

Seed priming for improving crop performance of partially deteriorated rice seeds

A

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Odisha University of Agriculture and Technology
In Partial fulfilment of the Requirement
for the degree of
Master of Sciences
in Agriculture (Seed Science and Technology)*

By

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It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

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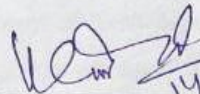
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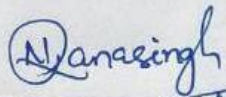
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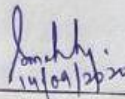
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ABBREVIATIONS

@: At the rate
B:C ratio: Benefit Cost ratio
cm: centimeter
CD: Critical difference
CGR: Crop Growth Rate
DAS: Days After Sowing
°C: Degree Celsius
e.g.: Exempli gratia (for example)
et al.: and others
etc.: et cetera (and other things)
FAO: Food and Agriculture Organization
Fig.: Figure
g: gram
g/l: gram per liter
GDP: Gross Domestic product
ha: hectare
h: hours
ISTA: International Seed Testing Association
Kg: Kilogram
LAI: Leaf Area Index
mg: milligram
ml: milliliter
mm: millimeter
Min: Minute
NAR: Net Assimilation Rate
No.: Number
OUAT: Odisha University of Agriculture Technology
%: Percentage
/: per
PEG: Poly Ethylene Glycol
Q: Quintal
RH: Relative humidity
Sec.: Second
SVI: Seedling vigour index
TP: Top of the paper
Viz.: Videlicet (namely)

ABSTRACT

Rice (*Oryza sativa* L.) is consumed as staple food by majority of population in the world especially in south east Asia. Seed priming is one of the best seed treatment technique that improves germination, planting value and seedling establishment leading to increase in the yield of various crop seeds. The present research entitled "Seed priming for improving crop performance of partially deteriorated rice seeds" comprising of laboratory and field studies were carried out at Dr. G.V. Chalam Seed Testing Research Laboratory and Agronomy field of OUAT, Bhubaneswar during Rabi, 2019-20. The experiment was laid down in the Factorial CRD and RBD of 14 treatments to observe the impact of various priming agents in improving the quality parameters and yield attributing characters in rice. Fresh Rabi (2018-19) and one-year old Kharif (2018) seeds of rice varieties (Naveen, Hiranmayee) were treated with water, KNO₃(@0.3%), KH₂PO₄(@0.5%), ZnSO₄(@0.3%) + MnSO₄(@0.5%) for 30 hours and then dried in shade. Some hydro-primed seeds were then bio-primed with *Trichoderma harzianum* (2 x 10⁶ cfu), BioNPK, Biogrow, Biophos containing (1 x 10⁹ cfu), drought alleviating bacteria by coating the seeds 30 minutes before sowing. Untreated seeds were taken as control. Primed seeds by different methods revealed significant variation over the unprimed seed under lab condition with respect to highest germination percentage (94.7%), seedling vigour index-I (2301.76) and seedling vigour index-II (7.35) for fresh seeds of Naveen variety. Significant variation for all the growth and yield attributing characters were recorded maximum in field emergence (84.4%), plant population at 30 DAS (79.7%), total number of tillers / plant (16.38), effective tillers / hill (14.4), panicle length (30.92 cm), seeds per panicle (153.86), seed yield / plant (22.58 g), seed yield / hectare (48.49 q), harvest index (51.17) and B:C ratio (2.30) in the field over the unprimed of one year old seed. Among one year old and fresh seed observation, the fresh seed of priming treatment recorded higher seed quality parameters, growth and yield attributing characters both in laboratory and field conditions. Fresh seed of Naveen and Hiranmayee variety expressed higher positive response than the one-year old seeds with response to different seed priming treatments. Among the rice varieties, both Naveen and Hiranmayee variety which were treated with *Trichoderma harzianum* seeds showed the most positive response to priming treatments in maximum of these traits. From this study, it is concluded that seed quality, planting value, productivity & B-C ratio of partially deteriorated rice seeds could be improved by using seed priming.

Key words: Seed priming, KNO₃, KH₂PO₄, ZnSO₄, MnSO₄, *Trichoderma harzianum*, BioNPK, Biogrow, Biophos, Drought Alleviating Bacteria, partially deteriorated seeds, harvest index, B-C ratio.

INTRODUCTION

Seed is the basic agricultural input. The most important and feasible approach to enhance the productivity of crops would be the production of high-quality seeds. Farmers need always a good deal inquisitive about the best seed management practices that are safe, environmentally sound and scientifically standardized technologies. To meet the potential challenge of catering to the food need of 1.4 billion people of our country by 2025, a quantum increase in agricultural productivity from the confined land resources is very much essential. Hence production and distribution of high-quality seeds of improved varieties of cereals, pulses, oil seeds and vegetables to the farming community is becoming increasingly important in a sustainable manner as well as economic upliftment of the common farmers leading to boost of GDP in the country.

Rice (*Oryza sativa* L.) is an important cereal crop that serves as staple food for more than half of the world's population. It has been reported that rice is cultivated over 165.0 million ha with a net production over 780 million tons of rice with an average yield of approximately 4.7 tons per ha. Asia is the largest consumer of rice housing more than 95% of the 2.7 billion. The highest production & productivity is China followed by India. It accounts for around 25 percent of global calorie intake. (FAO, 2017-18)

In India, rice is grown in 43.5 million ha, the production is 118.80 million tons and productivity about 2600 kg/ha (Paddy outlook- 2018-19). Also 90% of the cultivated land belongs to marginal, small and medium farmers which is another constrain in increasing the productivity of rice in country. Besides meeting the dietary requirements of the people, it accounts about 5.7% of the total value added in agriculture and 1.3% of gross domestic product (GDP) and also contributes to the country's foreign exchange exchequer as an export item. On an average 75 percentages of Indian farmers grow rice and one third of their total calorie needs are met through rice. It is estimated that the growing population of India along with the changing food habits will need around 130 million tons of rice by the year 2025. (DESA, Ministry of Agriculture, New Delhi). To meet the rice requirement at national level, the rice production has to increase at the rate of 2 million tons per year.

In Odisha, rice is cultivated in an area of around 69% and is the major crop covering 63 percent of total area under food grain. It is the staple food of Odisha.

Presently rice is grown in Odisha over an area of 3.70 million ha with production over 6.53 million tons and productivity over 1765 kg/ha. Both environment condition and input should be properly managed for producing quality seed. (Agricultural Statistics at a Glance, 2018)

Poor seed germination and crop establishment are main constrains of production of cereals like rice (Jones and Wanbi, 1992). Irregularity in germination and can extend over long periods particularly in drought-prone environments; resulting consequences e.g. poor crop germination leaving gaps in the canopy, which are rapidly filled by vigorously growing weeds during onset of monsoon and compete with the crop plants for light, water and nutrients (Kropff and Van Laar, 1993). So, accelerating and homogenizing the germination through seed invigoration technique is a prerequisite for a good crop establishment, the effective use of resources leading to increase in yield. (Harris, 1996)

Seed priming can be described as it is a seed treatment that involve the controlled hydration of seed to permit pre-germinative metabolic events to take place, however inadequate to allow radical protrusion through the seed coat. It enhances stand, improve seedling vigor, seedling establishment, plant density, fertile tillers, crop growth, number of grains per panicle, test weight of seeds etc. with respect to non-primed seeds (Du and Tuong, 2002).

The seed priming treatment can be achieved by either overnight soaking of seeds (on-farm priming) or soaking in solution of low water potential. The seeds are then dried down closer to the original moisture level. Priming technique is used widely for betterment of seed performance through higher rate of germination and uniformity of establishment, reduction in emergence time, ensuring uniform emergence and better of stand establishment in many crops now-a-days. (Ashraf and Foolad, 2005).

Priming is one of the short-term and most pragmatic approaches to overcome poor crop establishment and water-stress effects in direct seeded rice (DSR), which involves partial hydration to a degree where germination-related metabolic processes begin, but radical emergence does not occur. On-farm priming in direct seeded rice results in a faster rate of germination and emergence, more uniform and vigorous seedling

growth, and a wide range of phenological and yield associated benefits. (Farooq *et al.*, 2003, 2015)

In rice seed priming techniques causes reduction in time between seed sowing and seedling emergence, resulting in rapid and uniform seedlings emergence, high seed vigor, better and uniform stand establishment, better allometries and yield in partially deteriorated rice seeds. Priming in seeds were uniquely significantly affect with physiological potential, including germination and vigor, which is expected to bring benefits to the faster establishment and uniform stands in the field in upland rice. (Mondo *et al.*, 2016)

The beneficial effects of seed priming may be due to enzymatic activation associated with endosperm utilization, reserve mobilization, alternation in hormonal balance and protein synthesis that play a crucial role in seed germination. It restores the process of priming memory that helps to reactivate the germination & vigour in less vigorous old partially deteriorated seeds. So, priming emerges as a promising technology to combat abiotic stress in crops without much affecting its fitness improving B:C ratio of rice farmers. (Sharma and Parikh, 2020)

The entire studies properly indicated that seed priming enables improved germination and seedling vigour. There are several seed priming methods available but limited testing were undertaken to compare various priming techniques and their effects in the present research entitled "Seed priming for improving crop performance of partially deteriorated rice seeds" in two different varieties of rice with following objectives:

1. To study the role of priming treatments in improving the planting value of partially deteriorated rice seeds.
2. To assess the performance of primed seeds under field conditions with regards to plant growth and seed yield.
3. To evaluate the physiological quality of seeds produced from primed seeds.
4. To study the economics of seed priming treatments as against the unprimed seeds.

REVIEW OF LITERATURE

2.1. Seed priming

The theory of seed priming was first proposed by Heydecker (1973) who stated that it is a simple and low-cost hydration technique which enhance rapid and uniform emergence and to achieve high vigour; leading to better stand establishment and yield. Here, the seeds are partially hydrated to a point where pre-germination metabolic activities start without actual germination, and then re-dried until close to the original dry weight.

According to Taylor *et al.* (1989), the process of seed enhancements is the range of seed treatments that improve performance in the germination, seedling growth or facilitate the delivery of seeds and other material required at the time of sowing. So, seed enhancements act as a value-added technique for a given seed lot. Arif (2005) reported that plants of primed seeds require fewer days to emerge, achieve earlier at flowering and maturity, produced more plants per unit area, taller plants and higher grain yield w.r.t. non-primed seeds. It is used to improve germination, emergence and seedling growth by changing the seed vigor and other physiological characteristics of the seed. The main purpose of these treatments is to reduce the duration between planting and emergence. (Black and Peter, 2006)

2.2. Different methods of priming

There are various seed priming techniques out of which hydro-priming, halo-priming, biopriming are important and affect seed quality on various quality attributes resulting in higher yield of crops.

2.2.1. Hydropriming

The process of priming of seeds in pure water is termed as hydropriming. Hydro-priming enhance seed germination and seedling emergence under both saline and non-saline conditions. It has also beneficial effects on activity of enzyme essential for rapid germination. It is the simplest method of seed priming, based on soaking of seeds in pure water & then re-drying to its original moisture content prior to sowing.

As far as abiotic components are concerned according to Burgass and Powell (1984), the temperature and the duration of treatment should be carefully monitored to prevent over-priming that may leads to radicle protrusion and microbial growth. Hydropriming is low cost, low-risk intervention simple process with positive impact on the wider farming system and has proved high popularity among farmers (Harris *et al.*, 1999).

Roy and Srivastava (1999) conducted hydro-priming effect on wheat kernels and found out that there was improvement in germination rate, field emergence, field stand, plant growth under saline & non-saline conditions. He also confirmed that hydro-priming plays an important role in faster radicle and plumule emergence in different crop species.

Rahman *et al.* (2011) also reported the beneficial effect of hydropriming on seed germination and seedling growth under both optimal and stress conditions, in various crop plants such as chickpea, maize, rice mung bean and capsicum.

Meena *et al.* (2013) conducted field experiments to evaluate the influence of hydro-priming grain yield of wheat. They reported that the hydro-primed seeds established earlier than dry seeds causing better crop establishment leading to higher seedling growth, tillering and grain yield.

2.2.2. Halo-priming

Halo-priming is the process of pre-sowing treatment of seeds in solution of inorganic salts [e.g. calcium chloride (CaCl₂), potassium chloride (KCl), sodium chloride (NaCl), sodium nitrate (NaNO₃), manganese sulphate (MnSO₄), magnesium chloride (MgCl₂) and potassium nitrate (KNO₃), etc.] This process helps the seeds to develop a stress related priming memory that help the seeds to combat unfavorable conditions in field. So, it can act as an alternative approach to overcome the salinity problem in agricultural lands. A number of studies have reported a significant improvement in seed germination, seedling emergence and yield in salt affected soil in response to halo-priming. (Ashraf and Rauf, 2001; Sivritepe *et al.*, 2003)

2.2.3. Bio-priming

Bio-priming is a process of coating of seeds with agriculturally beneficial microorganisms (bio-inoculants) e.g. *Trichoderma*, Phosphobacteria, *Azospirillum*, etc. to protect seed from insect, pests and diseases. It is an eco-friendly approach & can be used as a substitute of chemical fungicides using either bacteria or selected fungal antagonists against the soil and seed-borne pathogens by rapid and uniform seed colonization. (Challan *et al.*, 1997)

Harman (2000) reported that genus *Trichoderma* is popularly used in organic farming and in agricultural sector widely because it releases a variety of compounds that induce systemic resistance against soil borne pathogen and enhances crop productivity.

The method of using microbial symbiont within the plants activates the microbial enzymatic processes by which organic substance are mineralized and turn into inorganic substances to provide phosphate, nitrogen, potassium, etc. that can be absorbed by crop. So, biopriming act as a biofertilizer containing growth prompting microbes that produce plant nutrient and can be a good substitute for chemical fertilizers. (Wu *et al.*, 2005; Bais *et al.*, 2006)

Trichoderma is well known as bio-control agent through various mechanisms e.g. antibiosis, competition, enzymatic hydrolysis and mycoparasitism (Mascarin *et al.*, 2012). Various experiments also have suggested that colonization of plants with *Trichoderma* enhances the water-stress tolerance of plants through genetic regulation by coding for antioxidant enzymes or other transcriptional factors. (Mastouri *et al.*, 2012)

2.3. Beneficial effect of priming in crops

2.3.1. Seed priming for improving the planting value of different crop seeds

Bensen *et al.* (1990) demonstrated in soybean crop that hypocotyls growth rate is directly associated with the amount of Gibberellic acid (GA3). So, seed priming with GA3 (hormonal priming) enhanced plant height followed by KCl, KH₂PO₄ which was due to the improved and faster plant emergence.

Nagar *et al.* (1998) also reported that hydropriming had significant effects on field emergence, its rate and early seedling growth in maize crop and it improved the field establishment and plant growth both at vegetative and maturity stages.

Cheng and Bradford (1999) stated that crop establishment composed of sequence growth stages of crop plants that includes seeding, seed germination, seedling emergence and development up to that stage where seedlings could be expected to grow at maturity. Priming causes improvement in seed vigor in terms of radicle, plumule length and their root shoot ratio and fresh weight that shows early, uniform emergence and good stand establishment even in partially deteriorated seeds. Seed priming with various salts of calcium, potassium and growth regulators etc. are proved to be best for enhancing vigorous seeds and better stand establishment improving overall planting value of crop. (Basra *et al.*, 2003; Shabbir *et al.*, 2014)

Ruan *et al.* (2002) and Farooq *et al.* (2008) conducted an experiment in wheat and reported that hydropriming diminished mean emergence time, enhanced seedling emergence and produced better stand establishment.

Basra *et al.* (2003) conducted an experiment to observe the duration of priming treatment in wheat and reported that wheat seeds respond to hydropriming for 48 h showed the maximum invigoration followed by priming for 24 hours. These findings confirmed the improvement of germination rate and percentage could be achieved by hydropriming for longer duration. Filho and Kikuti (2008) suggested same result of improvement in speed of germination and speed of seedling emergence in cauliflower.

Yu-jie *et al.* (2009) reported on mass production of China aster (*Callistephus chinensis* Nees.) revealed that hydro-primed seeds with 500 ml of water per 1 g of seeds for 48 h at 15°C recorded highest speed of germination in poor quality partially deteriorated seeds even in unfavorable weather conditions during seed development and maturation.

Anese *et al.* (2011) conducted an experiment to study the effect of seed priming in improving endosperm weakening, germination and seedling development of *Solanum lycopersicum* and reported that hydro-priming for 15 days at 15 °C was useful a method to improve seed germination and seedling development of *Solanum lycopersicum*.

Nik *et al.* (2011) reported the impact of biological and chemical fertilizers (N, P) on chlorophyll content in *Artemisia annua* L. that Bio-phosphorus (*Bacillus* and *Pseudomonas*) and Vermicompost fertilizer had better impact on chlorophyll content than chemical fertilizer and improved the planting value of crop.

Ahmadvand *et al.* (2012) conducted both laboratory and green house experiments to evaluate effect of seed priming with potassium nitrate (KNO₃) on germination and emergence traits of two soybean cultivars cv. Gorgan-3 and cv. Sahar. They reported that KNO₃ seed priming caused a significant increase in planting values e.g. germination and emergence percentage, radicle and plumule length, seedling dry weight, plant height, plant leaf area and plant dry weight with respect to non-primed control seeds.

Elouaer and Hannachi (2012) conducted a germination experiment in which safflower seeds primed with 5 g/l NaCl and KCl solutions and concluded that NaCl seed priming had the highest germination percentage, germination index, shoot and root length followed closely by KCl priming & control.

Shehzad *et al.* (2012) conducted experiment to evaluate the effects of hydro-priming, halopriming with KNO₃ and CaCl₂ (1% solution) on seed emergence and seedling growth of forage sorghum. All the priming treatments significantly affected the fresh weight, shoot length, number of roots, root length, vigor index, time to start emergence, time to 50% emergence and energy of emergence, mean emergence time.

Ahmadi *et al.* (2015) studied the effects of some biological fertilizers on growth parameters of three barley cultivars: Yousef, Nosrat and Reihan, and different biological fertilizers and found out that Bio-phosphorus improved morphological characters e.g. emergence %, shoot length, volume of seminal roots, and wet and dry weight.

Haroni *et al.* (2015) conducted an experiment on effect of seed halopriming with potassium nitrate (KNO₃) for 48 h on germination and emergence traits of *Cercis siliquastrum* L seeds resulted in significant enhancement in emergence and shoot length, root length, collar diameter, shoot dry weight, root dry weight, number of leaves, leaf area and seedling quality index compared to control.

Tahami *et al.* (2017) treated the partially deteriorated Basil (*Ocimum Basilicum* L.) seeds with biofertilizers: Nitroxin (containing *Azotobacter* sp. and *Azospirillum*), Bio-phosphorus (containing *Bacillus* sp. and *Pseudomonas* sp.), Mixture of Nitroxin & Bio-phosphorus. The results showed that there was significant improvement in plant height, number of branches, plant dry matter and leaf area index, number of branches, were obtained from the plants treated with Bio-phosphorous.

Pehlivan *et al.* (2018) investigated the effects of biopriming with *Trichoderma viride* on tomato (*Solanum lycopersicum* L.) seeds were drought stress. They reported significant improvement in root colonization induced changes in growth performance indexes like root growth, root branching, and leaf number as compared to the untreated seedlings & also effective in inducing the drought tolerance of tomato plant by decreasing H₂O₂ concentration and activating the antioxidant enzymes.

2.3.2. Effect of seed priming on physiological quality of crop

Many researchers reported that seed priming and seed hardening treatment in the seeds with different chemicals like Ca(NO₃)₂, KNO₃, NH₄(SO₄)₂, NaCl, KCl, KH₂PO₄ and Mg(NO₃)₂ at various concentrations which significantly improve seed germination and healthy seedling establishment may be due enhancement in the water uptake, amylase activity, protease activity, solubilization of nitrogen from endosperm to growing embryonic axis & improves the other biochemical parameters i.e. nitrate reductase activity, chlorophyll content etc. in different crop (Mandal and Basu, 1984; Graf *et al.*, 1987; Bose and Mishra, 1999; Sharma and Bose, 2006; Anaytullah and Bose, 2007) also reported that KH₂PO₄ priming recorded relatively positive effect on germination because phosphorous reserves in the seed play very important role in the metabolism of germinating seed.

Raun *et al.* (2002) reported that priming the rice seed with KCl (halo-priming) improved its germination index. Greater efficiency of seed priming with KCl is may be due to the osmotic advantage that K⁺ has in improving cell water saturation and that acts as co-factor in the activation of numerous enzymes (Taiz and Zeiger, 2002).

Tajbakhsh *et al.* (2004) in onion and Venkatasubramaniam, Umarani (2007) in onion & tomato respectively reported about increased germination percentage, rate of germination and uniformity of germination and seed vigour along with other quality parameters due to seed priming.

Afzal *et al.* (2008) and Bakht *et al.* (2011) reported in various experiments that halo-priming with CaCl_2 improved salt tolerance of wheat cultivars due to improvement seedling vigor, increased sugar content as well as enhanced K^+ , Ca^{2+} accumulation and decreased Na^+ accumulation in the seedlings.

Moradi and Younesi, (2009) conducted an experiment in the sorghum seeds by hydro-priming for different time (12, 24 and 36 hours) and they reported that hydro-priming improved the percentage and mean emergence time (MET) of seeds at sub-optimal temperature of 15°C . Seed treatment for 12 and 24 hours had a positive and significant effect on percentage and speed of emergence.

Mohseney *et al.* (2010) evaluated the effect of seed priming with water and control on corn varieties (704 and 640 K.SC). They reported that varieties maximum speed of germination was recorded for hydropriming. Xiaoying *et al.* (2005) also observed that hydropriming can overcome the germination barriers related to seed coat in triploid watermelon seeds.

Aymen and Hannachi (2012) carried out a study to evaluate the effect of NaCl seed halo-priming (Conc. 5, 10, 15 and 20 g/l) for 12, 24 and 36 hours on germination and early growth of safflower (*Carthamus tinctorius* L.). They concluded that different priming concentrations and duration have significant effect on total germination percentage, mean germination time in seeds.

Nagaraju *et al.* (2012) reported on bio-primed *Trichoderma harzianum* on a highly susceptible sunflower cultivar seeds to evaluate their ability to promote growth and induce resistance in sunflower against downy mildew disease caused by *Plasmopara halstedii*. They concluded that priming increased seed germination and vigour index that ultimately results in enhancing vegetative and reproductive growth parameters (e.g. plant height, early flowering, reduced crop duration, ear head size and crop yield under field condition) by increasing biotic stress in crop with respect to control.

Tiwari *et al.* (2014) studied the effect of hydropriming on seed quality parameters, growth and yield in six varieties of pigeonpea (*Cajanus cajan* L.): NDA 1, Bahar, LRG 30, UPAS 120, TS 30 and Pusa 2002-2 for 6 hours. They reported that hydro-primed seeds significantly enhanced the seed germination, seedling length, seedling dry weight, vigour index I and II and finally test weight and grain yield.

Khormizi *et al.* (2015) conducted an experiment to study the effect of seed priming on morphophysiological characteristics of seedlings of chickpea (*Cicer arietinum* L.) under salinity stress with osmotic solutions of NaCl and PEG and CaCl₂. They reported enhancement in Leaf area, membrane stability index, relative water content and leaf proline content in seedlings grown from seed priming, as compared to control.

Lopez *et al.* (2015) reported that *Trichoderma* species were found effective as compost activator in rice straw-based compost by enhancing the nutrient content of the compost. It also produced different amounts of metabolites that inhibit the growth of *S. rolfsii* and significantly reduce the disease incidence of cucumber.

Qasemin and Rai (2016) conducted an experiment to evaluate the effects of bio-priming with bio-fertilizer (*Trichoderma*) w.r.t. durations of priming on germination percentages, vigour and viability of maize (*Zea mays* L.) seeds and reported significant influence on germination percentage, vigor index, seedling dry weight and seedling length of maize seeds.

Sridevi *et al.* (2016) conducted an experiment to determine the influence of seed priming with water, KH₂PO₄ (2%) and *Pseudomonas fluorescens* (20%) on seeds of foxtail millet for their physiological quality. They reported that among the given treatments, seeds primed with *Pseudomonas fluorescens* showed early germination, higher germination, shoot and root length, dry matter production, vigour index and seed metabolic efficiency followed by KH₂PO₄ and hydro-primed w.r.t. non-primed seeds.

Saleem *et al.* (2017) investigated the effects of seed priming (halopriming with calcium chloride (CaCl₂), potassium nitrate (KNO₃), potassium chloride (KCl) and hydropriming on germination and seedling vigor of *Gerbera jamesonii* and *Zinnia elegans*. Halopriming was found out to be an effective priming technique for invigoration of gerbera and zinnia seeds by reducing time to 50% germination, higher final germination

percentage, seedling vigor, and fresh weight and dry weight of the seedlings over hydro-priming.

2.3.3. Effect of seed priming on grain quality, crop growth, yield and productivity

Du and Tuong (2002) examined the effect of halo-priming on rice seeds and found out that plant density, earlier flowering, number of final tillers and grain yield were high in those crops which are primed with 14% KCl and CaHPO₄ solution even under suboptimal and stress conditions.

Ojaghloo *et al.* (2007) in their study reported that maximum protein, plant growth, plant height, branch number, fresh and dry weight and ultimately grain yield in barley (*Hordeum vulgare* L.) & safflower was obtained by pertaining application of phosphate solubilizing microorganisms (*Azotobacter* biofertilizer, bio-phosphate fertilizer).

Ghassemi-Golezani *et al.* (2010) reported that the highest yield attributes in chickpea seeds with 16h of hydropriming. The higher values obtained for yield and yield attributes may be due to increased germination rate and greater germination uniformity, growth parameters, periodic dry matter accumulation with seed priming. Simillar result was found by Basra *et al.* (2004).

Yari *et al.* (2010) conducted an experiment to analyse the effect of different seed priming techniques e.g. 20% PEG, 2% KCl, 0.5% & 1% KH₂PO₄ on germination and early growth of wheat. They reported that KCl & KH₂PO₄ enhanced germination, emergence, growth, stand establishment, tillering, grain and straw yields and harvest index of wheat.

Li *et al.* (2011) conducted laboratory experiments to evaluate effect of hydropriming freshly harvested pyrethrum (*Tanacetum cinerariifolium*) seeds and concluded that hydropriming shortened the duration of Mean Germination Time (MGT) and improved the germination percentage resulting the increase in yield attributing characters.

Gupta and Singh (2012) conducted an experiment in chickpea seeds and reported that hydropriming improved plant height, nodule dry weight, seed index, dry matter accumulation, yield and yield attributes. They also proposed that soaking in water

for about 8h significantly influenced plant height and nodule dry weight, higher pods/plant, seeds/pod, grain and biological yield with respect to un-primed seeds.

Ramansyah *et al.* (2013) carried out priming with bio-inorganic fertilizer (e.g. Bio NPK) in two cultivars of local maize (*Zea mays ceratina* L., Faramita-hybrid) to analyze yield quality within total plant biomass, grain number/ear, hundred seed weight and harvest index. They reported that all yield attributing characters are significantly enhanced and also biofertilizer based on microbial application is an effort to minimize dependency on chemical fertilizer & could be a strategy for achieving sustainable agriculture for the local corn cultivation.

2.3.4. Economic impact of priming treatments in seeds

The method of seed priming is a simple, low-cost, less-risk and powerful technique for improvement in seedling emergence, seedling vigour and yields of several field crops by improved seedling emergence percent, seedling vigor as well as agronomic traits including yield of the crop species resulting less variable input cost and improve farmer's livelihood. (Maiti and Pramanik, 2013). Seed priming treatment recorded maximum filled grains / panicle, grain weight / panicle and economic parameters i.e., gross return, net return and B:C ratio (Yadav, 2016)¹

Sharma *et al.* (2017) conducted field study to analyze the effect of seed priming on pod and seed yield along with economics of okra (var. A-4, Phule Utkarsha and VRO-6) cultivation. They concluded that hydropriming in A-4, halopriming with 1% CaCl₂ in VRO-6 and solid matrix priming in cv. Phule Utkarsha, were found to be the most economical for pod and seed production with maximum B-C ratio with respect to other treatments.

2.4. Seed priming and its effect on rice

2.4.1. Seed priming for improving the planting value of rice seeds

Farooq *et al.* (2005) studied the influence of seed priming on the improvement of agronomic traits of direct sown rice and found significant improvement in seed germination, field emergence, allometry, kernel yield by hydropriming and osmo-priming with KCl and CaCl₂ to 24 hours. In another study, Farooq *et al.* (2007) observed similar enhancing effects on planting value of different priming treatment on transplanted rice.

Ramesh and Singh (2006) conducted an experiment on seed priming in rice on four varieties (Pusa Basmati-1, Basmati-385, Saket-4 and IR-36) with different concentrations of K_2SO_4 salt for different durations. They reported that priming with K_2SO_4 for 24h was effective in enhancing germination, seedling growth, root length, no. of roots/seedling, shoot length, fresh and dry weights of seedling and germination. Among the four cultivars of rice evaluated, IR-36 was highly responsive to K_2SO_4 salt particularly at 1.0 % concentration.

Zhu *et al.* (2010) conducted an experiment by using hybrid rice cultivar-“Shan-you 63” and they concluded that germination percentage, germination energy and vigor index, seedling establishment rate, seedling height and seedling weight were enhanced & emergence time was shortened by priming with 0.5% PVA (polyvinyl alcohol) + 1.0% KNO_3 . He also suggested that leakage of soluble sugar in primed seeds were significantly decreased.

Birendra and Shambhoo (2011) reported that all the hydropriming treatments resulted in enhancement of seed germination at both first and final count and seedling vigour, relative growth index and mean daily emergence for rice. Silva and Silva (2016) also reported effect of hydro-priming and $ZnSO_4$ priming enhancing seedling length, germination percentage w.r.t. control in “Puita” cultivar of rice.

Subedi *et al.* (2015) studied the effect of different priming methods (Hydro-priming, $CaCl_2$, KCl , KNO_3 , $NaCl$) in rice. They reported that both hydro priming and PEG improved germination energy, germination index, germination speed, radical length, and plumule length with respect to other priming treatments.

Pant and Bose (2016) reported the beneficial impacts of seed priming to overcome moisture stress during germination of partially deteriorated rice seeds. They concluded that rice crop raised from hydro and osmo-primed seeds showed an increment in germination, vigour index, germination index, fresh and dry weights, plant height, number of leaves, LAI, CGR, RGR, NAR, effective tillers, nitrogen proline, chlorophyll content, nitrate reductase and super oxide activities in leaves w.r.t. control leading to better planting value of crops.

2.4.2. Effect of seed priming on physiological quality of rice

Kokila (2014) conducted an experiment on seed priming of rice hybrid “CORH 4” and its parental lines “COMS 23A” and “CB 174R” revealed that bio-primed with 15 % liquid phosphor-bacteria or 20 % liquid-*Azophos* for 12 h had registered earlier germination, higher germination percentage, longest root and shoot, maximum dry matter production and vigour index w.r.t. hydro-primed and control seeds.

Khan *et al.* (2016) conducted experiment on sterilized seeds of Shalimar rice-I which were primed with ZnSO₄, KH₂PO₄(Halo-primed), bio-primed with vermiwash and hydro-primed. Various priming treatments significantly improved seed germinability, seed vigour, root and shoot dry weight & length over control.

Sivakumara *et al.* (2016) conducted an experiment to observe the impact of hydropriming & biopriming with Phospho-bacteria on rice variety “cv. MDU 6” with different concentrations and durations. The study revealed that biopriming with Phospho-bacteria (20 % conc.) for 24 h expressed higher values most of the parameters e.g. speed of germination, germination (%), root length, shoot length, dry matter production and vigour index over hydro-primed and control seeds. Similar result was confirmed by Kavitha (2011) priming with liquid phosphor-bacteria (15%) for 12 h in rice seeds.

Geetha *et al.* (2017) conducted a study to determine the effect of seed bio-priming with liquid phspho-bacteria on germination and vigour of rice var. PMK (R) 4 under salinity stress condition of NaCl. They reported that rice seeds bio-primed with combinations of *Azospirillum* + phosphobacteria @ 20% solution for 18 h performed better in germination and vigour followed by 20% of *Azospirillum* alone. So, they suggested that phosphor-bacteria as a best seed enhancement technique for improving physiological qualities of rice under salinity stress condition w.r.t. hydropriming and control.

Somasundaram and Baskaran (2017) reported improved crop establishment and productivity by using hydro-primed and bio-primed (4% *P. fluorescent*) for 12h in partially deteriorated rice seeds in uplands & recorded higher germination and vigour and seed longevity in bio-primed seeds w.r.t. hydropriming.

An experiment was conducted by Srivastava *et al.* (2017) to investigate the absorption and utilization of nitrogen by rice seed through halo-priming with Nitrate salts. They reported that seed priming with KNO₃, Mg (NO₃)₂ perform better than hydro-primed and control sets in enhancing seed germination and nitrate reductase enzyme activity in leaves that promote the nitrogen accumulation in different plant parts e.g. enhanced soluble and insoluble nitrogen content in seed, nitrogen gathering capacity in seed and straw resulting in higher yield.

Devi *et al.* (2019) conducted an experiment on bio-priming of rice seeds with *Trichoderma harzianum* isolates for their efficacy of bio-controlling ability and improvement in seedling vigour of the plant. They reported that the treatment of *Trichoderma* recorded highest seed germination (92%) and seedling vigour index which was superior over *Trichoderma viride*.

2.4.3. Effect of seed priming on grain quality, crop growth, yield and productivity of rice.

Basra *et al.* (2003) studied the effect of osmo-priming with different durations on yield and yield components of canola rice and observed that maximum branches per plant were recorded in fresh osmo-primed seeds for 8h followed by 4h and number of seeds per pod was higher in osmo-primed seeds for 4h. Similarly, higher 1000-grain weight, biological yield and seed yield were observed in previously osmo-primed seeds for 4h w.r.t. control.

Mahajan *et al.* (2011) conducted an experiment to improve the performance of dry direct seeded basmati rice with osmo-priming, water hardening and hydro-priming. They concluded that crop with hydro-priming gave superior performance in enhancing grain yield, panicles/m², filled grain per panicle, 1000-grain weight, germination index, seedling vigour index and germination energy and significantly reduce mean germination time followed by water hardening.

Sarkar (2012) conducted an experiment to study the effect of seed priming under flooded and non-flooded conditions in rice variety Swarna by priming with water and 2% Jamun (*Syzygium cumini*) leaf extract (hormonal priming) and found out that priming improved seedling establishment, greater accumulation of biomass, hastened

the activities of total amylase and alcohol dehydrogenase and ultimately on yield attributing parameters under flooding condition. There was also significant decrease in weed biomass in field.

Shoaei *et al.* (2012) conducted an experiment to evaluate effect of bio-phosphorus formulation on yield and yield components of maize (*Zea mays*) in the condition of normal and deficit irrigation. They reported that biological fertilizer consisting of bio-phosphorus (*Pseudomonas* sp + *Bacillus* sp) increased nutrient absorption, biomass, forage yield under both normal and drought stress condition in maize.

Srivastava and Bose (2012) conducted a study on improvement in yield attributes in rice by use of seed halo-priming with nitrate salts e.g. KNO_3 and $\text{Mg}(\text{NO}_3)_2$ in rice seeds and concluded that priming resulted in significant earlier seedling emergence, attaining maturity and emergence of number of productive tillers & filled spikeletes, LAI, CGR, NAR, grain yield, biomass yield and harvest index. This result was confirmed by Tilahun -Tadesse *et. al.*, (2013) in rainfed lowland rice.

Jisha and Puthur (2014) recorded positive influence of halo-priming on enhancement of metabolism and other physiological parameters with respect to hydropriming in rice seeds which ultimately resulted in improved seedlings vigour and tolerance under stress conditions. Kota *et. al.*, (2014) confirmed this finding in six different rice under seed varieties with various priming media and concluded that may be due to better mobilisation of food reserve.

Rahman *et al.* (2015) conducted an experiment to study about the effect of hydropriming, osmo-priming with 3% ZnSO_4 solution and bio-priming with *Trichoderma harzianum* on seedling establishment and yield performance of dry direct seeded Boro (winter) rice. They reported that osmo-priming & bio-priming gave higher number of seedlings, length and dry matter of shoot-root and yield with respect to hydropriming.

Tiwari *et al.* (2015) conducted a field experiment on one year old two rice (*Oryza sativa* L.) varieties Viz., Pusa Sugandha-5 and Sambha Mahsoori (partially deteriorated) by priming with 0.25% KNO_3 solution. He stated that there was significant

increase in the germination, seedling vigour and yield attributes in both the varieties over control under salt stress condition.

Shakori and Sharifi (2016) conducted a field experiment on contribution of two phosphate biofertilizers (Barvar2, Bio-phosphorus and Barvar2 + Bio-phosphorus) on *Vicia faba*. They concluded that the effect of phosphate biofertilizer was significant effect on number of pods per plant, plant height, hundred seed weight and seed yield. So, they suggested that biofertilizer can be raised as an alternative for chemical fertilizer in faba bean for sustainable agriculture.

Kumar *et al.* (2018) reported that seed priming in rice seeds with distilled water (hydro), $Mg(NO_3)_2$ salt (halo) and kinetin & salicylic acid (hormonal) significantly enhance the grains/panicle, test weight, harvest index, panicle number/hill, panicle length and amylose content and ultimately influencing the yield attributes and grain quality parameters in both timely and late sown rice crops.

Singh *et al.* (2018) conducted an experiment to assess the effect of priming with bioformulations (NPK liquid formulation + Zn solubilizing bacteria and bio-grow) on quality and physiological parameters of groundnut. They reported that application of bioformulation as liquid NPK with Zn solubilizing bacteria resulted in better physiological growth (LAI, CGR, RGR), highest kernel & haulm, protein, oil yield of groundnut crop followed by bio-grow application.

Vanitha and Kathiravan (2019) reported on halo-primed of Pigeonpea seeds with $CaCl_2$ (2%), $ZnSO_4$ (100 ppm), KH_2PO_4 (1%), KCl (1%), $MnSO_4$ (100 ppm) and water. Primed seeds of $ZnSO_4$ showed maximum increased in germination %, drymatter production, number of branches, flowers, pods, seed yield and 1000 seed weight in kharif season.

2.4.4. Economic impact of priming treatments in rice seeds

Balasubramanian and hill (2002) stated that seed priming is a promising cost-effective technology that requires less labour, water, pesticides and weedicides with respect to conventional rice cultivation ensuring high benefit cost ratio to farmers.

Binang *et al.* (2012) conducted a field experiment to evaluate the effect of a range of priming treatments (hydropriming, Osmo-priming, vitamin priming, osmo-

hardening) on agronomic performance of New Rice for Africa (NERICA) and to quantify their benefits to farmers. Seed priming had significant impact on physiological and yield attributing characters. Based on net returns, osmo- & vitamin priming was recorded as the most cost-effective method for NERICA rice with respect to other priming treatments.

Meena *et al.* (2013) reported on hydropriming of seed improves the water use efficiency, grain yield and net economic return of wheat under different moisture regimes. He stated that the priming with plain water and pregerminated seeds improved germination indices, seedling growth and crop establishment.

Yadav (2016) studied the effect of soil type, irrigation levels and seed priming on direct seeded rice of variety “Narendra-359”. They reported that hydropriming treatment recorded the maximum values of growth parameters like plant height, tiller /m², dry matter accumulation, active leaf count, panicles/m², filled grains/panicle, grain weight/panicle & economic parameters i.e. gross return were found out to be 10858/ha and 11357/ha resulting the B-C ratio 37.5%.

Pandit and Mookherjee (2017) studied the effect of seed priming with respect to foliar application of micronutrients on direct seeded upland rice (*Oryza sativa* L). They reported that Significantly highest yield was recorded in seed halo-priming with 2.2% CaCl₂ solution & priming had a greater impact in production economics (return rupee-1 of investment is 1.45) of direct seeded rice with respect to foliar application.

Pal *et al.* (2020) conducted an experiment on influence of nutrient management on yield and economics of rice with three crop establishment methods, viz. puddled transplanted rice (M-TPR), wet direct-seeded rice (M2-DSR-wet) and dry direct-seeded rice (M3-DSR-dry) with five different nutrient management methods- 100% STCR Based Dose of Fertilizer + ZnSO₄ @ 25 kg/ ha, 75% DF + 25% STRC, 100% STCR based Recommended dose of Nitrogen through Vermicompost. They reported significantly higher plant height, yield attributing characters (number of tillers, panicles, filled grains per panicles and test weight) resulting higher C:B ratio (1.73) with respect to control giving farmers an alternative method for rice production.

MATERIALS AND METHOD

The present research was carried out to evaluate the efficiency of various priming agents in enhancing crop performance of partially deteriorated rice seeds. The whole experiment was conducted in three parts. The details of the material used and methods employed during the course of investigation were presented in this context.

Expt. I: Preparation of seed priming chemicals and seed priming treatments (Laboratory experiment-1).

Expt. II: Effect of seed priming on the field performance of partially deteriorated rice seeds (Field experiment).

Expt. III: Examining the effects of priming on the quality parameters of the harvested seeds (Laboratory experiment-2).

3.1. Laboratory experiment-1

3.1.1. Experimental site

This experiment was conducted in the Dr. G. V. Chalam Seed Testing Research Laboratory, Department of Seed Science and Technology, OUAT, Bhubaneswar during 31st August 2019 to March-May 2020.

3.1.2. Experimental material

The experimental material for the present investigation consisted of seeds of two different rice varieties namely Naveen and Hiranmayee of Kharif (2018) and Rabi (2018-19) strains. Partially deteriorated seeds of these varieties were obtained from laboratory. The seeds after proper grading were subjected to the various priming treatments.

3.1.3. Evaluation of seed quality parameters before priming

The quality parameters of the rice seeds were evaluated in factorial CRD with 4 replications in the Research Laboratory of the Department of Seed Science and Technology, OUAT, Bhubaneswar.

3.1.3.1. Seed germination percentage

Germination test was conducted by TP method (ISTA, 1985). Total four hundred seeds of two varieties (old & fresh each) and 100 seeds of each strain were arranged on moist blotting paper in four different petri-dish and were kept in germinator at $(25^{\circ}\text{C}\pm 1)$ °C temperature. On the day of final count (14 day), the number of normal seedlings were counted and percentage of germination was computed.



Fig.3.1: Determination of seed germination percentage by TP method

3.1.3.2. Seed vigour

Seedling vigour index (SVI) of seeds for each treatment were calculated as per the formula given by Abdul-Baki and Anderson (1973).

$$\text{SVI- I} = \text{Germination (\%)} \times \text{Mean seedling length (cm)}$$

$$\text{SVI- II} = \text{Germination (\%)} \times \text{Mean seedling dry weight (mg)}$$

3.1.3.3. Priming treatments

The priming treatments of rice seeds were performed in the Research Laboratory of the Department of Seed Science and Technology, OUAT, Bhubaneswar. Seeds of the two rice varieties of different strains were packed in different packets of 200g each (56 nos. total) and were subjected to fourteen priming treatments (including control). The details of the priming treatments of the two rice varieties were presented in the following table.

<u>Varieties</u>	<u>Seed lots</u>
V ₁ - Naveen	S ₁ - Kharif 2018 (One- year old seeds)
V ₂ - Hiranmayee	S ₂ - Rabi 2018-19 (fresh seeds)

Priming solution formulation

- (a) KNO₃ solution: 1200 ml of 0.3% KNO₃ solution was prepared by adding 3.6g of KNO₃ in 1200 ml water.
- (b) KH₂PO₄ solution: 1200 ml of 0.5% KH₂PO₄ solution was prepared by adding 6g of KH₂PO₄ in 1200 ml water.
- (c) ZnSO₄+ MnSO₄ solution: 1200 ml of 0.3% ZnSO₄ and MnSO₄(mixture) solution was prepared by adding 3.6g of ZnSO₄ and 6g. of MnSO₄ in 1200ml water.

Methodology

Seed sample size: - V₁S₁=200g, V₁S₂=200g, V₂S₁=200g, V₂S₂=200g

- (a) Hydropriming (T₃, T₈ to T₁₄) =Seed sample of 200g each were treated with 300ml water.
- (b) Halopriming with KNO₃ (T₄) =Seed sample of 200g each were treated with 300ml and 0.3% KNO₃.
- (c) Halopriming with KH₂PO₄ (T₅) =Seed sample of 200g each were treated with 300ml 0.5% KH₂PO₄.
- (d) Halopriming with ZnSO₄ and MnSO₄ (T₆) =Seed sample of 200g each were treated with 300ml 0.3% ZnSO₄ and 0.5% MnSO₄ mixture.

Seed priming was done in two separate phases: -

(a) Hydropriming and Halopriming

The seeds (except treatments: T₁, T₂, T₇) were primed with water and salts (hydro-priming & halo-priming) in plastic containers for 30 hr. in laboratory. After priming treatments were completed, the soaked seeds were dried back to original moisture content by shade drying. The dried seeds were kept separately in small cloth bags under ambient conditions for evaluation of their field performance.

(b) Biopriming

After storage of seeds for about seven days the seeds (T₇ to T₁₄) were bio-primed with *Trichoderma*, BioNPK, Biogrow, Biophos, drought alleviating bacteria (bioformulation of *Pseudomonas*) 25-30 min. before sowing in tray.



Fig.3.2: Seed priming treatments (Hydropriming and Halopriming)



Fig.3.3: Seed priming treatments (Biopriming)

Table-3.1: Details of the seed priming treatments

Sl. No.	Treatment code	Treatment
1	T ₁	Control (Untreated)
2	T ₂	Control (Seed treatment with Thiram 2 g per kg seed)
3	T ₃	Hydropriming – Soaking in water 30 h at 25°C and drying
4	T ₄	Halopriming- Soaking in KNO ₃ (@0.3%) solution and drying
5	T ₅	Halopriming- Soaking in KH ₂ PO ₄ (@0.5%) solution and drying
6	T ₆	Halopriming- Soaking in ZnSO ₄ (@0.3%) + MnSO ₄ (@0.5%) solution and drying
7	T ₇	Seed coating (on dry seeds) with <i>Trichoderma harzianum</i> (CFU – 2 x 10 ⁶ per g) @ 15 g / kg seed
8	T ₈	Seed coating (on hydro-primed seeds) with <i>Trichoderma harzianum</i> (CFU – 2 x 10 ⁶ per g) @ 15 g / kg seed
9	T ₉	Seed coating (on hydro-primed seeds) with BioNPK (containing 1 x 10 ⁹ cfu)
10	T ₁₀	Seed coating (on hydro-primed seeds) with Biogrow (containing 1 x 10 ⁹ cfu)
11	T ₁₁	Seed coating (on hydro-primed seeds) with Biophos (containing 1 x 10 ⁹ cfu)
12	T ₁₂	Seed coating (on hydro-primed seeds) with Drought Alleviating Bacteria (bioformulation of <i>Pseudomonas</i>) + BioNPK
13	T ₁₃	Seed coating (on hydro-primed seeds) with Drought Alleviating Bacteria (bioformulation of <i>Pseudomonas</i>) + Biogrow
14	T ₁₄	Seed coating (on hydro-primed seeds) with Drought Alleviating Bacteria (bioformulation of <i>Pseudomonas</i>) + Biophos

3.2. Field experiment

3.2.1. Experimental site

The plot for field experiment was allotted in Agronomy field, OUAT, Bhubaneswar. The selected plot was located in a patch of medium land of well drained sandy loam soil.

3.2.2. Experimental materials

A portion of seeds of each priming treatment of 400 no. seeds each were counted manually and were used for raising the seed crops in the field.

The whole field experiment was done in two different phases: -

3.2.1.1. Tray sowing

Four hundred seeds under each treatment (56 nos.) were sown in 3 rows having 5cm gap in between them on a tray filled with proper levelled field soil. Total nineteen trays were used for sowing of 56 treatments (three treatments per single tray). Sprinkler irrigation was provided to maintain proper soil moisture condition. After 15-18 days, the number of seedlings that have emerged from the soil were counted and field emergence percentage was computed. The treatment T₂ was treated with Thiram 50% wp just before sowing.

3.2.1.2. Transplanting of seedlings in the field

(a) Land preparation

The field was thoroughly ploughed to make the soil well pulverized. The experiment was conducted in area of size 12,973 m². The main plot was divided into 168 sub plots of size 1.5m x 2m. The experiment was laid out in Factorial RBD with 3 replications.

(b) Raising of the seed crop

Nitrogen was applied in three splits i.e., 25% as basal, 50% at 35 DAS and 25% at panicle initiation stage. Total phosphorus was applied as basal and potash was

applied 50% at basal and 50% at panicle initiation stage, Gypsum, zinc sulfate and borax were applied as source of Sulphur, Zinc and Boron, respectively.

(c) Transplanting

The seedlings (treatments having more than 100 seedlings) were uprooted on 21 days after sowing from the tray bed on the day of transplanting. Then the seedlings were transplanted in the main field at a spacing of 20cm x 15cm with 1 seedling per hill. Total 100 seedlings were transplanted in a sub plot with 10 rows (10 plants in a row). Bulk transplanting was also done. Appropriate seed production technology was adopted to grow the crop.

(d) Irrigation

After transplanting of seedlings, flood irrigation was given through water supplying channel to facilitate availability of enough moisture to the seedlings to initiate the process of growth of the crop. Irrigation was given when required.

(e) Weeding and plant protection measures

In order to make the crop weed free hand weeding was done before top-dressing. Prophylactic plant protection measures were adopted to protect the crop from disease and pest attack. Two to three hand weeding were done as per requirements and Fipronil 0.03% GR was used to control menace of stem borer.

3.2.1.3. Field observations

Observations on growth parameters were recorded using 10 sample plants from the subplot of each treatment and replication. The following observations were recorded during investigation.

(a) Plant population at 30 DAS

After 30 days of transplanting seedlings in the field; the total no. of plant population in the field was recorded.

(b) Total number of tillers per plant

Total number of the tillers per each sample plant in each treatment and replication were counted at the final growth stage from which mean was computed.

(c) Number of effective tillers per plant

Total number of effective tillers per each sample plant in each treatment and replication were counted at final growth stage. The total numbers of effective tillers per plant were counted as the number of panicles bearing tillers. From this data, the mean was computed for each treatment.

(d) No. of days to maturity

The no. of days after sowing at which the maturity of crops was recorded.

(e) Panicle length

The length of the effective panicles in the sampled crop hills was measured from neck node to the tip and was expressed in centimeters. The average value was computed for each treatment.

(f) Number of seeds per Panicle

Total numbers of seeds formed in each Panicle in sample plants was counted and average value was computed for each treatment.

(g) Number of unfilled seeds per Panicle

Total numbers of unfilled seeds in each Panicle in sample plants was counted and average value was computed for each treatment.

(h) Seed yield per plant

The seeds obtained from the sample plants under each treatment and replication were cleaned and their weight measured by a top pan balance. From this data seed yield per plant was computed and expressed in gram.

(i) Seed yield per hectare

After threshing and cleaning, the grains obtained from each treatment and replication were processed by a seed grader and the yield was determined. From the observation data, the seed yield per hectare was computed and expressed in q/ha.

(j) Harvest index

The harvest index was calculated after calculating total crop yield obtained to total biological yield (total shoot dry matter) was calculated. (Donald, 1962; Amanullah, Inamullah, 2016)

$$\text{HI} = \frac{\text{Economic yield (Grain)}}{\text{Biological yield (Grain + Straw)}}$$

(k) 1000-seed weight

After harvest of seed crops and completion of post-harvest operation, 1000 seeds were counted from each replication under each treatment. The weight of 1000 seeds were taken by electronic balance and expressed in gram.

3.3. Laboratory experiment-2

The sowing quality of the harvested seeds were determined in the laboratory immediately after harvest by measuring germination (%), seed vigour indices by the earlier described procedures and formulae.

3.4. Evaluation of economics of seed priming treatments and seed production

The total cost of cultivation along with the cost of seed priming in each treatment was worked out. The gross return and total cost related to whole experiment were evaluated. The net return & B-C ratio was calculated using following formulae: -

$$\text{Net return} = \text{Gross return} - \text{cost of cultivation}$$

$$\text{B-C ratio} = \frac{\text{Gross return incurred from the crop yield}}{\text{Total cost incurred during the experiment (both laboratory, field)}} \times 100$$

Table-3.2: Cost of the seed priming agents

Sl. No.	Name of seed priming agent(s)	Market price (Rs. /amount)	Amount used (gram or ml/ kg seeds)	Experimental cost (Rs.) /ha
1	KNO ₃	580/ 500g	2g/ kg	174
2	KH ₂ PO ₄	690/ 500g	2g/ kg	207
3	MnSO ₄	300/500g	2g/ kg	90
4	ZnSO ₄	350/ 500g	2g/ kg	105
5	Bio-NPK	300/ 500ml	5ml/ kg	225
6	Biogrow	300/ 500ml	5ml/ kg	225
7	Biophos	100/ 100ml	5ml/ kg	375
8	<i>Tichoderma</i>	150/ 500g	15g/ kg	337.5
9	Drought alleviating bacteria	300/ 500ml	5ml/ kg	225
10	Thiram	125/ 150g	2g/ kg	125

(Notes: -**Seed rate of rice = 50kg/ ha****MSP of rice = 1800 Rs.****Cost of cultivation of rice per ha = 40,000 Rs. Gross return = MSP of rice × yield)****3.5. Statistical analysis**

The observation & data recorded on various parameters were subjected to statistical analysis by using INDOSTAT-7.1 software. The significance of difference between any two means was tested through computation of critical differences.

RESULT

The present study was carried out to evaluate the effect of seed priming for improving crop performance of partially deteriorated rice varieties (one year old and fresh seed) viz., Naveen and Hiranmayee to analyse the influence of various seed priming treatments on their laboratory and field performance. The data recorded here were statistically analysed in relation to different characters and significance of results were also verified. The experimental results are presented under the following four sub headings.

4.1. Laboratory studies

4.1.1. Effect of seed priming on germination (%), SVI-I and SVI-II in rice

4.1.1.1 Germination percentage (first count)

The data on the seed germination percentage (first count) of one year old and fresh seed as influenced by different seed priming treatments is presented in the Table 1. Among all the treatments T₈ resulted highest germination percentage followed by T₇ in both Naveen and Hiranmayee. There is no significant difference between T₈ (34.90), T₇ (34.75) **in Naveen and T₈ (35.90), T₇ (35.09) in Hiranmayee**. Similarly, there is no significant difference in between treatments like T₁₃, T₄, T₁₀, T₃, T₉, T₁₁, and T₆ in Hiranmayee while in Naveen it was T₁₀, T₆, T₁₃, T₅, T₉, T₃, T₁₁, T₄, T₁₂ and T₁₄. The lowest seed germination percentage (first count) was recorded in T₁ i.e., 26.33 (Naveen) and 29.37 in (Hiranmayee). The interaction effect shows that significant difference among the different seed lots (one year old and fresh collection seeds) and the priming treatments.

4.1.1.2. Germination percentage (final count)

Data pertaining to germination percentage before seed treatment as influenced by one-year old, fresh seeds and seed priming treatments of two rice varieties present in Table -2. The mean germination percentage of one-year old, fresh seeds and seed priming treatments differ significantly immediately after seed treatments both in Naveen and Hiranmayee varieties.

Table 4.1: Seed germination percentage (First count) of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Seed germination percentage (First count)					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	26.67 (31.09)	32.62 (34.83)	29.64 (32.99)	26.33 (30.87)	32.40 (34.70)	29.37 (32.81)
T₂	26.99 (31.30)	34.30 (35.85)	30.65 (33.61)	26.33 (30.87)	35.33 (36.47)	30.83 (33.73)
T₃	30.00 (33.21)	35.91 (36.82)	32.96 (35.03)	28.67 (32.37)	37.00 (37.46)	32.84 (34.96)
T₄	30.12 (33.29)	35.41 (36.52)	32.77 (34.92)	29.67 (33.00)	36.67 (37.27)	33.17 (35.17)
T₅	30.34 (33.42)	35.65 (36.66)	33.00 (35.06)	30.14 (33.30)	33.33 (35.26)	31.73 (34.28)
T₆	30.53 (33.54)	35.97 (36.85)	33.25 (35.21)	28.99 (32.58)	35.67 (36.67)	32.33 (34.65)
T₇	31.33 (34.04)	38.17 (38.16)	34.75 (36.12)	30.83 (33.73)	39.44 (38.84)	35.09 (36.32)
T₈	30.67 (33.63)	39.13 (38.72)	34.90 (36.21)	31.47 (34.12)	40.33 (39.42)	35.90 (36.81)
T₉	29.96 (33.18)	35.99 (36.87)	32.98 (35.05)	30.00 (33.21)	34.99 (36.27)	32.50 (34.76)
T₁₀	29.87 (33.13)	36.67 (37.27)	33.27 (35.22)	31.35 (34.05)	35.67 (36.67)	33.51 (35.37)
T₁₁	29.47 (32.88)	36.34 (37.07)	32.90 (35.00)	28.33 (32.16)	36.34 (37.07)	32.34 (34.66)
T₁₂	30.00 (33.21)	35.32 (36.46)	32.66 (34.85)	28.67 (32.37)	35.67 (36.67)	32.17 (34.55)
T₁₃	29.29 (32.77)	36.84 (37.37)	33.07 (35.10)	30.78 (33.70)	35.67 (36.67)	33.23 (35.20)
T₁₄	29.89 (33.14)	35.40 (36.51)	32.65 (34.85)	28.67 (32.38)	34.67 (36.07)	31.67 (34.25)
Mean	29.30 (32.73)	35.93 (36.82)		29.65 (32.99)	35.98 (36.85)	
S.E.m (±)	S	T	S x T	S	T	S x T
	0.096	0.254	0.359	0.139	0.369	0.523
CD (0.05)	0.272	0.719	1.018	0.396	1.047	1.481

(Figures in the parenthesis are arc sine transformed values)

Table 4.2: Seed germination percentage (final count) of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Seed germination percentage (final count)					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	80.3 (63.7)	88.8 (70.4)	84.6 (66.8)	80.7 (63.9)	89.3 (70.9)	85.0 (67.2)
T₂	81.3 (64.4)	90.7 (72.2)	86.0 (68.0)	81.0 (64.2)	91.0 (72.5)	86.0 (68.0)
T₃	87.3 (69.1)	92.3 (73.9)	89.8 (71.4)	87.7 (69.4)	92.4 (73.9)	90.0 (71.6)
T₄	88.3 (70.0)	91.3 (72.9)	89.8 (71.4)	87.3 (69.1)	91.3 (72.9)	89.3 (70.9)
T₅	87.3 (69.1)	91.0 (72.5)	89.2 (70.8)	86.7 (68.6)	91.0 (72.5)	88.8 (70.5)
T₆	88.0 (69.7)	91.7 (73.2)	89.8 (71.4)	86.7 (68.6)	91.7 (73.2)	89.2 (70.8)
T₇	88.7 (70.3)	94.7 (76.6)	91.7 (73.2)	87.3 (69.2)	94.0 (75.8)	90.7 (72.2)
T₈	87.0 (68.8)	93.9 (75.7)	90.5 (72.0)	87.3 (69.1)	93.0 (74.7)	90.2 (71.7)
T₉	87.7 (69.4)	92.3 (73.9)	90.0 (71.6)	87.3 (69.1)	93.7 (75.4)	90.5 (72.0)
T₁₀	86.7 (68.5)	91.7 (73.2)	89.2 (70.8)	87.7 (69.4)	91.7 (73.2)	89.7 (71.2)
T₁₁	85.3 (67.4)	92.0 (73.5)	88.7 (70.3)	86.0 (68.0)	92.0 (73.6)	89.0 (70.6)
T₁₂	88.0 (69.7)	91.7 (73.2)	89.8 (71.4)	86.7 (68.6)	91.7 (73.2)	89.2 (70.8)
T₁₃	87.7 (69.4)	91.7 (73.3)	89.7 (71.3)	87.3 (69.1)	91.3 (72.9)	89.7 (71.3)
T₁₄	87.3 (69.1)	92.7 (74.3)	90.0 (71.6)	87.7 (69.5)	92.7 (74.3)	90.2 (71.7)
Mean	86.5 (68.5)	91.9 (73.5)		86.2 (68.4)	92.0 (73.6)	
S.E.m (±)	S	T	S x T	S	T	S x T
	0.043	0.114	0.161	0.043	0.117	0.165
CD (0.05)	0.122	0.324	0.458	0.125	0.332	0.469

(Figures in the parenthesis are arc sine transformed values)

The fresh seed lot was recorded highest germination percentage 91.9 % (Naveen) and 92.0 % (Hiranmayee). The data obtained from table represents seed germination for Naveen in both the cases i.e., one year old and fresh seeds after seed priming treatments ranged from 80.3 - 88.7% and 88.80- 94.7% while for Hiranmayee it ranged from 80.7 - 87.7% and 89.3 - 94.0% respectively. Among all the treatments T₇ resulted highest germination percentage followed by T₈ in both Naveen and Hiranmayee. Interaction effect also reflected significantly among the two different stages of seed and priming treatments. The lowest percentage of seed germination was recorded in T₁ i.e., 84.6% & 85.0% (Naveen) and (Hiranmayee).

4.1.1.3. Seedling Vigour Index -I (SVI-I)

Data on the Table 3 indicated seedling vigour index -I which represents that T₃ and T₇ are statistically at par (Hiranmayee) to the priming treatments. Data on the table also represents there is no significant difference between the treatments of T₄, T₈ and T₁₂. The experimental finding also represents T₄, T₁₀, T₁₂ and T₁₃ are statistically at par so also T₂, T₅, T₆, T₉ and T₁₄. There is no significant difference between the treatments of T₉ and T₁₁. Among all the treatments, seedling vigour index- I was recorded highest in T₇ and T₃ (Hiranmayee) i.e., 2276.69 and 2276.0 respectively followed by T₈, T₄, T₁₂ i.e., 2250.5, 2249.58, 2241.85 respectively. Among all the treatments T₁ recorded lowest vigour index- I in Hiranmayee (2031.5). The data in this table represents SVI-I on Naveen variety which revealed similar trends in Hiranmayee. In case of Naveen, T₇ and T₈ both are statistically at par i.e., 2301.87, 2296.69 respectively followed by T₁₂, T₆, T₄, T₃, T₉ and T₁₀. The lowest seedling vigour index -I was observed in T₁ (1846.5- Naveen). The interaction effect shows that significant difference among the different seasons (old and fresh seeds) and the priming treatments with respect to seedling vigour index-I.

4.1.1.4. Seedling Vigour Index -II (SVI-II)

Significant variation in seedling vigour index-II was observed between one-year old, fresh seed and the priming treatments of two rice varieties. Among all the treatments T₈ recorded highest vigour index-II i.e., 7.35 followed by T₇ (7.22) and T₉ (7.09). T₁₀ and T₁₃ are statistically similar. Data on the Table 3 represents there is no significant difference between the treatments of T₄, T₆, T₉, T₁₀, T₁₂ and T₁₃ (Hiranmayee) for both the seed. Among all the treatments seedling vigour index II was also lowest in control (T₁- 6.55, Naveen) and (T₁- 6.37, Hiranmayee) and highest in (T₇-7.22, Naveen) and (T₇-7.35, Hiranmayee). In case of Naveen T₁₃, T₁₀ and T₆ are statistically similar and so also T₁₁, T₁₄, T₉, T₁₂, T₁₄ and T₅ statistically at par. T₂ and T₃ in case of Naveen are statistically at par. There is interaction effect exist between the old, fresh seeds with the different seed priming treatments.

Table 4.3: Seedling Vigour Index- I of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Seedling Vigour Index- I					
	Var- Naveen			Var-Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	1918.57	2236.52	2077.55	1846.50	2215.80	2031.15
T₂	1946.16	2357.80	2151.98	2016.24	2394.90	2205.57
T₃	2036.14	2380.37	2208.25	2108.07	2443.93	2276.00
T₄	2126.76	2374.83	2250.80	2107.33	2391.83	2249.58
T₅	2066.27	2339.91	2203.09	2079.50	2295.23	2187.37
T₆	2152.00	2367.53	2259.76	2079.47	2327.87	2203.67
T₇	2185.26	2418.47	2301.87	2156.14	2397.67	2276.90
T₈	2171.80	2421.57	2296.69	2124.92	2380.07	2252.50
T₉	2124.90	2362.10	2243.50	2124.77	2248.96	2186.87
T₁₀	2108.60	2372.94	2240.77	2104.37	2355.97	2230.17
T₁₁	2031.93	2324.20	2178.07	2081.33	2249.64	2165.48
T₁₂	2138.00	2383.70	2260.85	2117.30	2366.40	2241.85
T₁₃	2118.77	2370.63	2244.70	2117.45	2341.94	2229.70
T₁₄	2092.83	2338.04	2215.44	2079.77	2336.50	2208.14
Mean	1918.57	2236.52		1846.50	2215.80	
	S	T	S x T	S	T	S x T
S.E.m (±)	3.396	8.986	12.709	2.874	7.603	10.753
CD (0.05)	9.623	25.459	36.004	8.141	21.539	30.461

Table 4.4: Seedling Vigour Index- II of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Seedling Vigour Index- II					
	Var- Naveen			Var-Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	5.91	7.19	6.55	5.58	7.16	6.37
T₂	6.20	7.39	6.79	6.36	7.47	6.91
T₃	6.32	7.21	6.76	6.37	7.55	6.96
T₄	6.34	7.43	6.89	6.38	7.43	6.91
T₅	6.39	7.32	6.86	6.31	7.06	6.69
T₆	6.55	7.36	6.95	6.33	7.48	6.90
T₇	6.60	7.84	7.22	6.80	7.63	7.22
T₈	6.44	7.78	7.11	6.91	7.78	7.35
T₉	6.41	7.36	6.88	6.46	7.71	7.09
T₁₀	6.41	7.50	6.96	6.40	7.56	6.98
T₁₁	6.30	7.49	6.90	6.33	7.48	6.90
T₁₂	6.29	7.43	6.86	6.44	7.40	6.92
T₁₃	6.43	7.54	6.98	6.37	7.52	6.95
T₁₄	6.33	7.39	6.86	6.40	7.44	6.92
Mean	6.35	7.45		6.39	7.48	
S.E.m (±)	S	T	S x T	S	T	S x T
	0.006	0.017	0.024	0.007	0.019	0.027
CD (0.05)	0.018	0.049	0.070	0.020	0.054	0.076

4.2. Field studies

4.2.1. Effect of seed priming on Plant growth and seed yield in rice

4.2.1.1. Field emergence percentage

Table - 5 representing field emergence percentage of fresh and one-year old seeds of two rice varieties (Naveen) and (Hiranmayee) revealed that among all the treatments T₇ and T₈ were recorded highest field emergence i.e., 83.7, 84.3 and 84.4, 84.3 respectively in Naveen and Hiranmayee. The lowest field emergence was recorded in control i.e., T₁ (76.5) and 77.5 in Naveen and Hiranmayee respectively. A mean value (79.6 & 84.2) for Naveen and (79.2, 84.4) for Hiranmayee was recorded for field emergence in one-year old, fresh seeds. In case of Hiranmayee T₉, T₁₁, T₁₃ and T₃ so also T₅, T₂, T₁₀, T₁₄, T₃, T₁₃, and T₁₁ are statistically at par. In case of Naveen T₇, T₈, and T₁₃ are statistically at par. Similar findings were also obtained in T₉, T₁₄, T₁₃, T₁₀ and T₅. Data on the table also represents there is no significant difference between the treatments and two old and fresh seed. The interaction effect shows that significant difference among the different seasons (old and fresh seeds) and the priming treatments.

4.2.1.2. Plant population at 30 DAS

Data in this Table 6 represents about plant population percentage at 30 days after sowing of fresh and one-year old seeds of two rice varieties i.e., Naveen and Hiranmayee as influenced by various priming and seed coating treatments respectively. Only T₈ recorded highest plant population i.e., 79.7% for Naveen and 79.8% for Hiranmayee followed by T₇ and T₁₀ i.e., 79.1% (Naveen) & 79.2% (Hiranmayee) and 78.9% (Naveen) & 79.0% (Hiranmayee) respectively. The table also explained that there is no significant difference between T₇ and T₁₀ in Hiranmayee and T₅, T₇ and T₁₀ (Naveen). T₄, T₆ and T₁₂ are statistically similar in Hiranmayee while T₁₃, T₁₁ and T₁₄ & T₃ are statistically similar (Naveen) in respect to priming treatments. The lowest plant population was observed in T₁ (Control) i.e., 71.8%- Naveen and 72.15 in Hiranmayee followed by T₂ (74.50%- Naveen) and (73.8% -Hiranmayee).

Table 4.5: Field emergence (%) of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Field emergence (%)					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	72.0	80.9	76.5	73.0	82.0	77.5
T₂	75.4	83.9	79.6	78.5	84.7	81.6
T₃	80.7	86.2	83.4	77.9	86.1	82.0
T₄	79.0	82.2	80.6	78.3	82.9	80.6
T₅	82.0	84.0	83.0	79.3	83.8	81.6
T₆	79.7	83.1	81.4	78.7	83.2	80.9
T₇	80.7	86.8	83.7	82.8	85.9	84.3
T₈	81.7	87.1	84.4	81.7	87.0	84.3
T₉	80.0	85.0	82.5	80.0	85.3	82.7
T₁₀	81.0	83.8	82.4	78.8	84.9	81.9
T₁₁	79.0	84.7	81.9	79.7	85.1	82.4
T₁₂	80.7	82.7	81.7	79.7	82.3	81.0
T₁₃	81.0	83.9	82.4	80.3	84.2	82.2
T₁₄	81.0	83.9	82.5	79.8	84.0	81.9
Mean	79.5	84.2		79.2	84.4	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.069	0.183	0.258	0.096	0.255	0.361
CD (0.05)	0.196	0.518	0.733	0.274	0.724	1.024

Table 4.6: Plant population (%) at 30 days after sowing of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Plant population (%) at 30 days after sowing					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	66.3	77.3	71.8	67.0	77.1	72.1
T₂	69.0	79.9	74.5	68.7	79.0	73.8
T₃	75.0	79.0	77.0	74.7	79.0	76.8
T₄	72.7	78.0	75.3	72.0	78.0	75.0
T₅	77.1	80.0	78.6	76.0	78.7	77.3
T₆	73.0	78.7	75.8	72.7	77.0	74.8
T₇	75.7	82.6	79.1	76.3	82.0	79.2
T₈	76.0	83.4	79.7	76.0	83.7	79.8
T₉	73.0	80.7	76.8	73.0	81.6	77.3
T₁₀	76.3	81.0	78.7	77.0	81.0	79.0
T₁₁	74.0	80.0	77.0	74.0	81.0	77.5
T₁₂	75.0	78.0	76.5	74.0	75.0	74.5
T₁₃	74.0	81.0	77.5	75.3	81.0	78.2
T₁₄	74.3	79.7	77.0	74.0	79.0	76.5
Mean	73.68	79.95		73.62	79.51	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.078	0.205	0.290	0.072	0.190	0.269
CD (0.05)	0.219	0.581	0.822	0.204	0.539	0.762

4.2.1.3. Total number of tillers per plant

Data in this Table 7 representing about total number of tillers per plant resulted in T₆ revealed highest i.e., 16.38- Naveen and 14.36 – Hiranmayee followed by T₈ (16.13- Naveen and 14.23-Hiranmayee). There is no significant difference between T₉ and T₁₃ (Naveen). The lowest nos. of tiller were recorded in T₁ (10.4-Naveen) and (9.52- Hiranmayee) followed by T₂ (10.71)-Naveen and T₂ (9.82) - Hiranmayee). The interaction effect shows that significant difference among the different seasons (old and fresh collection seeds) and the priming treatments.

4.2.1.4. Effective tillers / plant

Among all the treatments T₈ revealed that the highest number of effective tillers was obtained in both the varieties i.e., (T₈-14.4, Naveen) and (T₈-12.45, Hiranmayee). Among the two different seed lots, fresh seeds recorded more numbers of tillers i.e., 14.20 - Naveen and 11.34- Hiranmayee as compared to one-year old seed 11.18 (Naveen) and 10.16 (Hiranmayee). Similar findings were also noticed in case of Hiranmayee. The Table 8 also explained that there is no significant difference between T₄ and T₁₀ (Hiranmayee) only. The lowest numbers of effective tillers were recorded in T₁- (8.87)-Naveen and (7.55)-Hiranmayee in both the seasons followed by T₂-(9.29), Naveen and (7.77), Hiranmayee. The interaction effect shows that significant difference exists among the different seasons (old and fresh collection seeds) and the priming treatments.

4.2.1.5. Days to maturity

Among all the treatments T₁ Control) resulted highest days for maturity i.e., 125.38 (Naveen) and 137.10 (Hiranmayee) followed by T₂, T₃ and T₄ i.e., 124.21 (Naveen) and 135.72 (Hiranmayee) and T₃(123.57-Naveen & 135.31-Hiranmayee) respectfully. The Table 9 also represents the effect of priming materials reflected in T₆ which resulted lowest days for maturity of seeds i.e., 120.34 (Naveen) & 131.73 (Hiranmayee) in both of the varieties followed by T₈ and T₇ i.e., 120.48-Naveen and 131.85- Hiranmayee & 120.58 (Naveen) and 132.01 (Hiranmayee) respectively. The interaction effect shows that significant difference exists among the different seasons (old and fresh collection seeds) and the priming treatments. T₅ and T₁₀ so also T₁₂ and T₁₄ are statistically at par.

Table 4.7: Total Numbers of Tiller / Plant of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Total Numbers of Tiller / Plant					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	9.40	11.39	10.40	8.57	10.48	9.52
T₂	9.67	11.74	10.71	8.78	10.87	9.82
T₃	11.42	13.35	12.39	10.49	12.62	11.55
T₄	14.66	15.51	15.09	12.47	13.15	12.81
T₅	14.85	15.84	15.35	13.39	13.76	13.58
T₆	15.90	16.86	16.38	13.83	14.88	14.36
T₇	15.41	16.37	15.89	13.44	14.43	13.94
T₈	15.55	16.70	16.13	13.75	14.71	14.23
T₉	14.23	15.28	14.76	11.24	12.35	11.80
T₁₀	14.71	15.74	15.22	11.66	12.71	12.19
T₁₁	14.41	15.54	14.98	11.41	12.54	11.98
T₁₂	14.67	15.66	15.17	11.46	12.66	12.06
T₁₃	14.91	15.98	15.45	11.82	12.89	12.36
T₁₄	14.79	15.82	15.30	11.59	12.71	12.15
Mean	13.90	15.13				
	S	T	S x T	S	T	S x T
S.E.m (±)	0.028	0.076	0.107	0.030	0.080	0.113
CD (0.05)	0.082	0.216	0.306	0.086	0.227	0.321

Table 4.8: Number of effective tillers per plant of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Number of effective tillers per plant					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	7.31	10.43	8.87	6.35	8.74	7.55
T₂	7.84	10.74	9.29	6.61	8.93	7.77
T₃	9.44	12.77	11.11	8.27	10.35	9.31
T₄	11.96	14.72	13.34	10.84	11.24	11.04
T₅	12.32	15.24	13.78	11.40	12.26	11.83
T₆	12.74	15.87	14.31	11.72	12.76	12.24
T₇	12.61	15.65	14.13	11.64	12.53	12.08
T₈	12.86	15.95	14.41	11.94	12.95	12.45
T₉	11.37	14.35	12.86	10.25	11.14	10.70
T₁₀	11.61	14.53	13.07	10.56	11.46	11.01
T₁₁	11.44	14.44	12.94	10.37	11.24	10.81
T₁₂	11.54	14.48	13.01	10.58	11.63	11.11
T₁₃	11.83	14.95	13.39	10.93	11.85	11.39
T₁₄	11.69	14.72	13.20	10.80	11.74	11.27
Mean	11.18	14.20		10.16	11.34	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.004	0.011	0.016	0.008	0.022	0.031
CD (0.05)	0.012	0.032	0.046	0.023	0.063	0.089

Table 4.9: Days to maturity of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Days to maturity					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	126.22	124.53	125.38	137.75	136.44	137.10
T₂	125.15	123.27	124.21	136.34	135.11	135.72
T₃	124.49	122.64	123.57	135.76	134.85	135.31
T₄	123.46	121.14	122.30	134.43	133.35	133.89
T₅	122.75	120.71	121.73	133.92	132.24	133.08
T₆	121.22	119.46	120.34	132.14	131.33	131.73
T₇	121.43	119.74	120.58	132.44	131.57	132.01
T₈	121.31	119.65	120.48	132.26	131.44	131.85
T₉	122.97	120.86	121.91	133.61	132.85	133.23
T₁₀	122.74	120.72	121.73	133.51	132.63	133.07
T₁₁	122.37	120.45	121.41	133.32	132.42	132.87
T₁₂	122.22	120.27	121.25	133.19	132.36	132.78
T₁₃	121.75	119.93	120.84	132.84	131.76	132.30
T₁₄	122.22	120.25	121.24	133.28	132.27	132.77
Mean	122.88	120.97		133.91	132.90	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.009	0.025	0.036	0.008	0.021	0.030
CD (0.05)	0.027	0.072	0.102	0.023	0.061	0.087

4.2.1.6. Panicle length

Among all the treatments there is no significant difference between T₈ and T₆ which were recorded highest for panicle length (Hiranmayee) and significantly different in Naveen in case of T₆ and T₈. The Table 10 also explained that there is no significant difference between T₅ & T₁₀ and so also in T₁₁ & T₁₄ and T₄ (Hiranmayee). Among all the treatments T₁ & T₂ resulted lowest panicle length i.e., 26.47 (Naveen) & 22.25 (Hiranmayee) followed by 26.96 (Naveen) & 22.65 (Hiranmayee) in T₃ and T₄ respectively. Highest panicle length was observed in T₆ i.e., 30.92 (Naveen) and 26.89 (Hiranmayee) followed by 30.65 (Naveen) and 26.89 (Hiranmayee) respectively.

4.2.1.7. Seeds per panicle

Table 11 representing seeds per panicle indicated that significant variation among one-year old seed, fresh seed and all the seed priming treatments. Among all the treatments T₇ resulted highest number of seeds per panicle in Naveen when compared with Hiranmayee i.e., (153.86- Naveen & 106.07 Hiranmayee). The data also indicated highest number of panicles irrespective of all treatments is presented in Naveen while compared with Hiranmayee. T₁ among all the treatments recorded lowest number of seeds per panicle i.e. 134.89 (Naveen) and 84.8 (Hiranmayee). In case of Naveen T₈, T₇ and T₆ are statistically similar with respect to seeds per panicle of one year old and fresh seeds of two rice varieties. In T₅ and T₁₂, no significant different was noticed in Naveen variety. Similarly, there is no significant difference observed in T₄, T₉, T₁₁ (Naveen). The interaction effect shows that significant difference among the different seasons (old and fresh collection seeds) and the priming treatments.

4.2.1.8. Unfilled seeds per panicle

The data presented in Table 12 on unfilled seeds per panicle observed highest in T₁ followed by T₂ and T₃ i.e., 14.04 (Naveen), 19.01 (Hiranmayee); 13.07 (Naveen), 17.95 (Hiranmayee) & 12.75 (Naveen), 17.34 (Naveen). If we compare among two varieties, the Hiranmayee variety revealed highest unfilled seeds per panicle as compared to Naveen varieties. The data also represented lowest unfilled seeds per panicle was recorded in T₈ (8.12-Naveen and 12.65- Hiranmayee) followed by T₇, T₁₂, & T₁₃ i.e., 8.28-Naveen, 12.84- Hiranmayee; 9.21- Naveen, 13.47- Hiranmayee & 9.21- Naveen, 13.47 Hiranmayee and 9.41 Naveen & 13.51 Hiranmayee respectively. The data also represents T₉, T₁₀, T₁₁ and T₁₄ are statistically similar with respect to unfilled seeds per panicle in Hiranmayee and treatment T₁₀, T₁₂, T₁₃ and T₁₄ and so also T₇ and T₈ are statistically similar in Hiranmayee. In case of Naveen, there is no significant difference observed in T₆, T₉, T₁₄; also, in T₁₄, T₉, T₁₀; T₁₀ and T₁₃.

Table 4.10: Panicle length of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Panicle length					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	25.52	27.41	26.47	21.35	23.15	22.25
T₂	25.95	27.97	26.96	21.56	23.75	22.65
T₃	27.36	29.74	28.55	23.54	25.85	24.70
T₄	28.12	30.32	29.22	24.25	26.35	25.30
T₅	28.53	30.64	29.59	24.65	26.55	25.60
T₆	29.87	31.98	30.92	25.94	27.84	26.89
T₇	29.44	31.23	30.34	25.76	27.63	26.70
T₈	29.82	31.47	30.65	25.94	27.84	26.89
T₉	28.68	30.84	29.76	24.84	26.93	25.89
T₁₀	28.41	30.56	29.49	24.54	26.65	25.60
T₁₁	28.36	30.15	29.26	24.44	26.24	25.34
T₁₂	29.25	31.15	30.20	25.16	27.37	26.27
T₁₃	28.70	30.76	29.73	24.85	26.74	25.80
T₁₄	28.27	30.42	29.35	24.25	26.36	25.31
Mean	28.31	30.33		24.36	26.38	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.004	0.010	0.015	0.005	0.014	0.019
CD (0.05)	0.011	0.029	0.042	0.014	0.038	0.054

Table 4.11: Seeds per panicle of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Seed per panicle					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T ₁	131.41	138.37	134.89	79.74	89.85	84.80
T ₂	136.55	143.72	140.13	79.91	93.35	86.63
T ₃	141.77	148.23	145.00	91.76	99.57	95.67
T ₄	146.22	153.54	149.88	95.95	108.84	102.39
T ₅	148.81	157.87	153.34	97.82	110.35	104.09
T ₆	151.87	156.63	154.25	98.47	112.74	105.61
T ₇	151.35	156.38	153.86	98.35	113.80	106.07
T ₈	150.71	156.91	153.81	98.86	112.18	105.52
T ₉	147.34	152.45	149.89	96.58	109.15	102.87
T ₁₀	146.46	151.54	149.00	95.24	108.86	102.05
T ₁₁	147.64	152.75	150.20	96.88	109.88	103.38
T ₁₂	150.64	155.95	153.30	98.85	111.75	105.30
T ₁₃	150.53	155.14	152.83	98.72	111.33	105.02
T ₁₄	149.57	154.23	151.90	97.14	110.85	104.00
Mean	146.49	152.41		94.59	107.32	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.059	0.155	0.219	0.007	0.018	0.026
CD (0.05)	0.167	0.440	0.623	0.020	0.052	0.074

Table 4.12: Unfilled seeds per panicle of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Unfilled seeds per panicle					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	14.33	13.74	14.04	20.44	17.56	19.00
T₂	13.57	12.57	13.07	19.64	16.26	17.95
T₃	13.57	11.93	12.75	18.95	15.72	17.34
T₄	12.05	10.94	11.50	17.66	14.35	16.01
T₅	11.24	9.67	10.46	16.34	13.15	14.75
T₆	10.67	8.54	9.61	15.17	12.81	13.99
T₇	9.23	7.33	8.28	14.13	11.55	12.84
T₈	9.13	7.11	8.12	14.05	11.25	12.65
T₉	10.37	8.65	9.51	14.52	12.95	13.74
T₁₀	10.47	8.50	9.49	14.42	12.71	13.57
T₁₁	10.65	8.77	9.71	14.59	12.83	13.71
T₁₂	10.07	8.34	9.21	14.28	12.66	13.47
T₁₃	10.37	8.44	9.41	14.33	12.68	13.51
T₁₄	10.52	8.55	9.54	14.47	12.75	13.61
Mean	11.16	9.51		15.93	13.52	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.013	0.033	0.048	0.026	0.069	0.097
CD (0.05)	0.036	0.095	0.135	0.073	0.194	0.275

4.2.1.9. Seed Yield per plant

Seed yield/plant is an important parameter which presents about commercial cultivation and seed production ability of a crop. It depends upon various yield parameters viz., number of panicles per plant, panicle length, number of seeds per panicle and seed weight. The data reported in the Table 13 resulted mean seed yield per plant (g) revealed highest in fresh seeds in both the cases when it is compared to each other. Naveen recorded highest seed yield per plant i.e., 21.32 g (Naveen) and 17.31g (Hiranmayee) case of fresh seeds compared to old seeds (Naveen) 19.21 g and 15.18 g for Hiranmayee. The data also represents among all the treatments T₈ recorded highest seed yield per plant followed by T₇, T₁₄, T₁₂ and T₁₃ i.e., 22.58 (Naveen), 18.54 (Hiranmayee) ; 22.30 (Naveen), 18.44 (Hiranmayee) ; 21.82 (Naveen), 17.59 (Hiranmayee) ; 21.71 (Naveen), 17.59 (Hiranmayee) ; 21.67 (Naveen) and 17.60 (Hiranmayee). T₁ produced lowest seed yield per plant followed by T₂ and T₃ i.e., 16.25 for Naveen, 12.32 (Hiranmayee); 16.37 (Naveen), 12.44 (Hiranmayee) and 17.89 (Naveen), 13.40 (Hiranmayee) respectively. All of the priming and coating treatments revealed positive response over the control. The interaction effect shows that significant difference among the different seasons (old and fresh collection seeds) and the priming treatments for seed yield per plant.

4.2.2.0. Seed Yield per hectare

The data resulted seed yield per hectare among all the treatments T₈ recorded highest mean seed yield in case of Hiranmayee i.e., 39.23 followed by T₇ 38.86 and T₁₂- 38.55 respectively. But in case of Naveen T₇, T₈ & T₁₂ recorded 48.49, 48.51 & 48.36q/ha respectively which are statistically similar. Among all the treatments lowest seed yield q/ha was recorded in both the cases i.e., 22.26 (Hiranmayee) & 40.36 (Naveen). The whole analysis represents there was more seed yield in case of Naveen in both one year old and fresh seeds. All of the priming and coating treatments revealed positive response to seed yield per hectare over the control. In Naveen variety, T₉ and T₁₀ are statistically similar showing 47.16q/ha and 47.11q/ha respectively. The interaction effect shows that significant difference exists among the different seasons (old and fresh collection seeds) and the priming treatments with respect to seed yield quintal per hectare.

Table 4.13: Seed yield per plant (g) of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Seed yield per plant (g)					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	15.17	17.33	16.25	11.17	13.47	12.32
T₂	15.26	17.47	16.37	11.25	13.63	12.44
T₃	16.91	18.87	17.89	12.33	14.47	13.40
T₄	17.87	19.73	18.80	13.43	15.66	14.54
T₅	18.32	20.34	19.33	14.74	16.75	15.75
T₆	19.65	21.42	20.53	15.68	17.84	16.76
T₇	21.26	23.33	22.30	17.32	19.56	18.44
T₈	21.47	23.69	22.58	17.46	19.62	18.54
T₉	20.32	22.57	21.44	16.38	18.44	17.41
T₁₀	20.21	22.51	21.36	16.31	18.38	17.34
T₁₁	20.58	22.66	21.62	16.45	18.56	17.51
T₁₂	20.68	22.74	21.71	16.87	18.70	17.59
T₁₃	20.62	22.71	21.67	16.56	18.64	17.60
T₁₄	20.60	23.04	21.82	16.52	18.66	17.59
Mean	19.21	21.32		15.18	17.31	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.018	0.047	0.067	0.006	0.016	0.022
CD (0.05)	0.051	0.135	0.190	0.017	0.043	0.062

Table 4.14: Seed yield per hectare (quintal) of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Seed yield per hectare (quintal)					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	38.44	42.29	40.37	30.03	34.48	32.26
T₂	38.94	42.95	40.94	30.20	35.02	32.61
T₃	39.63	43.70	41.66	31.11	35.57	33.34
T₄	41.08	44.96	43.02	31.88	36.98	34.43
T₅	42.17	46.02	44.10	33.54	37.63	35.58
T₆	45.17	48.31	46.74	35.63	39.90	37.77
T₇	45.94	51.09	48.51	36.23	41.48	38.86
T₈	45.79	51.20	48.49	36.90	41.56	39.23
T₉	44.46	49.86	47.16	35.29	40.46	37.87
T₁₀	44.43	49.79	47.11	35.35	40.25	37.80
T₁₁	44.93	49.99	47.46	35.58	40.58	38.08
T₁₂	45.99	50.74	48.36	36.18	40.92	38.55
T₁₃	45.10	50.20	47.65	35.84	40.66	38.25
T₁₄	44.88	50.88	47.88	35.79	40.61	38.20
Mean	43.35	48.00		34.25	39.01	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.029	0.079	0.112	0.073	0.195	0.276
CD (0.05)	0.084	0.224	0.317	0.209	0.553	0.782

4.2.2.1. Harvest index (HI)

The data on the Table 15 revealed that there is no significant difference between T₇ and T₈ and T₁₂ (Hiranmayee) resulting the harvest index 51.17, 50.65, 50.28 respectively. The lowest harvest index (HI) was obtained in T₁ followed by T₂ in case of (Hiranmayee) i.e., 42.03 & 42.49 which are statistically similar. But in case of Naveen, similar findings were also noticed in T₇, T₈ and T₁₂ resulting 55.63, 55.60 and 55.46 respectively. The interaction effect shows that significant difference exists among the different seasons (old and fresh collection seeds) and the priming treatments with respect to HI. The whole data represents fresh seed in both of the rice varieties recorded highest harvest index i.e., 53.90 (Naveen) and 48.07 (Hiranmayee) respectively as compared to old one-year seed of Naveen and Hiranmayee i.e., 50.83 & 47.53 respectively.

4.3. Seed quality studies of harvested seeds

4.3.1. Effect of seed priming on 1000 seed weight, germination, SVI-I and SVI-II

4.3.1.1. 1000 seed weight (g)

The data on 1000 seed weight was measured after harvest of the crops which was influenced by different priming treatments in the laboratory are presented in the Table -16. Among all the treatments highest 1000 seed weight was recorded in T₈ followed by T₇, T₁₄ and T₁₃ i.e., 23.34 g, 23.04 g, 22.79 g & 22.73 g (Naveen). But in case of Hiranmayee, T₇ and T₈ are statistically similar i.e., 22.60 g & 22.52 g for both of the case over control i.e., 20.90 g (Hiranmayee) and 21.64g (Naveen) with respect to 1000 seed weight. The interaction effect shows that significant difference exists among the different seasons (old and fresh collection seeds) and the priming treatments with respect to 1000 seed weight.

4.3.1.2. Germination percentage

Data presented in Table 17 resulted T₈ revealed highest mean seed germination percentage of harvested seeds i.e., 93.4% (Hiranmayee) followed by T₃, T₇, T₁₀, T₁₄, & T₁₃ which are statistically at par to one year old and fresh seeds of Naveen and Hiranmayee varieties. While, T₇ resulted highest seed germination percentage for Naveen (91.7). The lowest seed germination percentage was recorded in T₁ i.e., 86.9 followed by T₅ and T₂ i.e., 86.9, 90.2, & 90.5 respectively. But in case of Naveen T₇, T₆, T₃ and T₈ are

statistically at par with respect to seed germination percentage. The lowest seed germination percentage was recorded in T₁ -86.1 (Naveen). The interaction effect shows that significant difference exists among the different seasons (old and fresh collection seeds) and the different priming treatments with respect to seed germination percentage of harvested seeds.

4.3.1.3. Seedling Vigour Index (SVI-I)

Seedling vigour index-I of harvested seed from one year old and fresh seeds of two rice varieties resulted statistically significant to various priming and coating treatments (Table -18). Among all the treatments T₇ recorded highest seedling vigour index i.e., 2446.87 followed by T₈- 2441.69, T₁₂- 2405.85 and T₆-2404.76 (Naveen) and (Hiranmayee). T₃ recorded highest seedling vigour index-I i.e., 2426.87 which is statistically at par with T₇ (2418.78). T₁ resulted lowest seedling vigour index- I i.e., 2222.55 (Naveen) and 2173.03 (Hiranmayee). The interaction effect shows that significant difference exists among the different seasons (old and fresh collection seeds) and the priming treatments with respect to seedling vigour index-I.

4.3.1.4. Seedling Vigour Index (SVI-II)

Significant variation in seedling vigour index II was observed between one-year old, fresh seeds and the seed priming treatment for two rice varieties. The data revealed that among all the treatments highest seedling vigour index -II was observed in T₈ and T₇ (Hiranmayee) i.e., 7.99 & 7.86 which were statistically at par (Table -19). The data revealed that there is no significant difference between T₇ and T₉ and also in T₁₀, T₁₁, T₁₂, T₁₃ and T₁₄. Lowest seedling vigour index-II was observed in T₁(Control- 6.94, Hiranmayee). In Naveen T₇, T₈, T₁₃, T₆ and T₁₀ there is no significant difference between the treatments i.e., 7.81, 7.70, 7.57, 7.54, and 7.55. Lowest SVI-II was recorded in T₁ i.e., 7.41 (Naveen).

Table 4.15: Harvest index of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	Harvest index					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	44.95	47.49	46.22	41.58	42.49	42.03
T₂	45.67	48.23	46.95	41.83	43.15	42.49
T₃	46.47	49.07	47.77	43.08	43.82	43.45
T₄	48.17	50.50	49.33	44.15	45.57	44.86
T₅	49.45	51.68	50.57	46.44	46.36	46.40
T₆	52.97	54.26	53.61	50.62	49.17	49.90
T₇	53.87	57.38	55.63	50.18	51.11	50.65
T₈	53.70	57.50	55.60	51.12	51.21	51.17
T₉	52.14	55.99	54.06	48.88	49.86	49.37
T₁₀	52.11	55.91	54.01	48.95	49.60	49.27
T₁₁	52.69	56.14	54.42	49.28	50.01	49.65
T₁₂	53.93	56.98	55.46	50.13	50.43	50.28
T₁₃	52.89	56.38	54.64	49.65	50.11	49.88
T₁₄	52.63	57.14	54.88	49.58	50.04	49.81
Mean	50.83	53.90		47.53	48.07	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.034	0.091	0.129	0.149	0.395	0.558
CD (0.05)	0.097	0.258	0.365	0.423	1.119	1.583

Table 4.16: 1000 seed weight of one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee) as influenced by various priming and coating treatments

Treatments	1000 seed weight					
	Var- Naveen			Var-Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	21.25	22.02	21.64	20.48	21.31	20.90
T₂	21.71	22.64	22.18	21.36	22.52	21.94
T₃	22.03	22.57	22.30	21.57	22.63	22.10
T₄	22.02	22.71	22.37	21.64	22.73	22.19
T₅	22.10	22.69	22.40	21.75	22.79	22.27
T₆	22.09	22.86	22.48	21.66	22.74	22.20
T₇	22.50	23.58	23.04	21.82	23.38	22.60
T₈	22.66	23.82	23.24	21.87	23.18	22.52
T₉	21.90	22.38	22.14	21.48	22.52	22.00
T₁₀	21.81	22.62	22.22	21.43	22.48	21.96
T₁₁	21.82	22.79	22.31	21.46	22.56	22.01
T₁₂	22.04	23.16	22.60	21.65	22.89	22.27
T₁₃	22.22	23.23	22.73	21.73	22.75	22.24
T₁₄	22.19	23.38	22.79	21.74	22.80	22.27
Mean	22.03	22.89		21.55	22.66	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.002	0.004	0.006	0.041	0.108	0.154
CD (0.05)	0.005	0.012	0.017	0.116	0.308	0.436

Table 4.17: Seed germination percentage of harvested seed from one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee)

Treatments	Seed germination percentage (final count)					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	82.9 (65.6)	89.3 (70.9)	86.1 (68.2)	83.0 (65.7)	90.9 (72.4)	86.9 (69.0)
T₂	85.7 (67.8)	91.7 (73.2)	88.7 (70.5)	88.6 (70.2)	92.3 (73.9)	90.5 (72.1)
T₃	88.5 (70.2)	94.0 (75.8)	91.3 (73.0)	89.9 (71.4)	94.0 (75.8)	91.9 (73.6)
T₄	88.1 (69.8)	93.0 (74.6)	90.5 (72.2)	89.6 (71.1)	91.9 (73.4)	90.7 (72.3)
T₅	87.9 (69.6)	92.7 (74.3)	90.3 (71.9)	88.0 (69.7)	92.5 (74.0)	90.2 (71.9)
T₆	88.6 (70.3)	94.0 (75.8)	91.3 (73.0)	87.9 (69.7)	93.9 (75.7)	90.9 (72.7)
T₇	89.0 (70.6)	94.3 (76.2)	91.7 (73.4)	90.8 (72.4)	94.1 (75.9)	92.5 (74.1)
T₈	88.0 (69.7)	94.3 (76.2)	91.2 (72.9)	92.1 (73.7)	94.8 (76.7)	93.4 (75.2)
T₉	87.7 (69.5)	93.4 (75.1)	90.6 (72.3)	89.0 (70.7)	94.0 (75.8)	91.5 (73.2)
T₁₀	87.0 (68.8)	93.0 (74.6)	90.0 (71.7)	89.1 (70.7)	94.6 (76.6)	91.9 (73.6)
T₁₁	86.7 (68.6)	94.0 (75.7)	90.3 (72.2)	87.7 (69.5)	93.6 (75.4)	90.6 (72.4)
T₁₂	88.3 (70.0)	93.0 (74.6)	90.7 (72.3)	89.2 (70.8)	92.9 (74.6)	91.1 (72.7)
T₁₃	88.0 (69.7)	93.7 (75.4)	90.9 (72.6)	90.8 (72.4)	94.3 (76.2)	92.6 (74.3)
T₁₄	87.5 (69.3)	94.0 (75.8)	90.8 (72.5)	89.8 (71.4)	94.0 (75.8)	91.9 (73.6)
Mean	87.43 (69.2)	93.17 (74.9)		88.97 (70.7)	93.41 (75.2)	
S.E.m (±)	S	T	S x T	S	T	S x T
	0.084	0.222	0.314	0.107	0.284	0.401
CD (0.05)	0.237	0.629	0.889	0.304	0.804	1.137

(Figures in the parenthesis are arc sine transformed values)

Table 4.18: Seedling Vigour Index-I of harvested seed from one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee)

Treatments	Seedling Vigour Index-I					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	2060.57	2384.52	2222.55	1983.25	2362.80	2173.03
T₂	2148.16	2505.80	2326.98	2152.99	2541.90	2347.44
T₃	2178.14	2528.37	2353.25	2262.82	2590.93	2426.87
T₄	2268.76	2522.83	2395.80	2244.11	2538.83	2391.47
T₅	2208.27	2487.91	2348.09	2204.29	2442.23	2323.26
T₆	2294.00	2515.53	2404.76	2216.25	2474.87	2345.56
T₇	2327.26	2566.47	2446.87	2292.89	2544.67	2418.78
T₈	2313.80	2569.57	2441.69	2256.67	2527.07	2391.87
T₉	2266.90	2510.10	2388.50	2261.57	2395.96	2328.77
T₁₀	2250.60	2520.94	2385.77	2241.18	2502.97	2372.08
T₁₁	2173.93	2472.20	2323.07	2218.14	2396.64	2307.39
T₁₂	2280.00	2531.70	2405.85	2249.10	2513.40	2381.25
T₁₃	2260.77	2518.63	2389.70	2253.93	2488.94	2371.43
T₁₄	2234.83	2486.04	2360.44	2216.24	2483.50	2349.87
Mean	2233.28	2508.61		2218.10	2486.05	
	S	T	S x T	S	T	S x T
S.E.m (±)	6.703	17.734	25.080	12.968	34.310	48.522
CD (0.05)	19.005	50.283	71.110	36.768	97.280	137.575

Table 4.19: Seedling Vigour Index-II of harvested seed from one-year old and fresh seeds of two rice varieties (cv. Naveen and Hiranmayee)

Treatments	Seed Vigour Index-II					
	Var– Naveen			Var–Hiranmayee		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
T₁	6.46	7.81	7.14	6.11	7.77	6.94
T₂	6.75	8.01	7.38	7.03	8.08	7.55
T₃	6.87	7.83	7.35	7.04	8.16	7.60
T₄	6.89	8.05	7.47	7.05	8.04	7.54
T₅	6.94	7.94	7.44	6.98	7.67	7.33
T₆	7.10	7.98	7.54	7.00	8.09	7.54
T₇	7.15	8.46	7.81	7.47	8.24	7.86
T₈	6.99	8.40	7.70	7.58	8.39	7.99
T₉	6.96	7.98	7.47	7.13	8.32	7.72
T₁₀	6.97	8.12	7.55	7.07	8.17	7.62
T₁₁	6.86	8.11	7.48	7.00	8.09	7.54
T₁₂	6.85	8.05	7.45	7.11	8.01	7.56
T₁₃	6.98	8.16	7.57	7.04	8.13	7.58
T₁₄	6.88	8.01	7.45	7.07	8.05	7.56
Mean	6.90	8.07		7.05	8.09	
	S	T	S x T	S	T	S x T
S.E.m (±)	0.037	0.099	0.141	0.027	0.071	0.101
CD (0.05)	0.107	0.283	0.400	0.076	0.202	0.286

4.4. Economics of Seed priming treatments

The data on cost benefit ratio (B:C) of different seed priming treatments for one year old and fresh seeds of two varieties of rice viz., Naveen and Hiranmayee were presented in Table 20 - 23.

4.4.1. B:C of various priming treatment with respect to Hiranmayee one-year old rice seed yield

Among all the treatments, Hiranmayee one-year old seed obtained highest gross return (Rs. 66428.04) with net return of Rs. 26383.04 having B:C -1.66 from 36.90 q/ha in T₈ followed by T₇ which resulted total gross return Rs. 65219.34 with net return Rs. 25174.34 having B:C i.e., 1.63 from total yield 36.23 q/ha. The lowest gross return with net return and B:C was obtained in control i.e., Rs. 54049.26, Rs. 14049.26 and B:C i.e., 1.35 respectively.

4.4.2. B:C of various priming treatment with respect to Hiranmayee fresh rice seed yield

In Hiranmayee, among all the treatments highest gross return (Rs. 74814.38) with net return of Rs. 34769.38 having B:C i.e., 1.87 from 41.56 q in T₈ followed by T₇ which resulted total gross return Rs. 74664.94 with net return Rs. 34619.94 having B:C i.e., 1.86 from total yield 41.48 q/ha was obtained from fresh seed. The lowest gross return with net return and B:C was obtained from T₁ (control) i.e., Rs. 62068.97, Rs. 22068.97 and B:C i.e., 1.55 from 34.48 q/ha respectively (Hiranmayee) fresh seed.

4.4.3. B:C of various priming treatment with respect to Naveen one-year old rice seed yield

But, in case of Naveen one-year old seed, among all the treatments highest gross return was obtained from T₇ which resulted total gross return Rs. 82684.44 with net return Rs. 42639.44 having B:C i.e., 2.06 from total yield is 45.94q/ha. followed by T₈ which resulted gross return (Rs. 82418.44) with net return of Rs. 42373.13 having B:C i.e., 2.06 from 45.79 q/ha. The lowest gross return with net return and B:C was obtained in T₁ (control) i.e., Rs. 69196.35, Rs. 29196.35 and 1.73 from 38.44 q/ha respectively.

4.4.4. B:C of various priming treatment with respect to Naveen fresh rice seed yield

But, in case of Naveen fresh seed, among all the treatments highest gross return (Rs. 92151.38) with net return of Rs. 52106.38 having B:C i.e., 2.30 was obtained from 51.20 q/ha in T₈ followed by T₇ which resulted total gross return Rs. 91964.45 with net return Rs. 51919.45 having B:C i.e., 2.30 from total yield of 51.09 q/ha. The lowest gross return with net return and B:C was obtained in T₁ (control) i.e., Rs. 76122.12, Rs. 36122.12 and 1.90 from 42.29 q/ha respectively.

Table 4.20: Cost of benefit ratio (B:C) of various priming treatments with respect to Hiranmayee rice yield (one-year old seed)

Hiranmayee (Old) (V₂S₁) (Per ha)						
Treatment No.	Treatment	Total Yield (Q)	Gross Return	Cost of cultivation	Net return	B:C ratio
T₁	Control	30.03	54049.26	40000.00	14049.26	1.35
T₂	Thiram	30.20	54366.84	40125.00	14241.84	1.35
T₃	Water	31.11	55995.30	40000.00	15995.30	1.40
T₄	KNO ₃	31.88	57379.68	40174.00	17205.68	1.43
T₅	KH ₂ PO ₄	33.54	60363.66	40207.00	20156.66	1.50
T₆	ZnSO ₄ + MnSO ₄	35.63	64130.58	40195.00	23935.58	1.60
T₇	Trichoderma	36.23	65219.34	40045.00	25174.34	1.63
T₈	Trichoderma+ Water	36.90	66428.04	40045.00	26383.04	1.66
T₉	BioNPK+ Water	35.29	63519.42	40090.00	23429.42	1.58
T₁₀	Biogrow+ Water	35.35	63623.16	40090.00	23533.16	1.59
T₁₁	Biophos+Water	35.58	64049.70	40375.00	23674.70	1.59
T₁₂	Drought Alleviating Bacteria + BioNPK	36.18	65127.60	40315.00	24812.60	1.62
T₁₃	Drought Alleviating Bacteria + Biogrow	35.84	64514.94	40315.00	24199.94	1.60
T₁₄	Drought Alleviating Bacteria + Biophos	35.79	64426.02	40600.00	23826.02	1.59

Table 4.21: Cost of benefit ratio (B:C) of various priming treatments with respect to Hiranmayee rice yield (fresh seed)

Hiranmayee (Fresh) (V₂S₂) (Per ha)						
Treatment No.	Treatment	Total Yield (Q)	Gross Return	Cost of cultivation	Net return	B:C ratio
T₁	Control	34.48	62068.97	40000.00	22068.97	1.55
T₂	Thiram	35.02	63034.10	40125.00	22909.10	1.57
T₃	Water	35.57	64026.99	40000.00	24026.99	1.60
T₄	KNO ₃	36.98	66571.21	40174.00	26397.21	1.66
T₅	KH ₂ PO ₄	37.63	67725.38	40207.00	27518.38	1.68
T₆	ZnSO ₄ + MnSO ₄	39.90	71826.59	40195.00	31631.59	1.79
T₇	Trichoderma	41.48	74664.94	40045.00	34619.94	1.86
T₈	Trichoderma+ Water	41.56	74814.38	40045.00	34769.38	1.87
T₉	BioNPK+ Water	40.46	72824.37	40090.00	32734.37	1.82
T₁₀	Biogrow+ Water	40.25	72444.38	40090.00	32354.38	1.81
T₁₁	Biophos+Water	40.58	73048.70	40375.00	32673.70	1.81
T₁₂	Drought Alleviating Bacteria + BioNPK	40.92	73659.76	40315.00	33344.76	1.83
T₁₃	Drought Alleviating Bacteria + Biogrow	40.66	73191.32	40315.00	32876.32	1.82
T₁₄	Drought Alleviating Bacteria + Biophos	40.61	73096.24	40600.00	32496.24	1.80

Table 4.22: Cost of benefit ratio (B:C) of various priming treatments with respect to Naveen rice yield (one-year old seed)

Naveen (Old) (V₁S₁) (Per ha)						
Treatment No.	Treatment	Total Yield (Q)	Gross Return	Cost of cultivation	Net return	B:C ratio
T₁	Control	38.44	69196.35	40000.00	29196.35	1.73
T₂	Thiram	38.94	70096.80	40125.00	29971.80	1.75
T₃	Water	39.63	71333.97	40000.00	31333.97	1.78
T₄	KNO ₃	41.08	73935.00	40174.00	33761.00	1.84
T₅	KH ₂ PO ₄	42.17	75906.51	40207.00	35699.51	1.89
T₆	ZnSO ₄ + MnSO ₄	45.17	81299.43	40195.00	41104.43	2.02
T₇	Trichoderma	45.94	82684.44	40045.00	42639.44	2.06
T₈	Trichoderma+ Water	45.79	82418.13	40045.00	42373.13	2.06
T₉	BioNPK+ Water	44.46	80019.57	40090.00	39929.57	2.00
T₁₀	Biogrow+ Water	44.43	79972.20	40090.00	39882.20	1.99
T₁₁	Biophos+Water	44.93	80868.00	40375.00	40493.00	2.00
T₁₂	Drought Alleviating Bacteria + BioNPK	45.99	82773.54	40315.00	42458.54	2.05
T₁₃	Drought Alleviating Bacteria + Biogrow	45.10	81175.53	40315.00	40860.53	2.01
T₁₄	Drought Alleviating Bacteria + Biophos	44.88	80778.84	40600.00	40178.84	1.99

Table 4.23: Cost of benefit ratio (B:C) of various priming treatments with respect to Naveen rice yield (fresh seed)

Naveen (Fresh) (V₁S₂) (Per ha)						
Treatment No.	Treatment	Total Yield (Q)	Gross Return	Cost of cultivation	Net return	B:C ratio
T₁	Control	42.29	76122.12	40000.00	36122.12	1.90
T₂	Thiram	42.95	77301.01	40125.00	37176.01	1.93
T₃	Water	43.70	78659.79	40000.00	38659.79	1.97
T₄	KNO ₃	44.96	80930.60	40174.00	40756.60	2.01
T₅	KH ₂ PO ₄	46.02	82843.26	40207.00	42636.26	2.06
T₆	ZnSO ₄ + MnSO ₄	48.31	86961.71	40195.00	46766.71	2.16
T₇	Trichoderma	51.09	91964.45	40045.00	51919.45	2.30
T₈	Trichoderma+ Water	51.20	92151.38	40045.00	52106.38	2.30
T₉	BioNPK+ Water	49.86	89743.50	40090.00	49653.50	2.24
T₁₀	Biogrow+ Water	49.79	89614.15	40090.00	49524.15	2.24
T₁₁	Biophos+Water	49.99	89980.63	40375.00	49605.63	2.23
T₁₂	Drought Alleviating Bacteria + BioNPK	50.74	91331.98	40315.00	51016.98	2.27
T₁₃	Drought Alleviating Bacteria + Biogrow	50.20	90368.71	40315.00	50053.71	2.24
T₁₄	Drought Alleviating Bacteria + Biophos	50.88	91584.08	40600.00	50984.08	2.26

DISCUSSION

The present investigation has been carried out to know the effect of different seed priming treatments on the different parameters of one-year old and fresh rice viz., germination (%), seedling vigour index-I (SVI-I), SVI-II, field emergence, plant population at 30DAS, total number of tillers / plant, effective tillers / plant, days to maturity, panicle length, seeds per panicle, unfilled seeds / panicle, seed yield / plant (g), seed yield (q)/ hectare, harvest index, 1000-seed weight (g), harvested seed germination percentage, seedling vigour index-I, seedling vigour index-II and B:C ratio of collected seed from research laboratory of Department of Seed Science and Technology, OUAT, Bhubaneswar.

5.1 Seed Germination and vigour index

Seed is used mainly to raise the crops. Consequently, maintenance of sowing quality and parameters is the most critical factor in any seed development programme. The germination status is one of the most important characteristics of seed to be used for the planting value. Seed planting value is evaluated in terms of different physiological parameters viz, germination, seedling vigour index-I and II and field emergence etc. The present findings with respect to impact of seed priming materials on two rice varieties viz., Naveen and Hiranmayee (old and fresh) and the results obtained were depicted in Chapter-IV. The reports do exist in literature are corroborating with the present findings will be discussed in this chapter. All the priming treatment resulted significantly higher germination than the control at both of one year old and fresh seeds of Naveen and Hiranmayee. The data obtained from germination percentage, seedling vigour index-I, II and field emergence recorded highest in T₇ and T₈ i.e., seed coating on *Trichoderma harzianum* @ (CFU- 2 x 10⁶ per g) 15 g per kg of hydroprimed seed. Similar findings also reported by Quasemin and Rai (2016) who studied the highest germination percentage and vigour index increases by biopriming with *Trichoderma* in Maize. It is due to the biocontrol and bio stimulant activity of *T. harzianum*. Seed priming technique is effective to improve traits studied in comparison with non-primed seed. This is in agreement with the researcher by Moradi and Younesi (2009) in sorghum, Pehlivan *et al.* (2018) who

studied the biopriming effect by *Trichoderma viride* in Tomato, Devi *et al.* (2019) in rice. Seed priming increases higher vigour index and germination percentage due to physiological and biochemical changes in the seed during the seed treatment and increase of α -amylase activity during metabolic process supported by Lee and Kim (2000). Mohseney (2010), Gupta and Singh (2012), Meena *et al.* (2013), Tiwari *et al.* (2014) and Subedi *et al.* (2015) suggested increasing of all seedling vigour index, germination percentage in rice, maize, pea and other crops obtained due to seed priming over non-primed seeds and corroborates with the present findings.

Primed seeds are emerged faster on the soil more uniformly than non-primed seeds due to limited adverse environmental exposure. Priming shortens the lag or metabolic phase in the germination process. The metabolic phase occurs just after seeds when fully imbibed and just prior radicle to emergence. As the seeds have gone through this lag phase, it reduced germination time by 50% upon subsequent rehydration. Priming is also being commercially used to eliminate and greatly reduced the amount of seed borne fungi and bacteria. This result is in accordance with the findings of Verma *et al.* (2006) in green gram, Farooq *et al.* (2008) and Mondal *et al.* (2011) in rice and similar with present findings for germination and seedling vigour index in rice. Biopriming is a process of coating the seeds with agriculturally beneficial organism (bioinoculants) i.e., *Trichoderma*, *phosphobacteria* & other biofertilizer to enhance the germination percentage, seedling growth and stress condition was reported by Rehman *et al.* (2011) in chick pea, maize and rice.

5.2 Growth and yield parameters

Highest field emergence percentage, plant population % at 30 DAS (days after sowing) and number of effective tillers and total number of tillers in rice was highest in T₇ and T₁₀ due to seed coating with (bioinoculants) i.e., *Trichoderma* sp. followed by hydroprimed seeds with biogrow. The rise in the field emergence potential was because of magnified in metabolic activity and bigger mobilization of food reserves by priming treatments. Positive impact of seed priming on field emergence of rice seed are supported by Farooq *et.al.*, (2006), Shoaie *et al.* (2012) in maize and Singh *et al.* (2018) in groundnut. The strong and vigorous seedling by this priming treatment resulted in higher number of productive tillers. This increase in growth and yield components might be due to better crop establishment due to vigorous crop growth

that resulted in timely completion of all phases of plant growth. Shehzad *et al.* (2012) supported hydropriming with bioinoculants increases germination percentage, seedling vigour index and 50 percent field emergence.

Naga (1998), Cheng and Bradford (1999), Raul *et al.* (2002), Farooq *et al.* (2008) and Anese *et al.* (2011) studied effect of hydropriming increases panicle length, seeds per panicle when mixed with bioinoculants i.e., *T. harzianum*, Phosphobacteria and Bio-NPK. These findings are in support to present results i.e., hydropriming seeds when inoculated with *T. Harzianum* increases panicle length and seeds per panicle and reduces the number of days to maturity.

Ozaghloo *et al.* (2007), Ghassemi-Golezani *et al.* (2010) and Ramansyah *et al.* (2013) suggested highest germination percentage, vigour index, 1000 seed weight and seed yield found when the seeds were subjected to hydropriming with *Trichoderma* spp. and also hydropriming with alleviating bacteria and bio NPK, narrated in different crops like Maize , Barley , Sunflower and chick pea.

Seed priming improved plant stand and provide benefits in terms of maturity, earlier emergence of seedlings by 1-3 days and significantly increased the plant stand, shorten the maturity period and initial growth vigour. The treatment of seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg of hydroprimed seed recorded highest mean seed yield in case of Hiranmayee i.e., 39.23q followed by the treatment of seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg seed - 38.86q and seed coating with drought alleviating bacteria + BioNPK -38.55q respectively. But in case of Naveen the treatment of seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg seed, *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seeds & drought alleviating bacteria + BioNPK recorded 48.49q, 48.51q & 48.36q/ha respectively which are statistically similar. The enhancement of seed yield in the present study was attributed to increase in the number of panicles per hill, panicle length and number of seeds per panicle, due to various priming treatments. Presence of enhancing effect of the priming treatments on seed yield has been reported in rice by several workers (Srivastav and Bose, 2012, Tilhaun-Tadesse *et al.*, 2013 and Rahman *et al.*, 2015 in rice). Lowest unfilled seeds per panicle, highest seed yield per plant and highest harvest index recorded in T₇, T₈, & T₁₂ in our present findings was supported by Nagaraj *et al.* (2012) in Sunflower and Quasemin and Rai (2016) in maize.

Priming of seeds resulted about 47 percent seed yield in chick pea suggested by Musa *et al.* (1999) and Gupta and Singh (2012) in Chick pea recorded higher pods per plant, seeds per pod, higher seeds (23.1%) and biological yield (22.0%) due to seed priming over non priming seeds. These results are in conformity with our present findings. Shoaie *et al.* (2012), Shakori and Sharifi (2016) and Singh *et al.* (2018) found highest seed yield of ground nut and maize due to inoculating with bio-NPK and Biophos. This finding also supported with the present findings recorded in Table 18 that among all the treatments seed coating with *T. harzianum* (bioinoculants) resulted highest seed quality and harvested seed yield followed by bio-NPK alleviating bacteria. All the priming treatments were significantly superior over the control for seed germination, seedling vigour index, seed yield and yield attributes in one year old and fresh seeds of Naveen and Hiranmayee rice varieties.

5.3. B:C of various priming treatments with respect to seed yield

Balasubramanian and Hill (2002), Binary *et al.* (2012), Yadav (2016) and Pandit and Mookherjee (2017) studied the effect of hydropriming and bioinoculants as priming agent to enhance the seed germination, seedling emergence, filled emergence and more number of tillers per plant resulting highest seed yield and cost benefit ratio (B:C). The present findings derived ample support from the results of above worker. Cost benefit ratio is an indicator of the relative economic performance of the different priming treatments by Yadav (2016) in rice and Pal *et al.* (2020) in rice. In this study among all the treatments, seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) revealed highest benefits cost ratio (T₈-1.66 and T₇-1.63) in Hiranmayee old seed, (T₈-1.87) in Hiranmayee fresh seed, (T₈ and T₇-2.06) in Naveen old seed and (T₈ and T₇-2.30) in Naveen fresh seed and followed by other priming treatments also over the control in one year old and fresh seed of rice varieties viz., Naveen and Hiranmayee. This indicates that the different priming treatments were biologically effective and have the potential for yielding in return on investment using these treatments.

As per the results, the other priming treatments like seed coating with drought alleviating bacteria + BioNPK, drought alleviating bacteria + Biogrow, drought alleviating bacteria + Biophos, KNO₃ (@ 0.3%) solution and drying, KH₂PO₄ (@ 0.5%) solution and drying, ZnSO₄ (@ 0.3%) + MnSO₄ (@ 0.5%) solution and drying, with BioNPK (containing 1×10^9 cfu), Biogrow (containing 1×10^9 cfu) and with Biophos (containing 1×10^9 cfu) may also be inferred for aged seed lots of both varieties of rice to enhance the seed germination, yield and B:C ratio for the seed production.

SUMMARY AND CONCLUSION

The present investigation was based on the study of the efficiency of different seed priming treatments that enhance seed quality parameters and field performance with respect to yield attributes in two (old and fresh) rice varieties viz., Naveen and Hiranmayee. The experiment was carried out in the year Rabi, 2019- 20. In partially deteriorated seeds of two rice varieties (two strains) that were subjected to priming treatments in the research laboratory of department of Seed Science and Technology, OUAT, Bhubaneswar.

Seeds of one year old and fresh seeds of rice varieties viz., Naveen (80.3%, 88.8%) and Hiranmayee (80.7%, 89.3%) having an initial germination and initial moisture content in Naveen (11.3%, 11.2%) and Hiranmayee (11.6%, 11.5%) respectively was used to study the effect of priming for improving crop performance of partially deteriorated rice seeds. The seeds were treated for 30 hours in water and dilute solution of KNO_3 (@0.3%), KH_2PO_4 (@0.5%) and $\{\text{ZnSO}_4$ (@0.3%) + MnSO_4 (@0.5%)} after which they were washed thoroughly and dried back under shade to the original weight and stored in small plastic containers for future experiments.

After an incubation period of approximately thirty days, the primed as well as un-primed seeds (control) were treated with biopriming agents (*T. harzianum*, BioNPK, Biogrow, Biophos and draught alleviating bacteria) and were finally assessed for various seed quality attributes under their field performance and laboratory condition in the Agronomy field, OUAT, Bhubaneswar.

The planting value of primed seeds was assessed in terms of germination, seed vigour and field emergence while the field performance by plant population, number of tillers, number of effective tillers, panicle length, number of seeds per panicle, 1000-seed weight, seed yield and harvest index.

Assessment on the effect of seed priming treatments on germination and seedling vigour index-I and II in rice varieties were carried out with fourteen treatments viz., seed treatment with Thiram 2 g per kg seed, soaking in water 30 h at 25°C and drying, soaking in KNO_3 (@ 0.3%) solution and drying, KH_2PO_4 (@ 0.5%) solution and drying, ZnSO_4 (@ 0.3%) + MnSO_4 (@ 0.5%) solution and drying, *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seed, seed coating with *Trichoderma harzianum* (CFU

– 2×10^6 per g) @ 15 g / kg seed, BioNPK (containing 1×10^9 cfu), Biogrow (containing 1×10^9 cfu), Biophos (containing 1×10^9 cfu), drought alleviating bacteria + BioNPK, drought alleviating bacteria + Biogrow, drought alleviating bacteria + Biophos and with un-primed seed as control in Completely Randomized Design (Factorial) with four replications for the two factors of old and fresh seed lots. Results obtained significant variation in both old and fresh seed and also among the seed priming treatments with respect to all the seedling characters studied.

Seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg seed resulted highest germination percentage followed by seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seed in both Naveen and Hiranmayee variety of rice. The lowest percentage of seed germination was recorded in Control (untreated) i.e., 84.6% & 85.0% (Naveen) and (Hiranmayee).

Seedling vigour index- I was recorded highest in seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seed and soaking in water 30 h at 25°C and drying (Hiranmayee) i.e., 2276.69 and 2276.0 respectively followed by *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg, KNO₃ (@ 0.3%) solution and drying, drought alleviating bacteria + BioNPK i.e., 2250.5, 2249.58, 2241.85 respectively. Among all the treatments Control (Untreated) recorded lowest vigour index-I in Hiranmayee (2031.5). While in seedling vigour index-II recorded highest in seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seed and seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg.

Seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seeds and seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg were recorded highest field emergence i.e., 83.7%, 84.3% and 84.4%, 84.3% respectively in Naveen and Hiranmayee. The lowest field emergence was recorded in control.

Only seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seeds has recorded highest plant population at 30DAS i.e., 79.7% for Naveen and 79.8% for Hiranmayee followed by seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg and Biogrow (containing 1×10^9 cfu) i.e., 79.1%(Naveen) & 79.2% (Hiranmayee) and 78.9% (Naveen) & 79.0% (Hiranmayee) respectively.

Significant variations were observed among the rice varieties, seed priming treatments as well as interaction effects in respect to total number of tillers and the effective tillers per hill. Highest number of total number of tillers and effective tillers were obtained in both of the varieties by the seed priming treatment with seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg of hydroprimed seeds. Among the two different seed lots, fresh seeds recorded a greater number of tillers as compared to one-year old seed.

Seed priming treatment by soaking in $ZnSO_4$ (@ 0.3%) + $MnSO_4$ (@ 0.5%) solution and drying resulted lowest days for maturity of seeds in both of the varieties followed by seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seed and seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg seed.

Panicle length and seeds per panicle in both of the rice varieties (old and fresh seeds) represented significant improvements by the seed priming treatments with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg of hydroprimed seeds and seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg seed, while same trend was observed (lowest number) in unfilled seeds per panicle. The highest panicle length and number of seeds per panicles was observed in Naveen followed by Hiranmayee.

Seed yield obtained on per plant and hectare basis revealed significant variations among the varieties and priming treatments. Among the varieties, the highest seed yield was observed in Naveen and among the treatments the highest yield was observed in the priming treatment with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seed, seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg seed and drought alleviating bacteria + BioNPK. Same trend treatment effects were also recorded for harvest index.

The seed quality attributes of freshly harvested seed (germination, seedling vigour index-I, seedling vigour-II and 1000 seed weight) also showed significant variation among the treatments. Seed harvested from the plants grown from the seed priming treatments with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg hydroprimed seed and seed coating with *Trichoderma harzianum* (CFU – 2×10^6 per g) @ 15 g / kg seed, Biogrow (containing 1×10^9 cfu, drought alleviating bacteria + Biophos, Biophos

(containing 1×10^9 cfu) and drought alleviating bacteria + Biogrow exhibited better quality attributes in comparison to other priming treatments.

From the present experiment it was evident that seed priming treatment amplify most of the seed quality attributes viz., germination, field emergence and vigour. These treatments not only enhanced the plant growth characteristics viz., number of tillers, number of panicles, panicle length, number of seeds per panicle, seed yield but also gained in harvest index.

Seed priming treatment with *Trichoderma harzianum* (CFU – 2×10^6 per g) revealed highest benefits cost ratio (T₈-1.66 and T₇-1.63) in Hiranmayee old seed, (T₈-1.87) in Hiranmayee fresh seed, (T₈ and T₇-2.06) in Naveen old seed and (T₈ and T₇-2.30) in Naveen fresh seed and followed by other priming treatments also over the control in one year old and fresh seed of rice varieties viz., Naveen and Hiranmayee. This indicates that the different priming treatments were biologically effective and have the potential for yielding in return on investment using these treatments.

The other priming treatments like seed coating with drought alleviating bacteria + BioNPK, drought alleviating bacteria + Biogrow, drought alleviating bacteria + Biophos, soaking in KNO₃ (@ 0.3%) solution and drying, KH₂PO₄ (@ 0.5%) solution and drying, ZnSO₄ (@ 0.3%) + MnSO₄ (@ 0.5%) solution and drying, BioNPK (containing 1×10^9 cfu), Biogrow (containing 1×10^9 cfu) and Biophos (containing 1×10^9 cfu) may also be inferred for aged seed lots of both varieties of rice to enhance the planting value, plant growth, seed yield and B:C ratio for the seed production.

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