), superior seedling vigour index (3039), reduced pathogen incidence (4.6%), and lower seed leachates(0.124dSm^{-1}). Seeds stored in super grain bags demonstrated higher germination rates, seedling vigour index, and lower pathogen incidence and seed leachates, regardless of variety or treatment. The study concluded that the CO (R) 50 rice variety harvested at physiological maturity (135 days), coated with water-soluble polymer at a rate of 4 ml + 12 ml water per kg of seed, and stored in a super grain bag-maintained seed quality above minimum certification standards for up to 12 months.

Keywords: CO (R) 50 rice variety; maturity stages; moisture content; vithai amirtham; water-soluble polymer storability; germination; seedling vigour.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is one of the most extensively cultivated cereal crops worldwide, serving as the world's second most important cereal after wheat. It plays a vital role as the staple food for more than 60% of the global population, contributing 21% of the world's per capita caloric intake and 15% of total protein consumption. According to the Food and Agriculture Organization of the United Nations" (FAO, 2021), global food production expected to increase by 70% to meet the nutritional demands of the 9.1 billion people by 2050. Asia, often referred to as the "rice bowl of the world" (Arunachalam et al*.,* 2024), which accounts for 90% of the global rice production, with nearly half of its population depending on rice as their principal food source (Tenorio et al*.,* 2013)." Seed moisture content is a crucial factor in determining the storability and quality of seeds during storage" (Jeya Chandra et al*.,* 2025). "Rice (*Oryza sativa* L.) seeds are hygroscopic and easily absorb or lose moisture from the surrounding environment until reaching equilibrium" (Zeng et al., 2006). Even slight fluctuations in seed moisture can accelerate metabolic activity, respiration, and microbial infections, ultimately reducing germination and vigour during extended storage (Copeland & McDonald, 2001; Wang et al., 2018; Tianshun et al., 2024). Therefore, maintaining optimal seed moisture through proper post-harvest handling, packaging, and storage practices is essential to preserve seed viability. The harvest stage plays a significant role in determining the initial seed moisture and physiological quality (Jeya Chandra et al*.,* 2025). Seed should be harvested at physiological maturity stage, this is the stage at which the maximum dry matter accumulates, where the moisture content of the seed is around 26% to 50%. If the seed is devoid of dormancy, it registers highest seed germination and vigour index at that stage. The seeds have to be effectively dried to safe moisture contents. Seed harvested before reaching the physiological maturity, being high in moisture, will shrivel when dry and probably won't germinate. On the other hand, delaying harvest excessively beyond physiological maturity generally will result in increase in field deterioration from insects and disease causing organisms and in turn encountering harvest loss (Renugadevi et al., 2025). On the other hand, delayed harvesting allows for partial field drying and reduces initial seed moisture, but excessive delays can expose seeds to weathering or mechanical damage during harvesting (Cavusoglu et al., 2024). The use of combine harvesters has become common in rice production systems due to labour savings and operational efficiency; however, seeds harvested with combines are often more susceptible to mechanical damage and varying moisture content depending on crop maturity and field conditions (Ponmani, 2015; Venkatesan et al., 2021).

The type of storage container significantly impacts the internal seed environment by controlling both moisture and gas exchange with the surrounding environment. Permeable containers, such as gunny or cloth bags, allow for moisture exchange with the air, leading to fluctuating seed moisture levels and accelerated deterioration. In contrast, moisture-proof or hermetic containers, such as super-grain bags, polyliners, or aluminium pouches, prevent moisture ingress, improving storability (Paul & Bordolui, 2025). Research has shown that using moisture-impermeable containers helps maintain seed moisture within safe limits and preserves germination for more extended periods (Kumar et al., 2019; Goud et al., 2024). Additionally, seed treatments and coatings can affect seed moisture dynamics and longevity. Polymer coatings, bio-stimulant formulations, and organic protectants, such as vithai amirtham, are increasingly used to enhance seed performance during storage and after planting. These coatings create a protective film over the seed surface, reducing exposure to ambient humidity and carrying antimicrobial and antioxidant compounds (Afzal et al., 2020; Nithya & Geetha, 2017). While several studies have highlighted the benefits of polymer coatings in maintaining seed vigour, information on their combined effects with storage containers and harvest maturity, particularly in combine-harvested rice, is limited.

Therefore, this study aimed to investigate the impact of seed treatments and containers on the storability of the CO (R) 50 rice variety harvested at different maturity stages using a combine harvester. The study aimed to evaluate changes in seed moisture content and its interaction with harvest stage, seed treatments, and storage containers over time under ambient conditions, with the goal of identifying suitable storage practices for maintaining rice seed quality.

2. MATERIALS AND METHODS

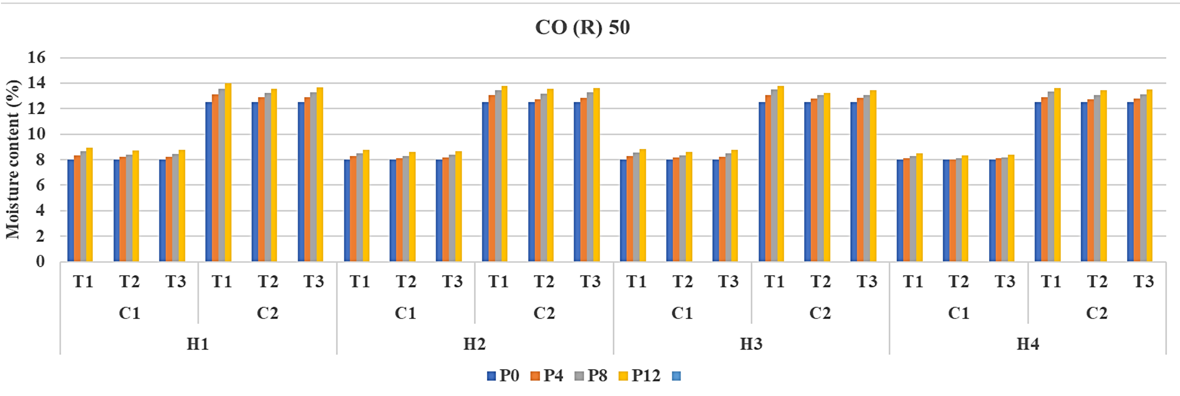
The study took place at the Department of Basic Engineering and Applied Sciences, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, from May 2023 to April 2025. The rice seed crop (Variety CO (R) 50) was harvested using a combine harvester at different seed moisture levels (ranging from 19% to 27%) with four distinct maturity stages. The treatments included harvesting the seed crop at physiological maturity (H1), two days after physiological maturity (H2), four days after physiological maturity (H3), and six days after physiological maturity (H4). The seeds collected from different maturity stages were cleaned and graded. The graded seeds were stored in both super grain bags (C1) and gunny bags (C2) containers with 8 to 12.50 per cent moisture content respectively for following the treatment of control (T1), water-soluble polymer 4ml + 12ml water/kg of seed (T2), and vithai amirtham 25ml/kg of seed (T3). The treated seeds were stored under ambient conditions. The experiment was designed using FCRD with three replications. Various quality parameters were recorded initially and at monthly intervals for 12 months to assess the storability of seeds. For the germination test, seeds were placed on a roll towel. Under each treatment, 400 seeds were sown with eight replications of 50 seeds each. Seed germination was calculated as the percentage of seeds producing normal seedlings. Fourteen days after sowing (ISTA, 2011), ten seedlings from each replication were randomly selected, and the root and shoot lengths were measured, with the mean value recorded. Ten random seedlings were dried in a hot air oven at 85°C for 24 hours, and the dry weight was recorded and expressed as g seedling^{-10}. The vigour index was calculated using the formula (Abdul–Baki & Anderson, 1973): Vigour Index = Percentage germination x Total seedling length (cm). Seeds were also analysed for electrical conductivity (Presley, 1958), dehydrogenase activity (Kittock & Law, 1968), insect infestation percentage, and pathogen infection percentage (ISTA, 1999) under each treatment. The results were subjected to statistical analysis to determine significant differences ($p = 0.05$) following the guidelines of Panse & Sukhatme (1999). Percentage values were transformed using arcsine values prior to statistical analysis.

3. RESULTS AND DISCUSSION

A higher moisture content in the seed enhances seed deterioration, thereby reducing the seed's quality (Kamruzzaman et al., 2015). The initial seed moisture content was 12.5%. Significant variation was found in the moisture percentage of rice seeds recorded from different storage materials at different storage periods. The results of the study revealed that the effect of seed treatments and containers on the storability of CO (R) 50 rice variety harvested at different maturity stages using a combine harvester revealed that the moisture content was significantly influenced by the harvested maturity stages, container used for storage, treatment applied, and period of storage. Irrespective of storage containers, the moisture content of seeds increased gradually with an increase in storage duration (Fig. 1). Among the maturity stages, the highest moisture content was recorded in the seeds obtained at the physiological maturity stage (10.76%), and the minimum moisture content at six days after physiological maturity (10.58%). Between the containers used for storage, the super grain bag maintained. In comparison, a lower moisture content (8.40%), while the seeds stored in the gunny bag exhibited a higher moisture content

(13.06%). Among the treatments, the maximum moisture was recorded in seeds coated with vithai amirtham (10.66%), followed by water-soluble polymer @ 4 ml + 12 ml water/kg (10.59%), while the maximum moisture content was observed in the control (10.79%). The conventional gunny bags exhibited the highest percentage increase in paddy seed moisture content at each storage duration. In contrast, the hermetically sealed SGBs showed a decline in moisture content for the same (Khandai et al., 2025). The super grain bag presumably acts more hermetically (or at least more moisture and vapour-resistant) than the gunny bag, which is usually relatively permeable.

Seed physiological parameters such as germination, seedling length, dry matter production, and vigour index were significantly influenced by the maturity stages, treatments, and period of storage. The maturity stage of harvest significantly influenced germination, containers used for storage, treatments, and storage period (Fig. 1). Among the maturity stages, the maximum germination was registered at the physiological maturity stage (88%), and the minimum germination was recorded in the seeds obtained at six days after physiological maturity stage (85%). Between the containers, the super grain bag maintained, while the lower germination was observed in the seeds stored in the gunny bag, showing a higher germination rate (87%), while the seeds stored in the gunny bag showed a lower germination rate (86%). Among the treatments, seeds coated with water-soluble polymer @ 4 ml + 12 ml water/kg



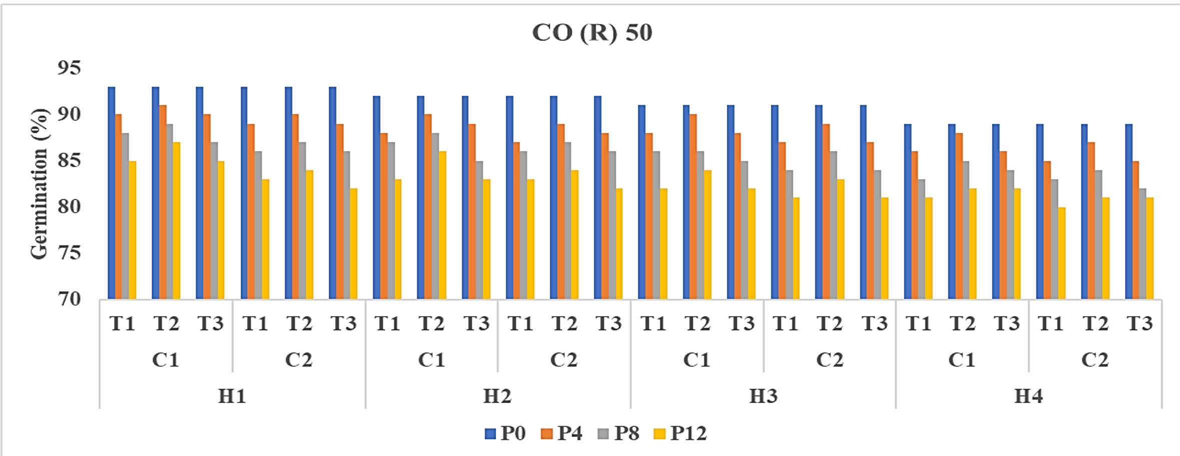


Fig. 1. Effect of maturity stages, combine harvesting, storage containers and seed treatments on moisture content (%) and germination (%) of CO (R) 50 rice variety

H_1 – At Physiological maturity	*P0- Initial Period of storage*	*T_1-Control*
H_2 – Two days after physiological maturity	*P4- 4 months of storage*	*T_2-Water Soluble Polymer 4ml + 12 ml water/kg*
H_3 – Four days after Physiological maturity	*P8- 8 months of storage*	
H_4 – Six days after Physiological maturity	*P12- 12 months of storage*	*T_3- Vithai Amirtham 25 ml/kg of seed*
	C_1-Super grain bag	
	C_2-Gunny bag	

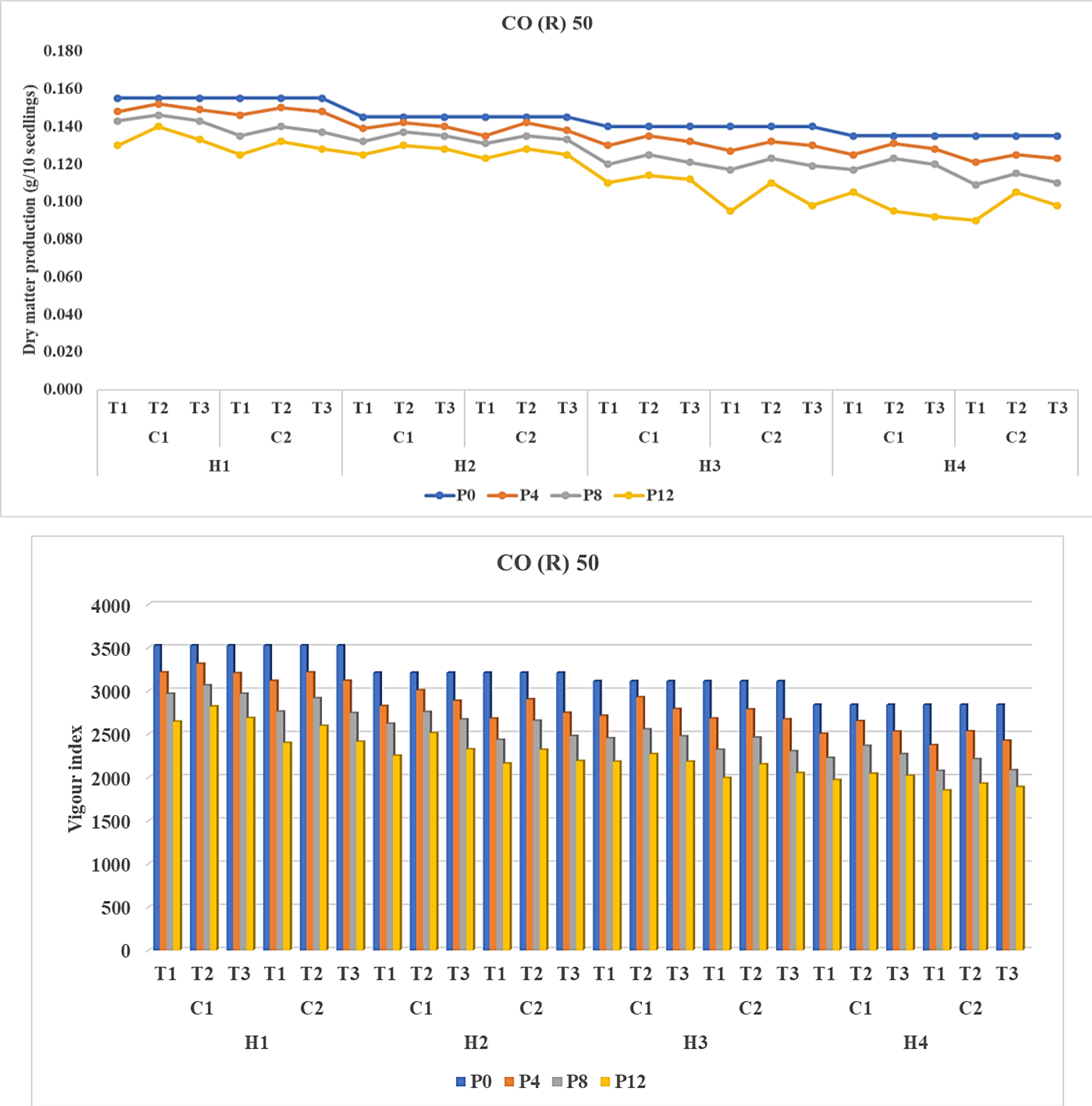


Fig. 2. Effect of maturity stages, combine harvesting, storage containers and seed treatments on dry matter production (g/10 seedlings) and vigour index of CO (R) 50 rice variety

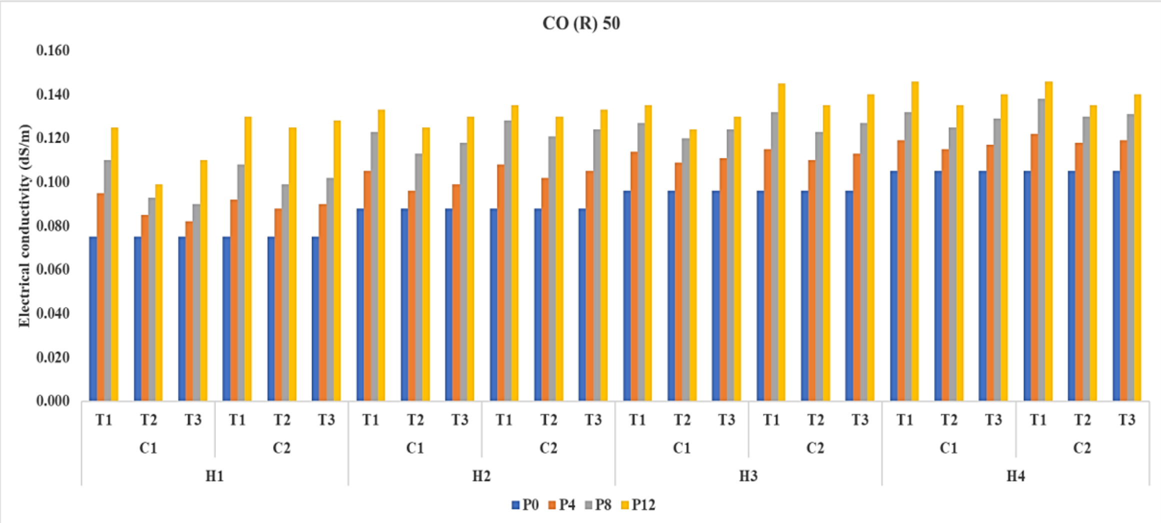
H_1 – At Physiological maturity
H_2 – Two days after physiological maturity
H_3 – Four days after Physiological maturity
H_4 – Six days after Physiological maturity

P0- Initial Period of storage
P4- 4 months of storage
P8- 8 months of storage
P12- 12 months of storage
C_1-Super grain bag
C_2-Gunny bag

T_1-Control
T_2-Water Soluble Polymer 4ml + 12 ml water/kg
T_3- Vithai Amirtham 25 ml/kg of seed

registered the maximum germination (88%), followed by vithai amirtham (87%), while the minimum germination was observed in the control (86%). The germination percentage of rice seeds decreased with increasing storage duration. Seeds stored in the PICS bag and the super grain bag retained the highest seed germination for a longer time (Khatri et al., 2019). A similar trend resulted in root length, shoot length, dry matter production, and vigour index (Fig. 2). Furthermore, the seedling length, dry matter production, and vigour index decreased gradually with the advancement of the storage period (Gowd et al., 2020).

The electrical conductivity was significantly influenced by harvesting stages, containers, treatments, and period of storage (Fig. 3). In the rice variety CO (R) 50, among the maturity stages, physiological maturity registered the lowest electrical conductivity (0.105 dSm^{-1}), and the highest leachates were obtained six days after physiological maturity (0.124 dSm^{-1}). Among the containers used for storage, the super grain bag exhibited the lower electrical conductivity (0.109 dSm-1), whereas the seeds stored in a gunny bag showed higher electrical conductivity (0.123 dSm^{-1}). Seeds coated with water-soluble polymer @ 4 ml + 12 ml water/kg registeredthe minimum electrical conductivity(0.109 dSm^{-1}), while the maximum electrical conductivity was observed in the control (0.115 dSm^{-1}). The electrical conductivity increased gradually with an increase in the storage period. In terms of dehydrogenase activity, physiological maturity registered the highest dehydrogenase activity (0.782), while the lowest dehydrogenase activity was observed six days after physiological maturity (0.745) (Fig. 3). The super grain bag maintained higher dehydrogenase activity (0.722) compared to the seeds stored in a gunny bag (0.717). Seeds coated with water-soluble polymer @ 4 ml + 12 ml water/kg had the maximum dehydrogenase activity (0.716), while the control had the minimum dehydrogenase activity (0.711). Dehydrogenase activity decreased gradually with increasing storage period.



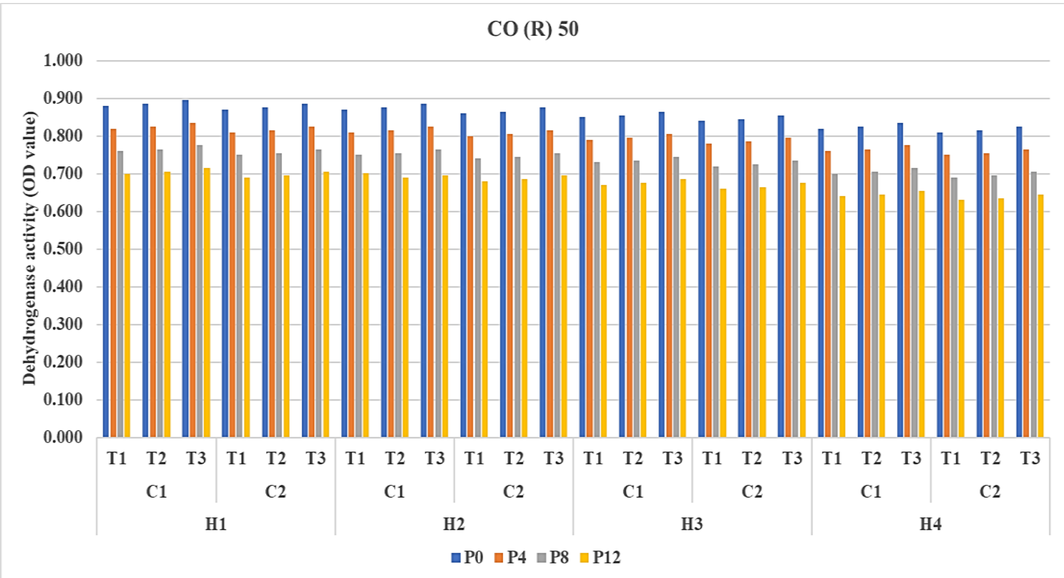


Fig. 3. Effect of maturity stages, combine harvesting, storage containers and seed treatments on electrical conductivity (dS/m) and dehydrogenase activity of CO (R) 50 rice variety

H_1 – At Physiological maturity
H_2 – Two days after physiological maturity
H_3 – Four days after Physiological maturity
H_4 – Six days after Physiological maturity

P0- Initial Period of storage
P4- 4 months of storage
P8- 8 months of storage
P12- 12 months of storage
C_1-Super grain bag
C_2-Gunny bag

T_1-Control
T_2-Water Soluble Polymer 4ml + 12 ml water/kg
T_3- Vithai Amirtham 25 ml/kg of seed

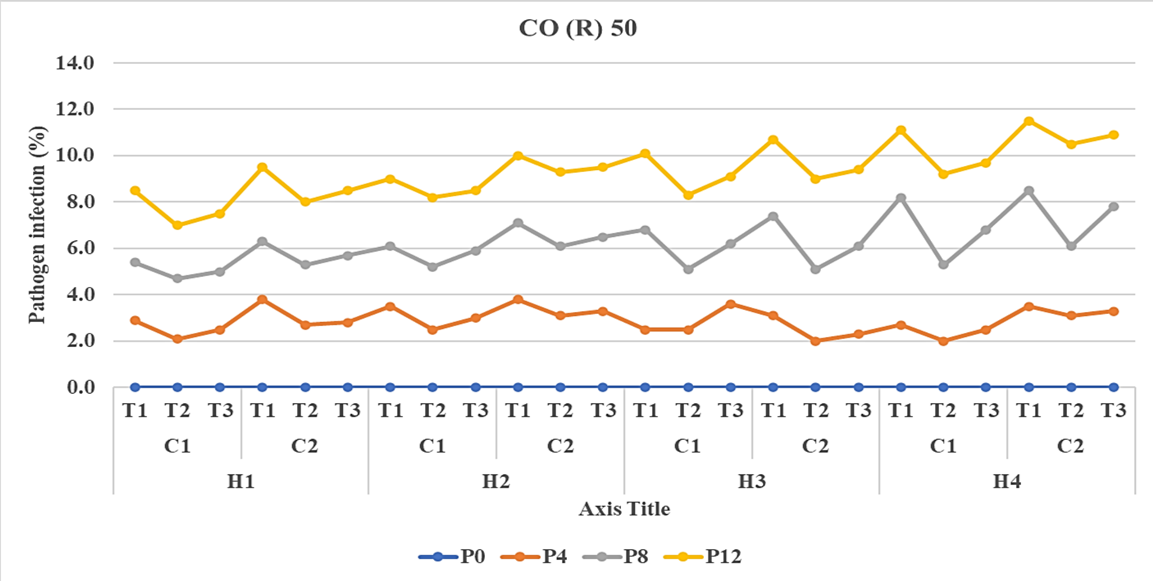


Fig. 4. Effect of maturity stages, combine harvesting, storage containers and seed treatments on Pathogen infection (%) of CO (R) 50 rice variety

H_1 – At Physiological maturity
H_2 – Two days after physiological maturity
H_3 – Four days after Physiological maturity
H_4 – Six days after Physiological maturity

P0- Initial Period of storage
P4- 4 months of storage
P8- 8 months of storage
P12- 12 months of storage
C_1-Super grain bag
C_2-Gunny bag

T_1-Control
T_2-Water Soluble Polymer 4ml + 12 ml water/kg
T_3- Vithai Amirtham 25 ml/kg of seed

Pathogen and insect infestation were assessed, with infection increasing as maturity stages and storage duration increased. Seeds stored in super grain bags had the lowest pathogen infection rate compared to those stored in gunny bags. T1 (control) had the highest infection rate, while T2 (water-soluble polymer) had the lowest (Fig. 4). A similar trend was observed with insect infestation, which increased with maturity stages and storage duration in all rice varieties. The highest insect infestation was observed six days after physiological maturity. Super grain bags had the lowest insect infestation compared to gunny bags, with T1 (control) having the highest infestation and T2 (water-soluble polymer) having the lowest. The use of hermetic storage bags proved more effective than traditional methods, maintaining 97% germination with just 1% damage, whereas traditional storage resulted in 95% germination with 6% damaged grains (Awal et al., 2017). Seeds stored in PICS (Purdue Improved Crop Storage) bags and super grain bags retained the highest seed germination for a longer time than other storage materials in rice (Khatri et al., 2019). Doddamani & Betageri (2021) reported that electrical conductivity increased with higher moisture content. A decrease in enzymatic activity in stored seeds over time led to reduced germination and vigor (Khan et al., 2013). Dehydrogenase activity gradually decreased with an increase in storage period, resulting in a loss of seed quality. Ajeet (2015) found that dehydrogenase activity significantly decreased from 8 months (0.163 OD) to 12 months (0.129 OD) in rice.

4. CONCLUSION

This study concludes that rice seed crop (Var. CO (R) 50) harvested using a combine harvester at physiological maturity or up to six days after the physiological maturity stage, then reduced to a moisture content of 8%, coated with water-soluble polymer @ 4 ml + 12 ml of water per kilogram of seed, and packed in a super grain bag, maintained more than 80% germination. It also met the Indian Minimum Seed Certification Standards for up to twelve months.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests, non-financial interests, or personal relationships that could have appeared to influence the work reported in this paper.

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