SEED PRIMING AND FOLIAR NUTRITION OF UPLAND RICE IN COCONUT GARDEN

by

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(2017-11-018)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"SEED PRIMING AND FOLIAR NUTRITION OF UPLAND RICE IN COCONUT GARDEN"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship or other similar title, of any other University or Society.

Vellayani
Date: 04/09/2019

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(2017-11-018)

CERTIFICATE

Certified that this thesis entitled **"SEED PRIMING AND FOLIAR NUTRITION OF UPLAND RICE IN COCONUT GARDEN"** is a record of research work done independently by Mr. Gopakumar.A.T under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

ANOVA	:	Analysis of variance
AT	:	Active tillering
B: C	:	Benefit cost
CD (0.05)	:	Critical difference at 5 % level
CGR	:	Crop growth rate
DAS	:	Days after sowing
DAT	:	Days after transplanting
DMP	:	Dry matter production
dS m^{-1}	:	Deci Siemens per metre
day^{-1}	:	Per day
EC	:	Electrical conductivity
et al.	:	Co-workers/ Co-authors
FAO	:	Food and Agriculture Organization
FYM	:	Farm yard manure
Fig.	:	Figure
g	:	Gram
GI	:	Germination index
GP	:	Germination percentage
GRI	:	Germination rate index
h^{-1}	:	Per hour
ha	:	Hectare
ha^{-1}	:	Per hectare
$hill^{-1}$	:	Per hill

IPNS	:	Integrated plant nutrient systems
i.e.	:	That is
K	:	Potassium
$KMNO_3$	:	Potassium nitrtae
KAU	:	Kerala Agricultural University
kg^{-1}	:	Per kilogram
L	:	Litre
LAI	:	Leaf area index
M	:	Molar
m^{2}	:	Square metre
m^{-2}	:	Per square metre
mg	:	Milligram
mm	:	Millimetre
mL	:	Millilitre
M ha	:	Million hectare
M t	:	Million tonnes
MSL	:	Mean sea level
N	:	Nitrogen
NAR	:	Net assimilation rate
NS	:	Non-significant
No.	:	Number
P	:	Phosphorus
PI	:	Panicle initiation
PSM	:	Phosphorus solubilizing bacteria
PGPR	:	Plant growth promoting rhizobacteria
pH	:	Potenz hydrogen
$Panicle^{-1}$	:	Per panicle
$q\ ha^{-1}$	:	Quintal per hectare

RBD	:	Randomized block design
RGR	:	Relative growth rate
S	:	Sulphur
SG	:	Speed of germination
SVI- I	:	Seedling vigour index I
Si	:	Silicon
SEm	:	Standard error of mean
t	:	Tonnes
viz.,	:	Namely
Zn	:	Zinc
$ZnSO_4$	:	Zinc sulphate
Yr	:	Year

LIST OF SYMBOLS

%	:	Per cent
@	:	at the rate of
^{o}C	:	Degree Celsius
µ	:	Micro
₹	:	Rupee

Introduction

1.INTRODUCTION

Upland rice cultivation is now being promoted by the Kerala government in the context of diminishing area and production of rice. Although traditionally raised as rainfed crop in the first crop season, upland rice can also be grown throughout the year, if irrigation is provided. Rice is a profligate user of water, consuming about half of all the developed fresh water resources of the world (Castaneda *et al*., 2002). Indian farmers are using as much as 15,000 L of water to produce one kilogram of rice while the maximum requirement is only 4,000 L (Kanmony, 2001). The increasing scarcity of fresh water threatens the sustainability of the irrigated rice ecosystems. Hence, "Grow more rice with less water" is gaining attention in all the rice growing regions. A fundamental approach to reduce water use in rice production is to grow it like an irrigated upland crop, such as wheat or maize. Higher water requirement and increasing labour cost are the major problems of traditional rice production system. Direct seeding in rice, without standing water, can be attractive and alternative. However, poor emergence and seedling establishment and weed infestation are the main hindrances in the adoption of this culture.

Seed priming is one of the techniques to obtain higher yield of rice by producing quality seedlings. Seed priming treatments can lead to better germination and establishment in main field. In seed priming, seeds are partially hydrated to allow metabolic events to occur without actual germination, and then re-dried (near to their original weight) to permit routine handling (Bradford, 1986). Primed seeds usually have better and more synchronized germination owing to less imbibition time (Brocklehurst and Dearman, 2008) and build-up of germination-enhancing metabolites (Farooq *et al.*, 2006).

Seed invigouration techniques are pragmatic approaches to achieve proper stand establishment in rice. They help in breaking dormancy and improving seedling density per unit area under optimal and adverse soil conditions. The rice seed priming can be performed by soaking simply in water, a solution of salts, hormones, osmoprotectants, matric strain-producing materials, and other nonconventional means. Despite certain limitations, such as water potential, oxygen and temperature, rice seed invigouration has been worthwhile in improving rice yield and quality.

Seed treatment with micronutrients has the potential to meet crop micronutrient requirements and improve seedling emergence and stand establishment, yield, and grain micronutrient enrichment. Micronutrients are vital for plant growth and human health. Soil and foliar applications are more prevalent methods of micronutrient addition but difficulty to spread uniformly over the soil and high labour cost are the major concerns.

With increase in soil pH, Zinc (Zn) solubility in soil and its uptake decreases concurrently. In several crops, higher soil phosphorus (P) content may induce Zn deficiency (Chang, 1999). Seed priming with Zn can improve crop emergence, stand establishment and subsequent growth and yield. Deficiency of B causes severe reductions in crop yield. Priming of rice seeds with low concentration of B improved the germination and early seedling growth (Farooq *et al.*, 2011).

Plant growth-promoting rhizobacteria (PGPR) are beneficial bacteria that colonize plant roots and enhance plant growth by a wide variety of mechanisms. The use of PGPR is steadily increasing in agriculture and offers an attractive way to partially substitute chemical fertilizers, pesticides, and supplements. In addition to improvement of plant growth, PGPR are directly involved in increased uptake of nitrogen (N), synthesis of phytohormones, solubilization of minerals such as P, and production of siderophores that chelate iron and make it available to the plant root.

With this back ground the present study entitled "Seed priming and foliar nutrition of upland rice in coconut garden" was carried out with the following objectives

- To standardize the ideal seed priming practice.
- To assess the influence of foliar application of PGPR mix 1 on growth and yield of upland rice raised as intercrop in coconut garden.

Review of Literature

2. REVIEW OF LITERATURE

Good seed germination is very important for rice (*Oryza sativa* L.). Uneven or poor germination and subsequently uneven seedling growth can lead to great financial losses to farmers by reducing the crop yield. Seed priming treatments can lead to better germination and establishment in many field crops, such as maize, wheat, and rice. Hence a study has been undertaken with an objective to standardize the ideal seed priming practice and to assess the influence of foliar application of PGPR mix 1 on growth and yield of upland rice raised as intercrop in coconut garden. The current state of knowledge regarding the effect of seed priming and on crop production, PGPR and effect of Zn and B on rice production is reviewed here.

2.1 EFFECT OF SEED PRIMING ON CROP PRODUCTION

Seed priming could be defined as controlling the hydration level within the seeds so that the metabolic activity necessary for germination can occur but radical emergence is prevented. The initiation of radical emergence requires high seed water content. Once sown, seeds spend significant amount of time for absorbing water from the soil. By reducing this time to a minimum, seeds can be made to germinate and seedlings emerge within shorter time levels (Taylor *et al.*, 1998). It has been reported that primed crop seeds emerged faster and grew more vigorously. They also flowered earlier, matured earlier and gave higher yields. Seed priming is the simple and low-cost technique of soaking seeds in solutions of different salts, nutrients or other osmoticum for a specified time followed by drying prior to sowing (Farooq *et al.*, 2006, 2011; Rehman *et al.*, 2011).

Primed seeds exhibit rapid germination and emergence under field conditions (McDonald, 2000, Ashraf and Foolad 2005). Different methods of seed priming adopted in rice includes osmopriming (soaking seeds in osmotic solutions such as polyethylene glycol), halopriming (soaking seeds in salt solutions), hydro-priming (soaking seeds in water), hormonal-priming (soaking of seeds in hormone solution) and matri-priming(placed within two layers of saturated jute mat) (Khan

1992, Chiu *et al.*, 2002, Ghassemi-Golezani *et al.*, 2008, Golshani *et al.*, 2010, Nouman *et al.*, 2012a; 2012b).

In a germination trial of 11 varieties of upland rice under limited water conditions, seed priming resulted in earlier and synchronized emergence (Harris and Jones 1997). Hydropriming enhanced seedling establishment and early vigor of upland rice, maize and chickpea (Harris *et al.*, 1999; Mondal *et al.*, 2011). $Mg(NO_3)_2$ invigorated seeds of rice varieties HUBR-3022, HUBR-2-1 and BPT-5204 showed improvement in the growth, yield attributes and antioxidant defense metabolism (Srivastava and Bose 2012).

2.1.1 Effect of Seed Priming on Growth Attributes

Lee *et al.* (1998) observed that seed priming improved the germination rate and speed of rice and ensures uniformity in germination even under less than optimum field condition. Zheng *et al.* (2002) reported that significantly higher and more rapid germination of osmo-primed rice seeds at low temperature (5^0C) and also observed that seed priming produced more number of tillers per unit area in rice over non –primed seeds. Maqsood *et al.* (2003) reported significant enhancing effects of hydropriming and osmopriming (KNO_3) treatments on speed of germination, mean germination time, fresh and dry weight of root and shoot, root and shoot length in rice. Primed seeds germinate earlier and enhanced the seedling emergence, stand establishment and tillering of rice (Farooq *et al.*, 2008). Seed priming was found to reduce the mean germination time and improved germination index, seedling vigour index and germination energy in rice. Hydropriming was the best treatment followed by water hardening in improving seedling growth, leaf area index (LAI), panicles m^{-2} and grain yield of dry direct seeded rice (Mahajan *et al.*, 2011). Prom-u-thai *et al.* (2012) stated that Zn priming promotes seed germination and seedling vigour of rice. They also revealed that Zn requirement of germinating rice seed and seedlings can be met from Zn accumulated in the husk due to Zn priming. Maize seeds primed in two per cent Zn solution + foliar application of Zn (two per cent) at one month after sowing significantly improved the plant height (Mohsin *et al.*, 2014). Rice crop raised from hydro and osmo primed seeds showed an increment in fresh and dry weights, plant height, number of leaves, LAI and effective tillers over control (Bose *et al.*, 2016).

Rehman *et al.* (2012) observed that seed priming with B improves growth of fine grain aromatic rice. Overall, B application at very low rate substantially improved the seedling emergence, leaf appearance and elongation and tillering.

2.1.2 Effect of Seed Priming on Yield Attributes

Priming rice seeds with low concentrations of $ZnSO_4$ was equally effective to soil application of $ZnSO_4$ (Giordano and Mortvedt, 1973). However, Mengel and Wilson (1979) found that priming rice seeds with Zn- EDTA or ZnO or Zn lignosulfonate was more effective in improving stand establishment and increasing the panicle number and grain yield than foliar Zn application at similar concentration. Seeds primed in $ZnSO_4$ 4.5 g kg^{-1} seed significantly improved the yield attributes in aerobic rice (Mukherjee and Pramanik, 2017). Iqbal *et al.* (2017) reported that priming of wheat seeds with 0.01 M B significantly improved 100 seed weight due to the role of B in grain setting.

2.1.3 Effect of Seed Priming on Yield

Slaton *et al.* (2001) suggested that seed priming is the best alternative to soil application and also observed that high grain yield was obtained from rice seeds primed with Zn compared to soil application. Harris *et al.* (2007) reported that seed priming of maize seeds with $ZnSO_4$ solution is a cost effective way to increase the maize yields of resource-poor farmers in the Zn deficient areas of Pakistan and also reported that maize seeds primed in one per cent $ZnSO_4$ for 16 h resulted in 27 per cent increase in grain yield over control. Osmohardening with $CaCl_2$ recorded significantly higher grain yield in direct seeded rice (Rehman *et al.*, 2011). Afzal *et al.* (2015) observed that maize seeds primed in 0.5 per cent $ZnSO_4$ solution recorded significantly higher grain yield (7.45 t ha^{-1}) over control (4.78 t ha^{-1}).

2.1.4 Seed Priming on Nutrient Availability in Soil and Uptake by Rice

Singh (2007) pointed out that seed priming treatments with concentrated micronutrient formulation slurry can be employed to improve the Zn-use efficiency in many crops in comparison to other Zn application methods.

Ajouri *et al.* (2004) observed that barley seeds primed in Zn @ 10 mg kg^{-1} seed increased the Zn content from 94 to 216 mg kg^{-1}. Mohammad *et al.* (2005) observed that seed priming improved the N uptake and increased total reductive sugar content in rice. Ali *et al.* (2013) reported that seed priming increased the agronomic use efficiency of N and partial factor productivity of N in maize.

Rehman *et al.* (2012) observed a linear increase in leaf and grain B content of fine grain aromatic rice with the increase in concentration of B in priming solution. Wheat seeds primed in 0.01 M B solution markedly enhanced the grain B content of grain by 27 per cent over control (Iqbal *et al.*, 2017). Ali *et al.* (2018) observed that nutripriming of wheat seeds with Zn and B enhanced the Zn and B content of grain. Maize seeds primed in 0.2 per cent P solution significantly enhanced the N uptake (Ali *et al.*, 2016). Seed treatment with $ZnSO_4$ (3.6 g kg^{-1} seed) with the recommended quantity of NPK significantly improved the grain yield of maize (Shabaz *et al.*, 2015).

Rakshit *et al.* (2015) reported that bio-priming with bio agents which promote plant growth maintain the soil and crop health by increasing the supply or availability of primary nutrients to the host plant. Meena *et al.* (2016) studied the effect of seed bio-priming and N doses under varied soil type on nitrogen use efficiency (NUE) of wheat (*Triticum aestivum* L.) under greenhouse conditions and revealed that biopriming with *Trichoderma harzianum* (BHU51) improved the NUE in wheat.

2.2 EFFECT OF PGPR ON CROP PRODUCTION

Plant growth promoting rhizobacteria are well known for enhancement of plant growth. For promoting plant growth and development, PGPR employ various mechanisms in different environmental conditions. PGPR have the ability to fix N which include Azospirillum (Garcia *et al.*, 1996), *Beijernckia* sp. (Baldani *et al.*,1997) and Rhizobium sp. (Antoun *et al.*,1998), Azotobacter (Jnawali *et al.*, 2015).

EL-Komy (2004) reported that *Azospirillum spp*. have multiple effect on plant which includes synthesis of phytohormones, N fixation and enhancing the mineral uptake which ultimately enhance plant growth. The beneficial effect of Azospirillum can be attributed from its favourable effect on N fixation and stimulating effect on root development (Noshin *et al.*, 2008). It has also been reported that Azospirillum-plant association is accompanied by biochemical changes in roots, which in turn promote plant growth and tolerance to low soil moisture. Pandirajan *et al*. (2012) reported that strains of Azospirillum will help the plants in utilization of various soil resources for better growth and are used as very efficient biofertilizers in crop plants all over the world.

Azotobacter spp. are non-symbiotic heterotrophic bacteria capable of fixing an average of 20 kg N ha^{-1} per year. Besides N fixation, Azotobacter produces plant growth promoting substances like thiamin, riboflavin, nicotine, indole acetic acid and gibberellin. Maize seeds inoculated with Azotobacter enhanced the germination to a significant level (Brakel and Hilger,1965). Application of Azotobacter helps to improve the plant growth and increase the soil N through nitrogen fixation by utilizing carbon for its metabolism (Monib *et al.*,1979). Rajaee *et al.* (2007) observed that inoculation of wheat seeds with Azotobacter helped in the uptake of N, P, Fe and Zn.

Phosphorous solubilizing microorganisms (PSM) inoculated plants showed increased plant growth and yield under glasshouse conditions (Zaidi *et al.*,2009; Khan *et al.*, 2010). The P solubilizers isolated from Kerala soils were highly efficient in releasing the soil P (Meenakumari *et al.,*2008*)*. Study conducted by

Singh and Reddy (2011) on wheat and maize under field condition revealed that PSMs reduced the need of chemical or organic fertilizers.

Inoculation of potash solubilizing bacteria in brinjal significantly enhanced the yield, plant height and K uptake compared to control (Ramarethinam and Chandra, 2005). Application of K solubilizes developed by Kerala Agricultural University (KAU) increased the beta carotene, vitamin C and crude protein content in Amaranthus (Sakthidharan 2011).

Sharifi *et al.* (2011) studied the effect of seed priming with PGPR on dry matter accumulation and yield of maize (*Zea mays* L.) hybrids and revealed that the highest dry matter accumulation (2019 g m^{-2}) and grain yield (7.01 t ha^{-1}) were recorded in maize seeds primed with Azotobacter. Grain and straw yields of *Basmati* rice significantly increased due to the inoculation of PGPR, and blue green algae with compost @ 5.0 t ha^{-1}, and chemical N fertilizer ($2/3^{rd}$ N through urea) over control (Meena *et al.*, 2013).

2.2.1 Effect of PGPR mix I on Plant Growth

PGPR mix I is a talc based consortium of N fixers, P and K solubilizers developed by Department of Agricultural Microbiology, College of Agriculture, Vellayani. It contains strains of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *Bacillus sporothermodurans* (KAU, 2017) and has been widely accepted by the farmers of Kerala.

Raj *et al.* (2013) conducted a field experiment on transplanted rice which could establish that basal application (2 kg ha^{-1}) of PGPR mix I with recommended half the dose of chemical fertilizers (45: 22.5: 7.5 kg NPK ha^{-1}) and lime top dressing (250 kg ha^{-1}) at 25 DAT had significant effect on grain yield and can be used as a viable alternative for reducing the usage of chemical fertilizer. Furthermore, Sathyan (2013) studied the effect of integrated plant nutrient systems on soil biological regimes in red loam soils and proved that PGPR mix I enriched vermicompost sustain the soil biological fertility and recorded higher economic returns in bhindi. Mohanan (2016) found that application of PGPR mix I increased the leaf breadth (9.66 cm), number of suckers per plant (4.25), number of ray florets (69.6) and length of ray florets (5.51 cm) in *Gerbera jamesonii*. More recently, Yadav (2017) conducted an on farm trial and proved that application of soil test based liming + PGPR mix I consortium + PGPR mix II as an economic and effective management method to reduce chemical fertilizer and pesticide load in crop production with the advantages of growth promoting effect and disease control.

2.3 EFFECT OF ZINC ON RICE PRODUCTION

Zinc plays a major role in carbohydrate metabolism, protein synthesis, auxin synthesis and pollen formation (Marschner, 1995). It also acts as an essential component of many enzymes and controls several biochemical processes in the plants required for growth (IRRI, 2000).

Stunted growth, chlorosis, production of smaller leaves and spikelet sterility are the major deficiency symptoms noticed in rice plants due to Zn deficiency. Deficiency also affected the quality of produce and proneness to fungal diseases (Marschner, 1995; Cakmak, 2000).

Zinc is the most deficient micronutrient in soils worldwide (Cakmak, 2002) and more than 30 per cent of soils have low Zn availability (Gibson, 2006: Alloway, 2008). Zinc deficiency is considered as a major threat to the global and regional food security (Rana and Kashif, 2014) and its deficiency caused yield reduction and Zn malnutrition in humans (Tiong *et al*., 2015).

Zinc fertilization significantly increased the plant height (Islam *et al*., 1999). Arya and Singh (2001) reported an increase in plant height due to application of $ZnSO_4$. Singh *et al*. (2012) observed that higher LAI at anthesis and dry matter production (DMP) at harvest were recorded with the application of 6 kg Zn ha^{-1}. Impa *et al*. (2013) observed that Zn fertilization had beneficial effect on tiller production. Application of Zn 5 mg kg^{-1} soil was found optimum for higher yield in soils deficient in Zn (Kalala *et al*., 2016).

Kumar *et al.* (2011) opined that chlorophyll synthesis in plants is directly related to the availability of micronutrients in plant available form. Muhammad *et al.* (2012) revealed that the chlorophyll content of rice plant increased significantly with the application of B and Zn as compared to the control. Combined application of $ZnSO_4$ (12.5 kg ha^{-1}) and borax (7.5 kg ha^{-1}) recorded the highest crop growth rate (CGR) and chlorophyll content in rice (Sarwar *et al.*, 2013).

Singh *et al.* (2012) observed that the yield attributes *viz.*, panicle m^{-2} and grains per panicle were significantly improved by the application Zn 6 mg kg^{-1} soil. Qadir *et al.* (2013) reported that spikelets per panicle and fertility percentage were significantly improved with the application of Zn 8 kg ha^{-1}. Yield attributing characters *viz.*, productive tillers m^{-2}, grains per panicle and test grain weight were significantly improved due to the foliar application of $ZnSO_4$ 10 kg ha^{-1} with the recommended dose of NPK (Mohan *et al.*, 2017).

Gangwar *et al.* (1989) reported higher dry matter and grain yield of rice with 10 mg Zn kg^{-1} soil. Application of Zn in low land rice soil of West Bengal caused an increase in yield of grain over the control to the tune of 37.8 per cent (Keram *et al.*, 2014). Sudha and Stalin (2015) reported a yield enhancement of 14 to 16 per cent in rice genotypes due to Zn fertilization. Kalala *et al.* (2016) found that in Zn deficient soils, Zn applied at 5 mg kg^{-1} soil was optimum for higher yield in rice. In BRRI dhan-33 rice, soil application of 4 kg Zn ha^{-1} recorded the highest grain and straw yield of 5.1 t ha^{-1} and 6.6 t ha^{-1} respectively. Kulhare *et al.* (2017) observed that foliar application of one per cent Zn salt at tillering and flag leaf stage significantly improved the grain and straw yield.

Fageria and Baligar (2005) pointed out that genotypes and Zn levels had significant effect on Zn content in grain. Foliar application of Zn at early milk and dough stages increased the Zn content in grain (Phattarakul *et al.*, 2012). Soil application of Zn 5 kg ha^{-1} and foliar application of Zn one kg ha^{-1} recorded the highest Zn uptake (Shivay *et al.*, 2015). Kumar *et al.* (2017) observed that soil application of $ZnSO_4$ 50 kg ha^{-1} and foliar spray of Zn-EDTA equivalent to 0.2 per cent $ZnSO_4$ recorded higher Zn content in grain.

2.4 EFFECT OF BORON ON RICE PRODUCTION

Similar to Zn, B a non-metal micronutrient is also essential for normal growth and development of rice (Gupta, 1979). Panicle sterility resulting from poor pollen germination and altered cell wall pectin reduced the number of grains per panicle and ultimately reduced the grain yield (Yang *et al.*, 1999; Nieuwenhuis *et al.*, 2000; Gowri 2005). Rashid *et al.* (2007) observed that B deficiency in rice not only reduced the paddy yield but also reduced the grain quality. Rehman *et al.* (2016) reported that B deficiency was observed in aerobic rice due to the low mobility of B.

In rice, seed treatment with B significantly improved the radicle and plumule length (Shelp 1993). Seed coating is an effective measure for enhancing the B availability during the initial plant growth stage. Seed coating of rice with B improved root and leaf production and tillering (Farooq *et al.*, 2011; Rehman *et al.* 2012). Boron seed priming enhances the growth of rice and it was more pronounced in aerobic rice (Rehman *et al.*, 2016).

Application of higher dose of B produced taller plants, but indiscriminate use of B caused toxicity in plants (Kushwaha *et al.*, 1999). Hosseini *et al.* (2007) reported that in corn (*Zea mays* L.), high levels of B decreased the plant height and dry matter production. Foliar application of 0.24 M B significantly improved the tillers in cultivars, Super basmati and Shaheen basmati (Rehman *et al.*, 2014). Ali *et al.* (2016) observed that foliar application of B 20 mg L^{-1} significantly improved the DMP in rice.

In rice, soil application of 2 kg B ha^{-1} resulted in a yield enhancement of 34.6 and 19 per cent, respectively in Mirpur and Satgara soils in Pakistan (Ali *et al.*,1996). Rashid *et al.* (2002) reported that 5 to 26 per cent increase in rice yield due to B application was observed in India. Hussain and Yasin, (2003) reported that, a yield enhancement of 16 per cent over control due to the application of one kg B ha^{-1}. Foliar spray of one per cent B significantly improved the grain yield (Ahmad *et al.*, 2012). Soil application of B significantly improved the grain yield in B deficient soils (Hussain *et al.*, 2012). Remesh and Rani (2017) reported that soil application of B one kg ha^{-1} recorded the highest grain yield in low land rice.

From the review it has been observed that seed priming had significant effect on the crop growth. The seed priming with $ZnSO_4$ and borax improved the growth and yield attributes. Application PGPR mix I a consortium of N fixers, P and K solubilizer also brought out significant improvement in growth and yield attributes. Since, no work has been conducted regarding the influence of seed priming with $ZnSO_4$ and borax in upland rice, the present work has been carried out with an objective to standardize the ideal seed priming practice and to assess the influence of PGPR mix I on the growth and yield of upland rice intercropped in coconut garden.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation entitled "Seed priming and foliar nutrition of upland rice in coconut garden" was conducted during *Kharif* 2018 (June to September 2018) at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala. The main objectives of the study were to standardize the ideal seed priming practice and to assess the influence of foliar application of PGPR mix I on growth and yield of upland rice raised as intercrop in coconut garden.

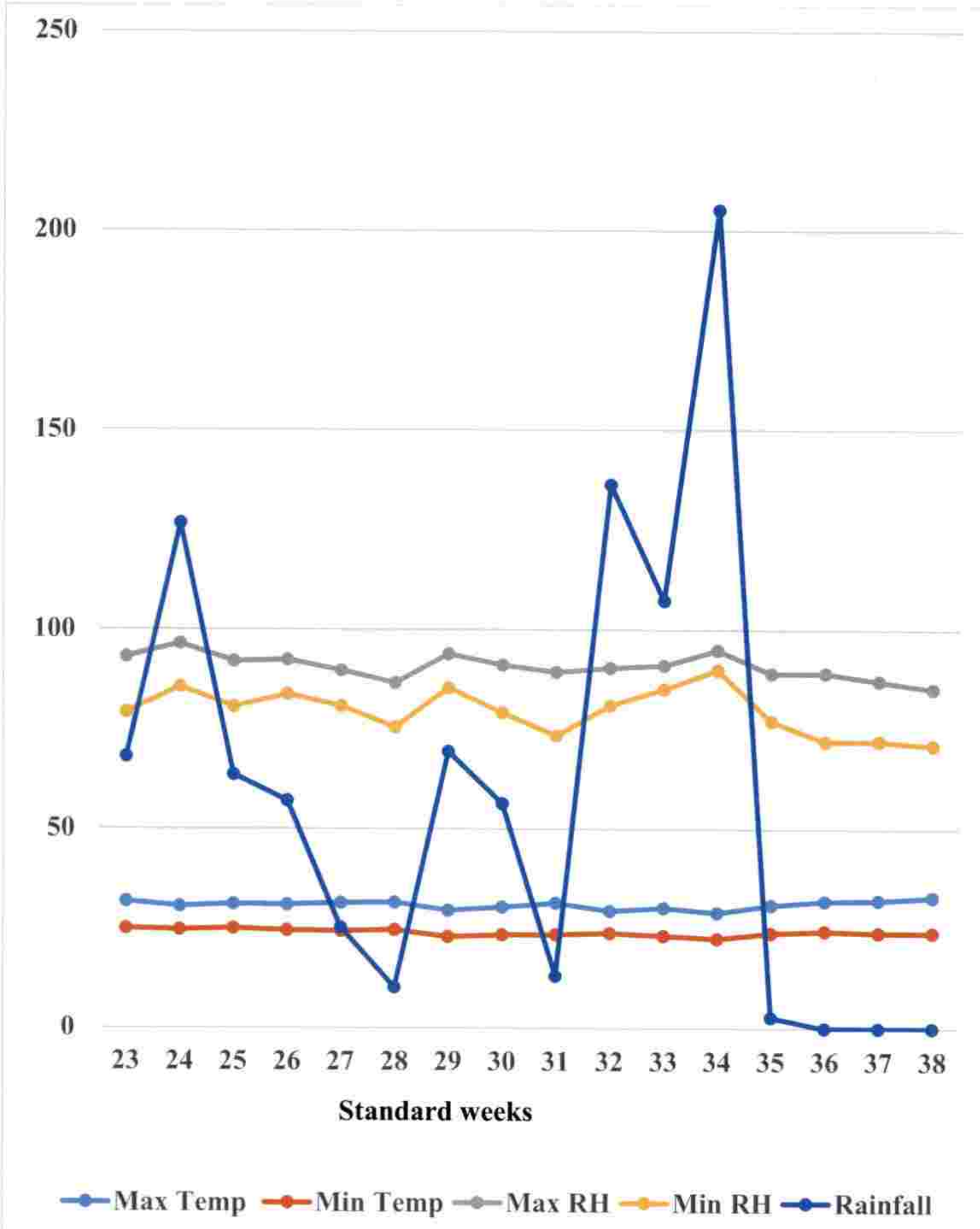
3.1 GENERAL DETAILS

3.1.1 Location

The experiment was conducted in Coconut Research Station (CRS), Balaramapuram, Thiruvananthapuram, Kerala, India located at 8° 22' 52" North latitude and 77° 1' 47" East longitude and at an altitude of 9 m above mean sea level.

3.1.2 Climate

A warm humid climate prevails over the experimental site. The daily weather parameters like mean temperature, relative humidity (RH), rainfall were recorded during the cropping period. The data were collected from the Class B Agro met observatory attached to Coconut Research Station, Balaramapuram. The rainfall received during the crop season extending from 9.6.2018 to 25.09.2018 was 960.4 mm. The mean maximum and minimum temperature recorded during the crop season were 31.6 and 19.5°C respectively. The mean weekly weather prevailed during the cropping period is presented in Appendix I and Fig. 1.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34
35
36
37
38
Standard weeks
Max Temp
Min Temp
Max RH
Min RH
Rainfall

Table 1. Physicochemical properties of the soil before the experiment

A. Mechanical composition

Sl. No.	Fractions	Content in soil (%)	Method Adopted
1	Sand	65.73	Bouyoucous hydrometer method (Bouyoucous,1962)
2	Silt	18.84	
3	Clay	14.96	

B. Chemical properties

Sl. No.	Parameters	Content	Method Adopted
1	Soil reaction	4.5 (Extremely acidic)	pH meter (1:2.5 soil water ratio) (Jackson, 1973)
2	EC, dSm^{-1}	0.10 (Normal)	Conductivity meter (1:2.5 soil water ratio) (Jackson, 1973)
3	Organic carbon, per cent	0.750 (Medium)	Walkley and Black rapid titration method (Walkley and Black, 1934)
4	Available N, kg ha^{-1}	281.01 (Medium)	Alkaline permanganate method (Subbiah and Asijia, 1956)
5	Available P, kg ha^{-1}	27.2 (High)	Bray colorimetric method (Jackson, 1973)
6	Available K, kg ha^{-1}	128.5 (Medium)	Ammonium acetate method (Jackson, 1973)
7	Available Zn, mg kg^{-1} soil	0.457 (Deficient)	HCl extraction and Atomic Absorption Spectrophotometry (Lindsay and Norwell, 1978)
8	Available B, mg kg^{-1} soil	0.08 (Deficient)	Hot water extraction and colorimetry using Azomethine-H (Hesse, 1971)

3.1.4 Soil

The experimental soil was red sandy loam in texture, acidic in reaction, medium in organic carbon, N and K and high in P status. The important physicochemical properties of the soil are presented in Table 1.

3.1.5 Cropping History of the Field

The crop was raised as an intercrop in 55 years old coconut trees planted at a spacing of 7.6 m x 7.6 m. The inter row space of coconut had banana crop during the previous season.

3.2. MATERIALS

3.2.1 Crop Variety

Prathyasa (MO-21), a short duration (100 to110 days) variety having red, long bold grains released from Rice Research Station, KAU, Moncompu was used for the experiment. The variety is photoinsensitive and moderately resistant to gall midge, brown plant hopper, sheath blight and sheath rot.

3.2.2 Source of Seed

The seeds for the experiment were procured from Rice Research Station, Moncompu, Kerala, India.

3.2.3 Manures and Fertilizers

Farm yard manure (0.45 per cent N, 0.17 per cent P_2O_5 and 0.5 per cent K_2O content) was used as a source of organic manure. Source of N, P, K, Zn and B for the experiment were urea (46 % N), rajphos (20 % P_2O_5), muriate of potash (60 % K_2O), $ZnSO_4$ (21% Zn) and borax (11.5% B). PGPR mix I, a consortium of *Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megatherium and Bacillus sporothermodurans* procured from Department of Agricultural Microbiology, College of Agriculture, Vellayani, Thiruvananthapuram was used as biofertlizer for seed priming, soil application and foliar nutrition.

3.3 METHODS

3.3.1 EXPERIMENT I: POT CULTURE EXPERIMENT-INFLUENCE OF SEED PRIMING ON GERMINATION AND SEEDLING VIGOUR OF PADDY

Pot culture experiment was conducted in the net house of Coconut Research Station, Balaramapuram, Thiruvananthapuram for a period of 14 days from 05.05.2018 to 19.05.2018. The variety used for the study was Prathyasa.

3.3.1.1 Design and Lay out

Design : CRD

Replication : 3

Treatments : 17

3.3.1.2 Treatment Details

T_1: Seed priming with $ZnSO_4$ 2g kg^{-1} seed

T_2: Seed priming with $ZnSO_4$ 3g kg^{-1} seed

T_3: Seed priming with $ZnSO_4$ 4g kg^{-1} seed

T_4: Seed priming with $ZnSO_4$ 5g kg^{-1} seed

T_5: T_1 + PGPR mix I @10 g kg^{-1} seed

T_6: T_2 + PGPR mix I @10 g kg^{-1} seed

T_7: T_3 + PGPR mix I @ 10 g kg^{-1} seed

T_8: T_4 + PGPR mix I @ 10 g kg^{-1} seed

T_9: Seed priming with borax 0.5g kg^{-1} seed

T_{10}: Seed priming with borax 1g kg^{-1} seed

T_{11}: Seed priming with borax 1.5 g kg^{-1} seed

T_{12}: Seed priming with borax 2g kg^{-1} seed

T_{13}: T_9 + PGPR mix I @10 g kg^{-1} seed

T_{14}: T_{10} + PGPR mix I @ 10 g kg^{-1} seed

Plate 1: Performance of best treatment in pot culture experiment

T_{15}: T_{11} + PGPR mix I@ 10 g kg^{-1} seed

T_{16}: T_{12} + PGPR mix I @ 10 g kg^{-1} seed

T_{17}: Control

The duration of priming was 16 h and after priming seeds were dried in shade for three days to bring back to original moisture content. The seeds were sown in polybags of size 20" x 20" and thickness of 150 μ filled with pure sand. In each polybag, 25 seeds were sown. The crop was maintained for 14 days and observations were recorded on 14 DAS.

To identify the two best priming treatments, score of 1 to 17 were assigned to different parameters *viz.*, time to 50 percent germination (T_{50}), speed of germination (SG), germination percentage (GP), germination index (GI) and seedling vigour index I (SVI-1). Score 1 was assigned to the best treatment and 17 to the least one. Two seed priming treatments scored lower scores were selected as the best priming treatments for the field experiment.

3.3.2 EXPERIMENT II: FIELD EXPERIMENT TO STUDY THE EFFECT OF SEED PRIMING AND FOLIAR NUTRITION ON THE GROWTH AND YIELD OF UPLAND RICE

3.3.2.1 Design and Lay Out

Design : RBD

Treatments : 11

Replication: 3

Variety : Prathyasa

Season : *Kharif*, 2018

Spacing : 15 cm x 10cm

Plot size : 3 m x 3m

Location : Coconut Research Station, Balaramapuram

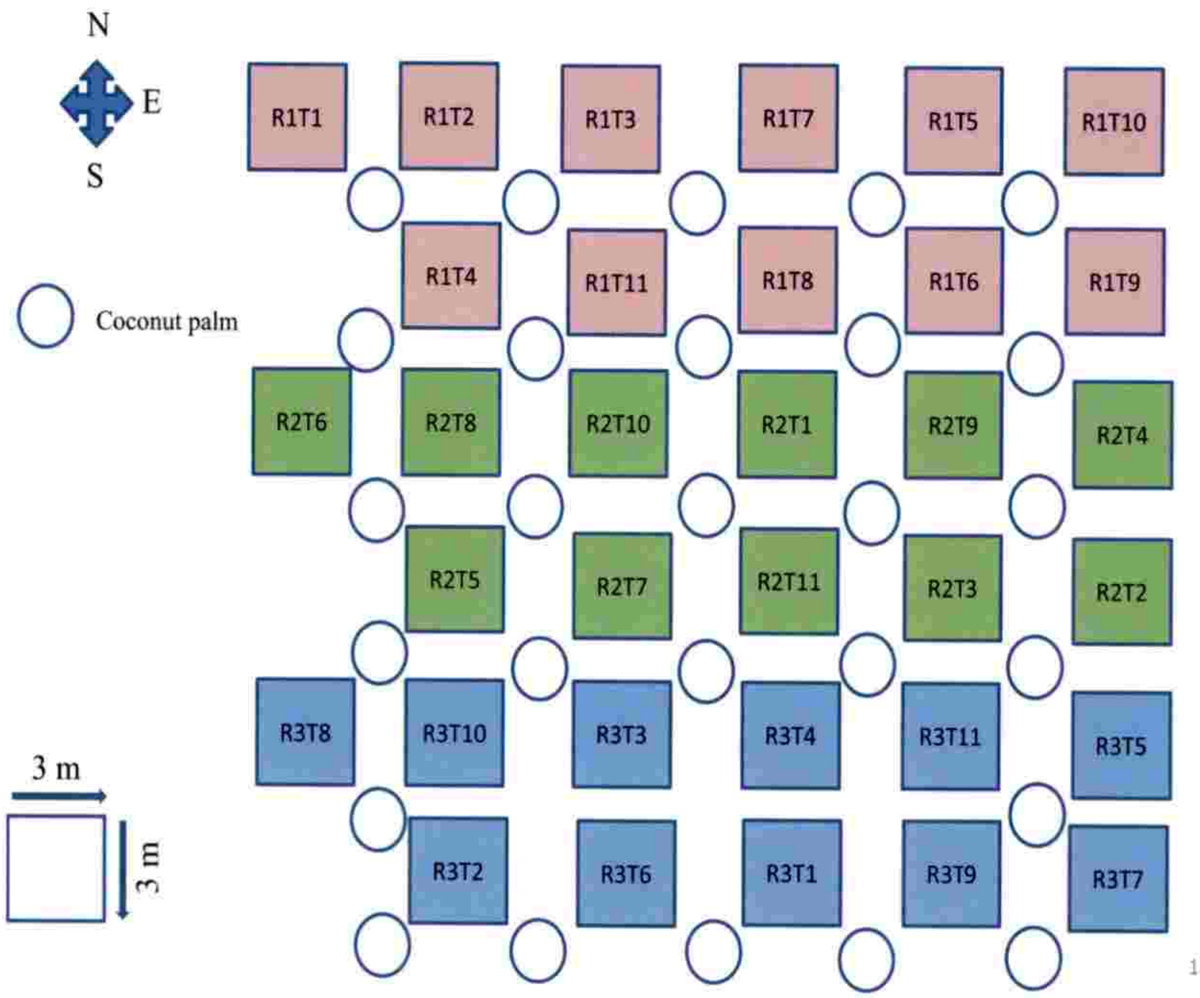

Fig 2. Lay out of experimental field

3.3.2.2 Treatment Details

T_1 : Seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I 10 g kg^{-1} seed

T_2 : Seed priming with borax 0.5 g kg^{-1} seed + PGPR mix I 10 g kg^{-1} seed

T_3 : T_1+ foliar application of PGPR mix I 2 per cent at panicle initiation stage

T_4 : T_2+ foliar application of PGPR mix I 2 per cent at panicle initiation stage

T_5 : T_1 + soil application of PGPR mix I 2 kg ha^{-1} at panicle initiation stage

T_6 : T_2 + soil application of PGPR mix I 2 kg ha^{-1} at panicle initiation stage

T_7: T_1 + foliar application of PGPR mix I 2 per cent at active tillering and panicle initiation stage

T_8: T_2 + foliar application of PGPR mix I 2 per cent at active tillering and panicle initiation stage

T_9: T_1 + soil application of PGPR mix I 2 kg ha^{-1} at active tillering and panicle initiation stage

T_{10}:T_2 + soil application of PGPR mix I 2 kg ha^{-1} at active tillering and panicle initiation stage

T_{11}: Control (POP)

3.3.2.3 Field Preparation and Lay Out

The experimental area (excluding coconut basins) was ploughed with power tiller and brought to a fine tilth. The experimental area was laid into plots of 3 x 3 m as per the layout plan.

3.3.2.4 Lime Application

Lime @ 600 kg ha $^{-1}$ was uniformly applied to all plots in two splits. 350 kg of lime was applied at the time of first ploughing and remaining 250 kg at one month after first application.

Plate2. General view of the experimental field

3.3.2.5 Manure and Fertilizer Application

Farm yard manure having a N content 0.47 per cent, P_2O_5 content 0.15 per cent and K_2O content 0.50 per cent was applied @ 5 t ha^{-1} at the time of second ploughing. The RDF of 70:35:35 N: P: Kha^{-1} was followed. N and K were applied in three split doses at 15, 35 and 55 days after sowing (DAS) and entire dose of P was applied as basal just before sowing the seeds.

3.3.2.6 Seeds and Sowing

The dry paddy seeds were sown in lines at a spacing of 15 cm x 10 cm on 9.6.2018. The seed rate adopted was 80 kg ha^{-1}.

3.3.2.7 Irrigation Management

The crop was raised as a rainfed crop. Irrigation was given during non-rainy periods to avoid the impact of moisture stress on crop growth.

3.3.2.8 Weed Management

For the effective control of weeds, early post emergence application of pyrazosulfuron 25 g ha^{-1} was done at 4 DAS followed by post emergence application of bispyribac sodium (25g ha^{-1}) at 25 DAS.

3.3.2.9 Plant Protection

Leaf folder attack observed at 20 DAS was controlled by spraying quinalphos (1000 mL ha^{-1}) and fish amino acid @ 5 ml L^{-1} was applied at flowering and milking stages to control the rice bug. No serious incidence of disease was observed during the crop growth period.

3.3.2.10 Harvest

The crop was harvested on 25.09.2018. The net plot area was harvested, threshed, winnowed and grain and straw weight were recorded separately and expressed in kg ha^{-1} on dry weight basis.

3.4 OBSERVATIONS

3.4.1 EXPERIMENT I: POT CULTURE EXPERIMENT-INFLUENCE OF SEED PRIMING ON GERMINATION AND SEEDLING VIGOUR OF PADDY

3.4.1.1 Observations on Seed Germination and Seedling Growth

3.4.1.1.1 Days to Germinate

Number of days taken by the seeds to germinate were counted and recorded. The observations were recorded up to 14^{th} day.

3.4.1.1.2 Number of Seeds Germinated on Each Day

Number of seeds germinated on each day was counted and recorded. Count was recorded up to 14^{th} day after sowing.

3.4.1.1.3 Seedling Root Length and Shoot Length

Five seedlings were randomly selected and uprooted from each pot on 14 DAS without damaging the root system. Root and shoot length were measured, average was worked out and expressed in cm.

3.4.1.1.4 Seedling Shoot and Root Fresh Weight

The root system was removed using a sharp knife from the same five seedlings selected for measuring the root length and shoot length. The fresh weight of shoot and root were recorded separately, the average was worked out and expressed in g.

3.4.1.1.5 Seedling Shoot and Root Dry Weight

The samples were dried in hot air oven at 65 ± 5 °C to constant weight and the dry weight of shoot and root were recorded and expressed in g.

3.4.1.1.6 Time to 50 Percent Germination (T_{50})

Time to 50 percent germination was worked out based on the formula suggested by Farooq *et al*. (2005) and expressed in days.

3.4.1.1.7 Speed of Germination (SG)

Speed of germination was computed by using the formula suggested by Czabator (1962).

3.4.1.1.8 Germination index (GI)

Germination index was calculated by the formula proposed by Bench *et al*. (1991).

***3.4.1.1.9 Germination Percentage* (GP)**

Germination percentage was worked out by the formula suggested by International Seed Testing Association (ISTA) (1985).

3.4.1.1.10 Seedling Vigour Index 1 (SVI-1)

Seedling vigour index was worked out by the formula suggested by Abdul-baki and Anderson (1973).

3.4.2 EXPERIMENT II: FIELD EXPERIMENT TO STUDY THE EFFECT OF SEED PRIMING AND FOLIAR NUTRITION ON THE GROWTH AND YIELD OF UPLAND RICE

3.4.2.1 Growth Parameters

3.4.2.1.1 Seedling Emergence Index

Seedling emergence index was calculated at 14 DAS based on the formula suggested by The Association of Official Seed Analysis (1983).

3.4.2.1.2 Plant Height

The plant height was measured from the base to the tip of the top most leaf at 40 and 60 DAS and at harvest from the base to the tip of the longest panicle and expressed in cm.

3.4.2.1.3 Tillers m^{-2}

Number of tillers was recorded at 40 and 60 DAS and at harvest by using a quadrat of size 0.5 m x 0.5 m from the net plot area of each treatment and the average was worked out.

3.4.2.1.4 Leaf Area Index

Leaf area index was worked out at 40 DAS and 60 DAS. Leaf length and breadth of the fourth leaf from top were measured from ten randomly selected primary tillers and leaf area was worked out by the formula suggested by Palanisamy and Gomez (1974).

Leaf area = K (L×B)

K = 0.75 (Yoshida *et al.*, 1976)

L = Leaf length (cm)

B = Maximum breadth of the leaf (cm)

By multiplying the leaf area with number of leaves in a tiller, leaf area tiller^{-1} was obtained and then the LAI was calculated as follows:

$$LAI = \frac{\text{Leaf area tiller}^{-1} \times \text{number of tillers m}^{-2}}{\text{Land Area}}$$

3.4.2.1.5 Dry Matter Production (DMP)

Dry matter production was recorded at harvest stage. Leaving one border row, five hills were randomly selected and uprooted from the sample rows outside the net plot area. The samples were initially sun dried for a day and later oven dried at 65 ± 5°C to constant weight. The total DMP was calculated and was expressed in kg ha^{-1}.

3.4.2.1.6 Root Shoot Ratio

Root shoot ratio was calculated by the following formula at 50 per cent flowering.

$$\text{Root shoot ratio} = \frac{\text{Dry weight of root}}{\text{Dry weight of shoot}}$$

3.4.2.2 Physiological Parameters

3.4.2.2.1 Crop Growth Rate (CGR)

Crop growth rate from 40 DAS to 60 DAS and from 60 DAS to harvest stage was calculated using the formula suggested by Watson (1958).

3.4.2.2.2 Chlorophyll Content

Total chlorophyll content of the leaves was analyzed at 50 per cent flowering stage by DMSO (dimethyl sulphoxide) method suggested by Yoshida *et al*. (1976).

3.4.2.2.3 Stomatal conductance

Stomatal conductance was measured at 50 per cent flowering between 9 am and 11 am using Portable Photosynthetic system (CIRAS-3, PP systems USA) and were expressed in mH_2O moles m^{-2} s^{-1}.

3.4.2.2.4 Relative water content

The relative water content was measured based on the method described by Turner (1981).

3.4.2.2.5 Proline content

Proline content was estimated as per the procedure described by Bates *et al.* (1973).

3.4.2.3 Yield Attributes

3.4.2.3.1 Days to 50 Per cent Flowering

Days to 50 per cent flowering was recorded by counting the number from sowing to 50 per cent of the plants in each plot produced flowers and expressed in days.

3.4.2.3.2 Number of Panicles m^{-2}

Productive tillers were recorded at harvest by using a quadrate of size 0.5 m x 0.5 m at two representative sites inside the net plot area and the mean number was worked out and expressed as panicle m^{-2}.

3.4.2.3.3 Panicle Length

The length of panicle was measured from the point of scar to the tip of the panicle from 10 randomly selected panicles in each treatment plot, average length was worked out and expressed in cm.

3.4.2.3.4 Panicle Weight

The same panicles selected for measuring the length was weighed separately and mean weight was worked out and expressed in g.

3.4.2.3.5 Number of Filled Grains Per Panicle

The filled grains were separated from each panicle, counted and the average number was arrived at.

3.4.2.3.6 Sterility Percentage

The total number of filled and unfilled grains were counted from 10 randomly selected panicles and the sterility percentage was worked out using the following formula

$$\text{Sterility per cent} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.4.2.3.7 Thousand Grains Weight

Thousand grains from each treatment were collected at random, dried and weighed at 14 per cent moisture content and expressed in g.

3.4.2.4 Yield and Harvest Index

3.4.2.4.1 Grain Yield

The grain harvested from the net plot area was sun dried to 14 per cent moisture content, the grain weight was recorded and expressed in kg ha^{-1}.

3.4.2.4.2 Straw Yield

The straw harvested from each net plot area was dried to constant weight under sunlight for three days and expressed in kg ha^{-1}.

3.4.2.4.3 Harvest Index

The harvest index was calculated using the following formula suggested by Donald and Hamblin (1976).

3.4.2.5 Observation on Weed

3.4.2.5.1 Weed Density

Total weed density was recorded at 20 and 40 DAS by placing a quadrat of size 0.25 m x 0.25 m randomly at two sites in each plot and expressed in no. m^{-2}.

3.4.2.5.2 Weed Dry Weight

Weed dry weight was recorded at 20 and 40 DAS by placing a quadrate of size 0.5 m x 0.5 m randomly at two sites in each plot. The weeds in the quadrate were uprooted and sundried for a day and then oven dried at 65 ± 5°C to constant weight was recorded as g m^{-2}.

3.5 CHEMICAL ANALYSIS

3.5.1 Soil Analysis

After the harvest of crop, composite soil samples were drawn from each treatment plot for the analysis of available N, P, K, Zn and B by following the method depicted in Table 1.

3.5.2 Plant Analysis

At 50 per cent flowering stage plant samples were analyzed for total B content and at harvest stage samples were analyzed for total N, P, K, Zn and B content. The samples were initially sun dried for a day and then dried in hot air oven at 65 ± 5 °C to constant weight, ground and used for analysis. The required quantities of samples were weighed out accurately, subjected to acid extraction and N, P, K, Zn and B content were determined by following the method shown in Table 2.

3.6 ECONOMICS

3.6.1 Net Income

Net income was computed using the formula

Net income (₹ ha^{-1}) = Gross income - Cost of cultivation

3.6.2 Benefit Cost Ratio

Benefit cost ratio was computed using the formula

$$\text{B: C Ratio} = \frac{\text{Gross Income}}{\text{Cost of cultivation}}$$

3.7 STATISTICAL ANALYSIS

The experimental data were analyzed statistically by using analysis of Variance technique for randomized block design (Cochran and Cox, 1965) and the significance was tested using F test. Wherever the F values were found significant, critical difference was calculated at five per cent probability level.

Table 2. Details of Plant Analysis

Sl. No.	Parameters	Method
1	Total N content	Modified microkjheldal method (Jackson, 1973)
2	Total P content	Vanadomolybdate phosphoric yellow colour method (Jackson, 1973).
3	Total K content	Dickman and Brays molybdenum blue method (Jackson, 1973)
4	Available Potassium	Using flame photometer (Jackson, 1973)
5	Available Zn	Using atomic absorption spectrophotometer (Lindsay and Norvell, 1978)
6	Available B	Azomethine-H calorimetric method suggested by Wolf, 1971

Results

4. RESULTS

The pot and field experiments for the present study were carried out during *Kharif* 2018 (June to September 2018) at Coconut Research Station, Balaramapuram, Kerala, India with an objective to standardize the ideal seed priming practice and to assess the influence of foliar application of PGPR mix I on growth and yield of upland rice raised as intercrop in coconut garden. The results of the experiment are presented in this chapter.

4.1 EXPERIMENT I: POT CULTURE EXPERIMENT - INFLUENCE OF SEED PRIMING ON GERMINATION AND SEEDLING VIGOUR OF PADDY

4.1.1 Germination Parameters

Data on germination parameters *viz.*, T_{50}, SG, GP, GI, SVI-I were statistically analyzed and presented in Table 4a and 4b.

4.1.1.1 Time to 50 Per cent Germination (T_{50})

Time to 50 per cent germination was not significantly influenced by seed priming treatments. Though not significant, T_7 (T_3 + PGPR mix I @ 10g kg^{-1} seed) and T_9 (seed priming with borax 0.5 g kg^{-1} seed) recorded the shortest number of days to attain 50 percent germination and T_{17} (control) recorded the longest number of days to attain 50 per cent germination .

4.1.1.2 Speed of Germination

Speed of germination was also significantly influenced by seed priming treatments. The treatment T_5 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mixI @10 g kg^{-1} seed) recorded the highest SG (2.79) and it was statistically comparable with T_1 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed), T_4 (seed priming with $ZnSO_4$ 5 g kg^{-1} seed) and T_6 (seed priming with borax 0.5 g kg^{-1} seed + PGPR mix I @10g kg^{-1} seed). The treatment T_{12} (seed priming with borax 2g kg^{-1} seed) registered the lowest speed of germination.

4.1.1.3 Germination Index

Germination index was statistically influenced by seed priming treatments. Among the treatments, T_{13} (seed priming with borax 0.5 g kg^{-1} seed + PGPR mix

I @ 10 g kg^{-1}seed) recorded the highest GI (129.3) and it was statistically comparable with T_5 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed). The lowest GI (82.3) was recorded by T_{12} (Seed priming with borax 2g kg^{-1} seed)

4.1.1.4 Germination Percentage

Seed priming treatments significantly influenced the germination percentage. The treatment T_{13} (seed priming with borax 0.5 g kg $^{-1}$ seed+ PGPR mix I @ 10 g kg^{-1} seed) recorded the highest germination percentage (92.2 %) and it was statistically comparable with T_1 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed) and T_5 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed). The lowest germination percentage was recorded in T_{17} (control).

4.1.1.5 Seedling Vigour Index- I

Seedling vigour index I was also significantly influenced by seed priming treatments. Among the seed priming treatments, T_{13} (seed priming with borax 0.5 g kg $^{-1}$ seed + PGPR mix I @ 10 g kg^{-1} seed) registered the highest SVI- I (2544.6) and it was statistically comparable with T_1 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed), T_4 (seed priming with $ZnSO_4$ 5 g kg^{-1} seed) and T_5 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10g kg^{-1} seed).The lowest SVI-I (1601.5) was recorded by T_{17} (control).

4.1.2. Scoring to Identify the Best Seed Priming Treatments

Scores of 1 to 17 were assigned to each germination parameter. Score of 1 was assigned to the best treatment and 17 to the treatment performed least (Table 5). Based on the total scores, T_5 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed) and T_{13} (seed priming with borax @ 0.5g kg^{-1} seed + PGPR mix I @ 10g kg^{1} seed) which scored total lower scores of 9 and 12, respectively were selected as the two best seed priming treatments for field experimentation.

Table 3a. Effect of seed priming treatments on time to 50 per cent germination speed of germination and germination index

Treatments	Time to 50 per cent germination	Speed of germination (days)	Germination index
T_1: Seed priming with $ZnSO_4$ 2 g kg^{-1} seed	5.3	2.59	118.67
T_2 : Seed priming with $ZnSO_4$ 3 mg kg^{-1} seed	4.7	2.11	100.67
T_3 : Seed priming with $ZnSO_4$ 4 mg kg^{-1} seed	5.7	2.18	104.67
T_4 :Seed priming with $ZnSO_4$ 5 mg kg^{-1} seed	5.7	2.62	112.67
T_5 : T_1 + PGPR mix I @ 10g kg^{-1}	5.0	2.79	126.67
T_6: T_2 + PGPR mix I @ 10g kg^{-1}	5.0	2.77	93.00
T_7 : T_3 + PGPR mix I @ 10g kg^{-1}	4.7	1.92	121.33
T_8 : T_4 + PGPR mix I @ 10g kg^{-1}	6.7	1.83	88.00
T_9: Seed priming with borax 0.5g kg^{-1} seed	4.7	2.04	95.67
T_{10} : Seed priming with borax 1 g kg^{-1} seed	6.0	2.16	103.0
T_{11} : Seed priming with borax 1.5 g kg^{-1} seed	6.7	2.21	105.3
T_{12} : Seed priming with borax 2g kg^{-1} seed	5.7	1.70	82.3
T_{13} : T_9 + PGPR mix I @ @10g kg^{-1} seed	4.7	2.49	129.3
T_{14}: T_{10} + PGPR mix I @10g kg^{-1} seed	4.7	2.06	116.6
T_{15}: T_{11} + PGPR mix I @10g kg^{-1} seed	5.3	2.03	100.3
T_{16}: T_{12} + PGPR mix I @10g kg^{-1} seed	5.3	1.89	89.0
T_{17} : Control	7.3	1.90	88.3
SEm (±)	0.2	0.06	1.4
CD (0.05)	NS	0.221	4.32

Table 3b. Effect of seed priming treatments on germination percentage and seedling vigour index

Treatments	Germination percentage	Seedling vigour index I
T_1: Seed priming with $ZnSO_4$ 2 g kg^{-1} seed	89.73	2511.7
T_2 : Seed priming with $ZnSO_4$ 3 mg kg^{-1} seed	84.44	2308.4
T_3 : Seed priming with $ZnSO_4$ 4 mg kg^{-1} seed	85.53	2134.9
T_4 :Seed priming with $ZnSO_4$ 5 mg kg^{-1} seed	86.66	251.4
T_5 : T_1 + PGPR mix I @ 10g kg^{-1}	89.73	2515.4
T_6: T_2 + PGPR mix I @ 10g kg^{-1}	86.63	1853.3
T_7 : T_3 + PGPR mix I @ 10g kg^{-1}	81.11	2431.5
T_8 : T_4 + PGPR mix I @ 10g kg^{-1}	82.23	1934.2
T_9: Seed priming with borax 0.5g kg^{-1} seed	81.11	2050.6
T_{10} : Seed priming with borax 1 g kg^{-1} seed	86.6	2220.9
T_{11} : Seed priming with borax 1.5 g kg^{-1} seed	84.4	2238.7
T_{12} : Seed priming with borax 2g kg^{-1} seed	81.1	1745.6
T_{13} : T_9 + PGPR mix I @10g kg^{-1} seed	92.2	2544.6
T_{14}: T_{10} + PGPR mix I @10g kg^{-1} seed	82.2	2392.0
T_{15}: T_{11} + PGPR mix I @10g kg^{-1} seed	82.2	2219.6
T_{16}: T_{12} + PGPR mix I @10g kg^{-1} seed	83.3	1812.7
T_{17} : Control	80.0	1601.5
SEm (±)	1.3	178.65
CD (0.05)	2.61	152.32

Table 4. Scoring to identify the best seed priming treatments for field experiment

Treatments	Time to 50 per cent germination	Speed of germination	Germination index	Germination percentage	Seedling vigour index	Total score
T_1	3	4	4	2	3	16
T_2	1	9	10	5	7	36
T_3	4	8	8	4	11	35
T_4	4	7	6	3	2	22
T_5	2	1	2	3	4	12
T_6	2	10	13	7	14	46
T_7	1	2	3	3	6	15
T_8	5	13	16	5	13	52
T_9	8	5	12	8	12	38
T_{10}	3	5	11	9	9	37

Table 4 contd. Scoring to identify the best seed priming treatments for field experiment

T_{11}	4	6	7	8	8	33
T_{12}	6	17	17	7	16	63
T_{13}	3	3	1	1	1	9
T_{14}	3	4	5	2	5	19
T_{15}	4	12	11	6	10	43
T_{16}	7	15	14	9	15	60
T_{17}	7	14	15	10	17	63

4.2 EXPERIMENT II: FIELD EXPERIMENT - INFLUENCE OF SEED PRIMING AND FOLIAR NUTRITION ON THE GROWTH AND YIELD OF UPLAND RICE

4.2.1 Growth Attributes

4.2.1.1 Seedling Emergence Index

Data related to the effect of seed priming and PGPR mix I nutrition on seedling emergence index at 14 DAS are presented in Table 5.

Seed priming and PGPR mix I nutrition significantly influenced the seedling emergence index at 14 DAS. The treatment T_5 recorded the highest seedling emergence index (98.6) which was statistically on par with T_2, T_3, T_4 and T_{10}.

4.2.1.2 Plant Height

Effect of seed priming and PGPR mix I nutrition on plant height at 40 DAS, 60 DAS and at harvest stage are presented in Table 6.

Seed priming and PGPR mix I nutrition significantly influenced the plant height at 40 DAS, 60 DAS and at harvest. At 40 DAS, the tallest plants were recorded in T_5 which was statistically comparable with all other treatments except T_2 and T_{11} and with T_1, T_4, T_7, T_9 and T_{10} at 60 DAS and at harvest. The shortest plants were recorded by T_{11} at all the three stages.

4.2.1.3 Tillers m^{-2}

Data pertaining to the seed priming and PGPR mix I nutrition on tillers m^{-2} at 40 DAS, 60 DAS and at harvest stage are presented in Table 7.

Tillers m^{-2} were significantly influenced by seed priming at all stages of observation. Results indicated that tillers m^{-2} was the highest in T_5 at all stages of observation. The treatment T_5 was statistically comparable with all other treatments

Table 5. Effect of seed priming and PGPR mix I nutrition on seedling emergence index

Treatments	Seedling emergence index
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	77.0
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	91.0
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	86.6
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	91.3
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	98.6
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	76.0
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	79.6
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	78.6
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	74.0
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	89.6
T_{11}: Control	61.0
SEm (±)	4.8
C D (0.05)	14.39

Table 6. Effect of seed priming and PGPR mix I nutrition on plant height, cm

Treatments	Plant height		
	40 DAS	60 DAS	At harvest
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	62.1	83.3	103.0
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	55.6	78.5	96.7
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	64.2	76.7	95.0
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	63.3	81.8	102.7
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	65.7	84.3	104.7
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-} at PI	63.1	78.7	97.0
T_7: T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	64.9	83.3	104.3
T_8: T_2+ foliar application of PGPR mix I @ 2 per cent at AT and PI	61.4	77.7	95.0
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	64.3	82.7	104.3
T_{10}: T_2+ soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	62.9	82.3	103.0
T_{11}: Control	57.5	76.3	92.7
SEm (±)	1.4	1.2	1.6
C D (0.05)	4.37	3.90	4.79

Table 7. Effect of seed priming and PGPR mix I nutrition on tillers m^{-2}

Treatments	Tillers m^{-2}		
	40 DAS	60 DAS	At harvest
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	537.3	553.3	508.3
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	628.0	640.0	587.0
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	629.3	638.7	585.7
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	600.0	617.3	560.7
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	662.7	676.3	622.0
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-} at PI	606.7	620.0	565.0
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	604.0	618.7	577.7
T_8 :T_2+ foliar application of PGPR mix I @ 2 per cent at AT and PI	656.0	667.3	607.0
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	594.7	619.3	666.3
T_{10}: T_2+ soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	605.3	617.3	556.7
T_{11}: Control	496.0	508.7	463.7
SEm (±)	29.6	28.3	24.3
C D (0.05)	89.71	85.83	73.47

except T_1 and T_{11} at 40 and 60 DAS and at harvest, T_5 was statistically on a line with all treatments except T_1.

4.2.1.4 Leaf Area Index

Data pertaining to the effect of seed priming and PGPR mix I nutrition on LAI is presented in Table 8.

Leaf area index was significantly influenced at 40 and 60 DAS. Results revealed that at 40 DAS, T_5 recorded significantly higher LAI (4.46). At 60 DAS also T_5 recorded the highest LAI (6.16) but it was on par with T_6. The control treatment recorded the lowest LAI both at 40 and 60 DAS.

4.2.1.5 Dry Matter Production (DMP)

Data related to the effect of seed priming and PGPR mix I nutrition on DMP at harvest is presented in Table 9.

A significant difference in DMP was observed due to seed priming and PGPR mix I @ nutrition. The treatment T_5 recorded the highest DMP (9751.3 kg ha^{-1}) and was on par with T_4, T_6, T_7, T_8 and T_9. The lowest DMP was observed in T_{11} (control).

4.2.1.6 Root shoot ratio

Root: shoot ratio at 50 per cent flowering was significantly influenced by seed priming and PGPR mix I nutrition (Table 10).

Among the treatments, the highest root shoot ratio was observed in T_7 and was statistically comparable with T_5, T_6 and T_2. The control treatment (T_{11}) recorded the lowest root: shoot ratio.

4.2.2 Physiological Attributes

4.2.2.1 Crop Growth Rate

Crop growth rate from 40 to 60 DAS and from 60 DAS to harvest was significantly influenced by seed priming and PGPR mix I nutrition (Table 11).

Table 8. Effect of seed priming and PGPR mix I nutrition on leaf area index

Treatments	Leaf area index	
	40 DAS	60 DAS
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	3.89	5.18
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	3.83	5.34
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	3.86	5.03
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	4.03	5.72
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	4.46	6.16
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	4.13	5.93
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	4.14	5.26
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	3.76	5.23
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	3.46	4.36
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	3.45	4.06
T_{11}: Control	2.71	3.63
SEm (±)	0.16	0.11
C D (0.05)	0.498	0.326

Table 9. Effect of seed priming and PGPR mix I nutrition on dry matter production at harvest, kg ha^{-1}

Treatments	DMP
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	8076.8
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	8564.7
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	7820.8
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	9407.2
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	9751.3
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	9749.1
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	8869.6
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	8889.5
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	9516.8
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	7167.0
T_{11}: Control	7466.8
SEm (±)	339.4
C D (0.05)	1021.06

Table 10. Effect of seed priming and PGPR mix I nutrition on root shoot ratio at 50 per cent flowering

Treatments	Root: shoot ratio
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	0.16
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	0.22
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	0.21
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	0.17
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	0.23
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	0.22
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	0.25
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	0.20
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.19
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.18
T_{11}: Control	0.14
SEm (±)	0.01
C D (0.05)	0.037

Among the treatments, T_5 recorded significantly higher CGR from 40 to 60 DAS, which was followed by T_3 and T_8. The CGR from 60 DAS to harvest was also the highest for T_5 but it was on par with T_8 and T_9.

4.2.2.2 Chlorophyll Content

Data pertaining to the effect of seed priming and PGPR mix I nutrition on total chlorophyll content in leaves at 50 per cent flowering are presented in Table 12.

Total chlorophyll was significantly influenced by seed priming and PGPR mix I nutrition. The treatment T_5 recorded higher chlorophyll content in leaves (5.56 mg g^{-1}) which T_5 was statistically on par with all other treatments except T_2, T_8 and T_{11} (control). The control treatment recorded the lowest total chlorophyll content.

4.2.2.3 Stomatal Conductance

Stomatal conductance at 50 per cent flowering was not significantly influenced by seed priming and PGPR mix I nutrition (Table 12).

4.2.2.4 Relative Water Content

The effect of seed priming and PGPR mix I nutrition on relative water content at 50 per cent flowering is presented in Table 13 and it was observed that seed priming and PGPR mix I nutrition did not have any significant effect on relative water content.

4.2.2.5 Proline Content

Proline content was not significantly influenced by seed priming and PGPR mix I nutrition (Table 13).

4.2.3 Observation on Weed

4.2.3.1 Weed Density

The effect of seed priming and PGPR mix I nutrition on weed density is presented in Table 14.

Table 11. Effect of seed priming and PGPR mix I nutrition on crop growth rate, g m^{-2} day^{-1}

Treatments	CGR	
	40 to 60 DAS	60 DAS to harvest
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	11.43	11.58
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	9.43	10.34
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	11.93	12.04
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	10.73	11.23
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	13.00	13.62
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	8.70	9.50
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	10.50	11.12
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	12.20	12.43
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	11.33	12.36
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	8.83	10.01
T_{11}: Control	7.56	8.65
SEm (±)	0.41	0.47
C D (0.05)	1.229	1.326

Table 12. Effect of seed priming and PGPR mix I nutrition on chlorophyll content and stomatal conductance at 50 per cent flowering

Treatments	Chlorophyll content ($mg\ g^{-1}$)	Stomatal conductance (mH_2o moles $m^{-2}\ s^{-1}$)
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	4.83	435
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	4.07	483
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	5.22	458
T_4 : T2 + foliar application of PGPR mix I @ 2 per cent at PI	5.40	523
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	5.56	445
T_6: T2 + soil application of PGPR mix I @ 2 kg ha at PI	5.33	548
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	5.39	598
T_8 :T_2+ foliar application of PGPR mix I @ 2 per cent at AT and PI	4.55	476
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	5.36	453
T_{10}: T_2+ soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	4.52	512
T_{11}: Control	3.91	11
SEm (±)	0.33	NS
C D (0.05)	1.002	

Table 13. Effect of seed priming and PGPR mix I nutrition on relative water content and proline content at 50 per cent flowering

Treatments	Relative water content (%)	Proline (μg^{-1} mol FW)
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	77.24	0.42
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	80.26	0.33
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	74.76	0.65
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	75.62	0.22
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	80.27	0.59
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha at PI	75.00	0.45
T_7: T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	75.66	0.49
T_8: T_2+ foliar application of PGPR mix I @ 2 per cent at AT and PI	75.94	0.68
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	80.66	0.45
T_{10}: T_2+ soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	76.93	0.39
T_{11}: Control	76.33	0.26
SEm (±)	3.45	0.12
C D (0.05)	NS	NS

Weed density at 20 DAS was significantly influenced by seed priming and PGPR mix I nutrition. The lowest weed density was recorded in T_5 which was significantly superior to other treatments. The highest weed density was recorded in the treatment T_{11} (control).

Weed density at 40 DAS was not significantly influenced by seed priming and PGPR mix I nutrition.

4.2.3.2 Weed Dry Weight

Table 15 shows the effect of seed priming and PGPR mix I nutrition on weed dry weight.

Seed priming and PGPR mix I nutrition significantly influenced the weed dry weight at 20 DAS. The treatment T_5 recorded the lowest weed dry weight at 20 DAS which was on par with T_3, T_4 and T_6. However, the highest weed dry weight was observed in control (T_{11}).

Weed dry weight was not significantly influenced by seed priming and PGPR mix I nutrition at 40 DAS.

4.2.4 Yield Attributes

4.2.4.1 Days to 50 Per Cent Flowering

Data pertaining to effect of seed priming and PGPR mix I @ nutrition on days to 50 per cent flowering is given in Table 16.

Seed priming and PGPR mix I nutrition had significant influence on days to 50 per cent flowering. The period for 50 per cent flowering was the shortest in T_7 which was statistically on par with T_5. The period for 50 per cent flowering was the longest in T_{11} (control).

4.2.4.2 Panicles m^{-2}

Data regarding the influence of seed priming and PGPR mix I nutrition on panicle m^{-2} is shown in Table 16.

Table 14. Effect of seed priming and PGPR mix I nutrition on weed density, no. m^{-2}

Treatments	20 DAS	40 DAS
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	14.6	10.3
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	14.6	8.7
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	10.6	8.7
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	10.6	8.3
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	8.0	6.0
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	16.0	10.3
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	14.7	12.7
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	13.3	10.6
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	13.3	8.7
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	10.7	7.6
T_{11}: Control	16.0	10.7
SEm (±)	0.31	0.2
C D (0.05)	1.325	NS

Table 15. Effect of seed priming and PGPR mix I nutrition on weed dry weight, g m^{-2}

Treatments	20 DAS	40 DAS
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	4.30	3.58
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	3.23	2.64
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	2.83	2.36
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	2.67	3.79
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	2.35	2.36
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	2.61	2.50
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	3.74	3.39
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	3.06	3.67
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	3.26	3.45
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	4.15	1.92
T_{11}: Control	4.36	3.82
SEm (±)	0.3	0.31
C D (0.05)	0.824	0.992

Panicles m^{-2} was significantly influenced by seed priming and PGPR mix I nutrition. The treatment T_5 recorded the highest number of panicles m^{-2} (525.3) which was statistically on par with all treatments except T_{11} (control). The lowest number of panicles m^{-2} was observed in control.

4.2.4.3 Panicle Length

Panicle length was not significantly influenced by seed priming and PGPR mix I nutrition (Table 16).

4.2.4.4 Panicle Weight

Panicle weight was significantly influenced by seed priming and PGPR mix I nutrition (Table 16). The treatment T_5 recorded the highest panicle weight (3.9 g) which was statistically on par with T_2 and T_4. The lowest panicle weight (2.7 g) was recorded in T_{11} (control).

4.2.4.5 Number of Filled Grains Per Panicle

Table 17 shows the influence of seed priming and PGPR mix I nutrition on number of filled grains per panicle.

Results revealed that the treatments had significant effect on number of filled grains per panicle. The treatment T_5 recorded the highest number of filled grains per panicle (129.3) which was significantly superior to other treatments. The lowest number of filled grains per panicle was recorded in T_{11} (control).

4.2.4.6 Sterility Percentage

The effect of seed priming and PGPR mix I nutrition on sterility percentage is given in Table 17.

Sterility percentage was also significantly influenced by seed priming and PGPR mix I nutrition. The lowest sterility percentage (16.2 per cent) was recorded in T_5 which was statistically comparable with T_7 and T_9. The highest sterility percentage (26.8 per cent) was recorded in the treatment T_{11} (control).

Table 16. Effect of seed priming and PGPR mix I nutrition on 50 per cent flowering, panicles m^{-2}, panicle length and panicle weight

Treatments	50 per cent flowering	Panicles m^{-2}	Panicle length, cm	Panicle weight, g
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	79.3	474.0	24.6	2.9
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	81.3	460.0	26.4	3.5
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	79.3	473.3	26.4	3.1
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	81.0	513.3	25.9	3.8
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	75.0	525.3	27.7	3.9
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	79.6	464.7	24.3	3.1
T_7: T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	74.3	516.0	27.3	3.4
T_8: T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	81.3	478.7	25.7	2.7
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	78.3	512.0	26.7	3.1
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	79.0	473.3	25.4	2.9
T_{11}: Control	82.3	409.3	23.1	2.7
SEm (±)	1.2	21.6	0.98	0.1
C D (0.05)	3.285	62.41	NS	0.418

Table 17. Effect of seed priming and PGPR mix I nutrition on filled grain per panicle, sterility percentage and 1000 grain weight

Treatments	Filled grains per panicle	Sterility percentage	1000 grain weight (g)
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	116.0	19.2	25.08
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	117.6	18.6	25.94
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	107.0	19.6	25.16
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	115.0	19.0	25.56
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	129.3	16.2	27.70
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	111.0	17.9	27.42
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	120.3	17.3	24.44
T_8:T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	115.7	18.6	25.62
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	120.6	16.8	24.04
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	93.3	24.5	25.72
T_{11}: Control	90.7	26.8	24.14
SEm (±)	2.6	0.4	1.21
C D (0.05)	7.7	1.3	NS

4.2.4.7 Thousand Grain Weight

Thousand grain was not significantly influenced by seed priming and PGPR mix I nutrition (Table 17).

4.2.5 Yield and Harvest Index

4.2.5.1 Grain Yield

The influence of seed priming and PGPR mix I nutrition on grain yield of upland rice is depicted in Table 18.

Grain yield was significantly influenced by seed priming and PGPR mix I nutrition. The treatment T_5 recorded the highest grain yield (4583.5 kg ha^{-1}) which was statistically on par with T_7 and T_9. The lowest grain yield (2637.2 kg ha^{-1}) was recorded in T_{11} (control).

4.2.5.2 Straw Yield

Table 18 reveals the effect of seed priming and PGPR mix I nutrition on straw yield.

Results indicated that seed priming and PGPR mix I nutrition had significant effect on straw yield. Among the different treatments, T_4 recorded the highest straw yield (5644.5 kg ha^{-1}) which was statistically comparable with T_5, T_6 and T_9. The lowest straw yield (3888.9 kg ha^{-1}) was recorded in T_{11} (control).

4.2.5.3 Harvest Index

The data depicting the influence of seed priming and PGPR mix I nutrition on harvest index is furnished in Table 18.

Harvest index was not significantly influenced by seed priming and PGPR mix I nutrition.

Table 18. Effect of seed priming and PGPR mix I on yield and harvest index

Treatments	Grain yield ($kg\ ha^{-1}$)	Straw yield ($kg\ ha^{-1}$)	Harvest index
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	4054.6	4622.2	0.44
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	4016.6	4548.2	0.47
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	3465.2	4355.6	0.44
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	3278.1	5644.5	0.39
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	4583.5	4933.4	0.48
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	3889.2	5629.6	0.40
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	4254.8	4614.8	0.47
T_8:T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	4078.4	4811.1	0.45
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	4255.0	5496.3	0.48
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	3762.8	4482.9	0.45
T_{11}: Control	2637.2	3888.9	0.37
SEm (±)	154.3	253.6	0.03
C D (0.05)	450.22	831.9	NS

4.2.6 Nutrient Uptake by Crop

The uptake of N, P, K, Zn and B by crop at harvest stage are presented in Table 19 and 20.

4.2.6.1 N Uptake

The results presented in Table 19 indicated that seed priming and PGPR mix I nutrition significantly influenced the N uptake by crop. The treatment T_5 recorded the highest N uptake (182.09 kg ha^{-1}) which was statistically comparable with the T_3, T_4 and T_6. The lowest N uptake was observed in the treatment T_{11} (control).

4.2.6.2 P Uptake

Seed priming and PGPR mix I nutrition significantly influenced the P uptake by crop (Table 19). The treatment, T_9 recorded significantly higher P uptake (28. 37 kg ha^{-1}) which was comparable with T_5 and T_{10}. The lowest P uptake (17.68 kg ha^{-1}) was recorded in T_7.

4.2.6.3 K Uptake

Potassium uptake by crop was significantly influenced by seed priming and PGPR mix I nutrition (Table 19). Among the treatments, T_5 recorded the highest K uptake (103.77 kg ha^{-1}), which was statistically comparable with T_4. The lowest K uptake (81.68 kg ha^{-1}) was recorded in T_{11} (control).

4.2.6.4 Zn Uptake

Seed priming and PGPR mix I nutrition significantly influenced the Zn uptake by crop at flowering and harvest stage (Table 20). The highest Zn uptake (0.245 kg ha^{-1}) at flowering stage was recorded in the treatment T_9 which was on par with T_3, T_5 and T_7. The control treatment (T_{11}) recorded the lowest Zn uptake.

Treatments with seed priming of $ZnSO_4$ recorded higher Zn uptake than treatments without the seed priming of zinc sulphate. The treatment, recorded the highest Zn uptake (0.641 kg ha^{-1}) which was statistically comparable with T_9. The lowest Zn uptake was recorded in T_{11} (control).

Table 19. Effect of seed priming and PGPR mix I on N, P and K uptake by crop at harvest stage of upland rice, kg ha^{-1}.

Treatments	N uptake	P uptake	K uptake
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	135.03	22.65	84.36
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	147.88	24.12	85.66
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	168.37	21.43	93.68
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	166.82	19.65	99.33
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	182.09	27.49	103.77
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	168.80	21.43	94.21
T_7: T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	153.14	17.68	89.83
T_8: T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	153.49	20.56	90.54
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	139.45	28.37	94.77
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	123.75	25.46	89.77
T_{11}: Control	119.59	18.46	81.68
SEm (±)	8.37	1.02	1.68
C D (0.05)	24.888	3.229	5.423

4.2.6.5 B uptake

The results presented in Table 20 depicted that seed priming and PGPR mix I nutrition had significant effect on B uptake by crop at flowering stage. The treatment T_6 recorded the highest B uptake (0.153 kg ha^{-1}) which was statistically comparable with T_4 and T_{10}. The lowest B uptake was observed in T_{11} (control).

Boron uptake by crop at harvest was also significantly influenced by seed priming and PGPR mix I nutrition. The treatment, T_{10} recorded the highest B uptake (0.432 kg ha^{-1}) which was on par with T_6. The lowest B uptake at harvest was observed in T_{11} (control).

4.2.7 Soil Nutrient Status After the Experiment

Data on organic carbon content, N, P, K, Zn and B status of post-harvest soil are presented in Table 21 and 22.

4.2.7.1 Organic Carbon

Seed priming and PGPR mix I nutrition did not have any significant effect on the organic carbon content of soil (Table 21).

4.2.7.2 Available N Status

Seed priming and PGPR mix I nutrition had significant effect on available N status of soil after the experiment (Table 21). The treatment T_9 (recorded significantly higher available soil N (384.6 kg ha^{-1}) which was statistically comparable with all treatments except T_1, T_8, and T_{11}. The lowest soil available N (292.6 kg ha^{-1}) was recorded in T_{11} (control).

4.2.7.3 Available P Status

The results presented in Table 21 indicated that seed priming and PGPR mix I nutrition significantly influenced the available P status of soil. The treatment, T_9 recorded the highest available soil P (23.0 kg ha^{-1}) which was on par with T_4. The lowest available soil P was recorded by T_1.

Table 20. Effect of seed priming and PGPR mix I nutrition on Zn and B uptake by crop at flowering and harvest stage, kg ha^{-1}

Treatments	Zn uptake		B uptake	
	At flowering	At harvest	At flowering	At harvest
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	0.174	0.495	0.112	0.300
T_2 : Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	0.182	0.417	0.128	0.367
T_3 : T_1 + foliar application of PGPR mix I @ 2 per cent at PI	0.213	0.530	0.124	0.275
T_4 : T_2 + foliar application of PGPR mix I @ 2 per cent at PI	0.181	0.447	0.149	0.305
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	0.235	0.641	0.116	0.299
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	0.191	0.450	0.153	0.392
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	0.211	0.510	0.106	0.317
T_8 :T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	0.196	0.448	0.121	0.355
T_9 : T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.245	0.566	0.131	0.334
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.197	0.435	0.140	0.432
T_{11}: Control	0.172	0.417	0.105	0.293
SEm (±)	0.014	0.026	0.005	0.017
C D (0.05)	0.045	0.077	0.014	0.052

4.2.7.4 Available K status

The data pertaining to available K status of soil revealed that seed priming and PGPR mix I nutrition had significant effect (Table 21). Among the different treatments, significantly higher available soil K (138.47 kg ha^{-1}) was recorded in T_6 which was statistically comparable with T_4 and T_9. The treatment T_7 recorded the lowest soil available soil K among the treatments.

4.2.7.5 Available Zn status

Results revealed that available Zn status of soil was significantly influenced by seed priming and PGPR mix I nutrition (Table 22). Among the different treatments, significantly higher available soil Zn (1.04 mg kg^{-1} soil) was recorded in T_7 which was statistically on par with all treatments except T_8 and T_{11}. The control treatment recorded the lowest soil available Zn.

4.2.7.6 Available B status

Seed priming and PGPR mix I nutrition significantly influenced the available B status of soil after the experiment (Table 22). The treatment T_8 recorded the highest soil available B which was on par with all treatments except T_1. The lowest soil available B was recorded in the treatment T_1.

4.2.8 Economics of Cultivation

4.2.8.1 Net Income

Data pertaining to the effect of seed priming and PGPR mix I nutrition on net income are presented in Table 23.

Results on net income indicated that the treatment, T_5 recorded significantly higher net income (₹ 53205 ha^{-1}) compared to other treatments and T_5 was followed by T_9. The treatment T_{11} (control) recorded the lowest net income (₹ 6263 ha^{-1}) which was significantly inferior to other treatments.

Table 21. Effect of seed priming and PGPR mix I nutrition on organic carbon content, soil available N, P and K content of post-harvest soil

Treatments	Organic carbon content (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	0.97	301.1	11.65	83.54
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	1.01	342.8	18.18	80.34
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	1.09	367.9	12.94	82.97
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	0.80	351.2	21.33	128.20
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	1.19	376.3	15.57	81.93
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	1.11	359.5	13.89	138.47
T_7: T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	0.96	376.3	18.62	73.78
T_8: T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	0.93	301.1	15.70	78.97
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.91	384.6	23.00	125.55
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.88	326.1	19.66	81.27
T_{11}: Control	0.91	292.6	17.58	88.61
SEm (±)	0.04	14.22	1.42	6.03
C D (0.05)	NS	42.241	4.214	18.945

4.2.8.2 B:C Ratio

Effect of seed priming and PGPR mix I nutrition on B:C ratio is presented in Table 22.

Seed priming and PGPR mix I nutrition had significant effect on B:C ratio. The highest B: C ratio (1.80) was recorded in the treatment T_5 which was statistically comparable with T_9. The lowest B:C ratio (1.04) was recorded in T_{11} (control).

Table 22. Effect of seed priming and PGPR mix I nutrition on soil available B and Zn, mg kg^{-1}soil

Treatments	Available Zn	Available B
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	0.61	0.050
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	0.66	0.081
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	0.79	0.072
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	0.85	0.067
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	0.86	0.082
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	0.72	0.082
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	1.04	0.070
T_8:T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	0.56	0.083
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.77	0.079
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	0.72	0.079
T_{11}: Control	0.52	0.068
SEm (±)	0.05	0.003
C D (0.05)	0.155	0.008

Table 23. Effect of seed priming and PGPR mix I nutrition on net income and B: C ratio

Treatments	Net income (₹ ha^{-1})	B:C ratio
T_1: $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	38937	1.59
T_2: Borax 0.5 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed	39405	1.58
T_3: T_1 + foliar application of PGPR mix I @ 2 per cent at PI	24829	1.33
T_4: T_2 + foliar application of PGPR mix I @ 2 per cent at PI	34260	1.44
T_5: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	53205	1.80
T_6: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI	43794	1.53
T_7:T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI	42007	1.60
T_8:T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI	38352	1.53
T_9: T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	46636	1.67
T_{10}: T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI	22303	1.28
T_{11}: Control	6263	1.04

DISCUSSION

5. DISCUSSION

The results of the field experiment entitled "Seed priming and foliar nutrition of upland rice in coconut garden" conducted at Coconut Research Station, Balaramapuram, Thiruvananthapuram district, Kerala, presented in chapter 4 are briefly described in this chapter.

5.1 EXPERIMENT NO.I : POT CULTURE EXPERIMENT TO STUDY THE INFLUENCE OF SEED PRIMING ON GERMINATION AND SEEDLING VIGOUR OF PADDY

5.1.1 Effect of Seed priming Treatments on Germination Parameters

Seed priming treatments significantly influenced the seed germination parameters *viz*, GP, SG, GI,T_{50} and SVI-I . However, T_{50} was not significantly influenced by seed priming. Among the treatments T 13 (seed priming with borax 0.5 g kg -1 seed+ PGPR mix1 @ 10 g kg^{-1} seed) recorded higher GP,GI,SVI-I and T_5(Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed + PGPR mix1 @ 10g kg^{-1}) seed recorded higher SG. T_{50} was shortest for T 7(T_3 + PGPR mix1@ 10g kg^{-1} seed) and T 9(seed priming with borax 0.5 g kg -1 seed). Faster germination of primed seeds was due to greater enzymatic activity and germination advancement in the primed seeds. Seed priming ensured the proper hydration, which resulted in enhanced activity of α - amylase that hydroloysed the macro starch molecules into smaller and simple sugars Similar results of seed priming treatments on germination behavior of rice seed was reported by Magsood et. al.,(2003). Lee et al. (1998) reported that germination and emergence rates and time from planting to 50% germination (T50) of primed seeds were 0.9-3.7 days less than those of untreated seeds. Farooq et al .,(2011) reported that seed priming in B solution of low concentration resulted in earliness and synchronization of germination, increased germination rate and seedling vigor. Prom-u-thai et al. (2012) stated that zinc priming promotes seed germination and seedling vigour of rice and the priming rice seed with Zn improved germination and seedling vigour.The increased growth of rice seedlings by application of PGPR is due to induction of IAA production and phosphorus solubilization.

5.2.2 Effect of Seed Priming And PGPR mix -I Nutrition on Growth Parameters

Seed priming and PGPR mix-1 nutrition significantly influenced the growth parameters *viz.*, seedling emergence index (14 DAS),plant height (40 DAS,60 DAS and at harvest), tillers m^{-2} (40 DAS, 60 DAS and at harvest), DMP (at harvest), LAI (40 and 60 DAS) and Root shoot ratio(50 per cent flowering)

Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with soil application of PGPR mix-I @ 2kg ha^{-1} (T_5) recorded higher values for plant height, tillers m^{-2}, and LAI at all stages of observation. This might be due to the fact that enhanced vigour of primed seeds that accelerated the initial growth and development of the plant. The result of the present study confirmed the finding of several workers (Mahajan et. al., 2011& Tilahun -Tadesse et. al.,2013). Also zinc contributed to accelerate the enzymatic activity and auxin metabolism in plants.These results are in agreement with the findings of Khan et al (2007).The increase in the field emergence was due to increase in metabolic activity and greater mobilization of food reserves to the growing points by the priming treatments. Positive effect of seed priming on field emergence percentage of rice seed have been reported by Farooq et.al., (2006).The increase in the tillers could be due to improvement of enzymatic and auxin metabolism in plants by Zn. Hafeez et al (2013) reported similar results. Higher nutrient absorption, early effect on attained leaf area and more leaf $hill^{-1}$ might encourage in the production of more photoassimilate that might enhance plant biomass which leaded to reduce tiller mortality and more dry matter production. Similar results were found by Srivastava et al.(2012). Significantly higher DMP at harvest was recorded with T_5 ($ZnSO_4$ @ 2 g kg^{-1} seed + PGPR mix-I @ 10 g kg^{-1} seed). This might be due to improved vegetative and reproductive growth as a result of taller plants, more number of panicles, larger leaf area, more number of grains panile^{-1}, grains with higher test weight, lower sterility percentage and higher grain yield. Root shoot ratio was also significantly influenced by seed priming treatments.This might be due to the release of IAA by PGPR which increased the root production.PGPR increased root growth and root length, resulting in greater root surface area which enables the plant to access more nutrients from soil (Barazani and Friedman, 1999). Other than phytohormones, solubilizing of phosphate can be other reason for growth enhancement in rice. Phosphate-solubilizing microorganisms present in PGPR mix –I in addition to provide phosphorus for plants, provide growth promoting substances like hormones, vitamins and amino acids.

5.2.3 Effect of Seed priming and PGPR mix-I Nutrition on Physiological Parameters

Seed priming treatments significantly influenced the chlorophyll content of leaf. Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with soil application of PGPR mix-I @ 2kg ha^{-1} registered the highest total chlorophyll content.Ayad *et al*. (2010) reported that Zn played a crucial role in triggering some of the chlorophyll biosynthetic pathway enzymes. Arif *et al*. (2012) opined that Zn fertilization resulted in considerable increase in total chlorophyll, chlorophyll a and b content in rice leaves. Crop growth rate was also significantly influenced by seed priming treatments. Improved crop growth rate is possibly due to strong and energetic start, which resulted in improved leaf area index that ended in improved crop growth rate. Sarwar et al (2013) reported that the maximum CGR and total chlorophyll content were registered with the combined application of borax (7.5 kg ha^{-1}) and zinc sulphate (12.5 kg ha^{-1}).

5.2.4 Effect of Seed Priming and PGPR nutrition on Yield Attributes

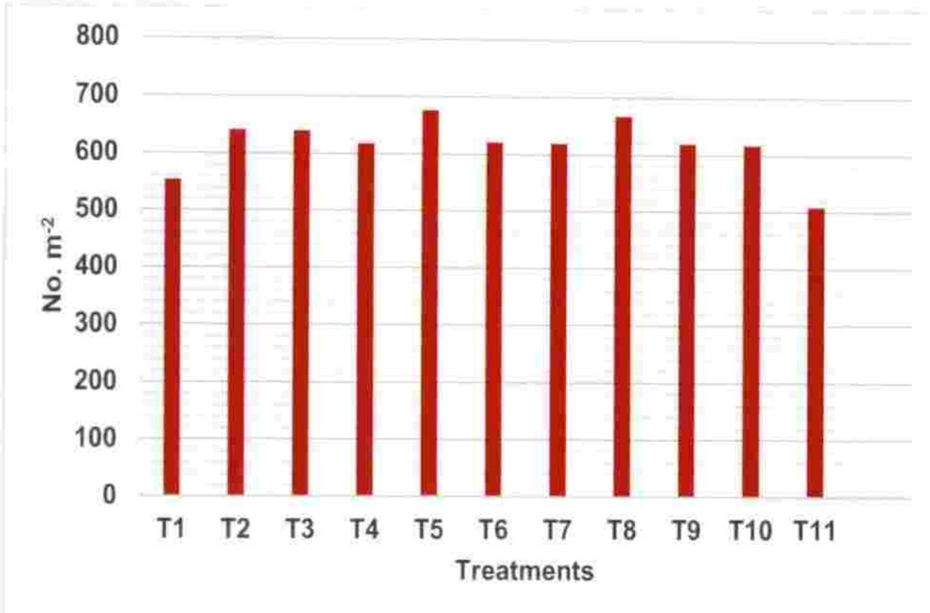

Fig.3. Effect of seed priming and PGPR mix I nutrition on tiller m^{-2} at 60 DAS

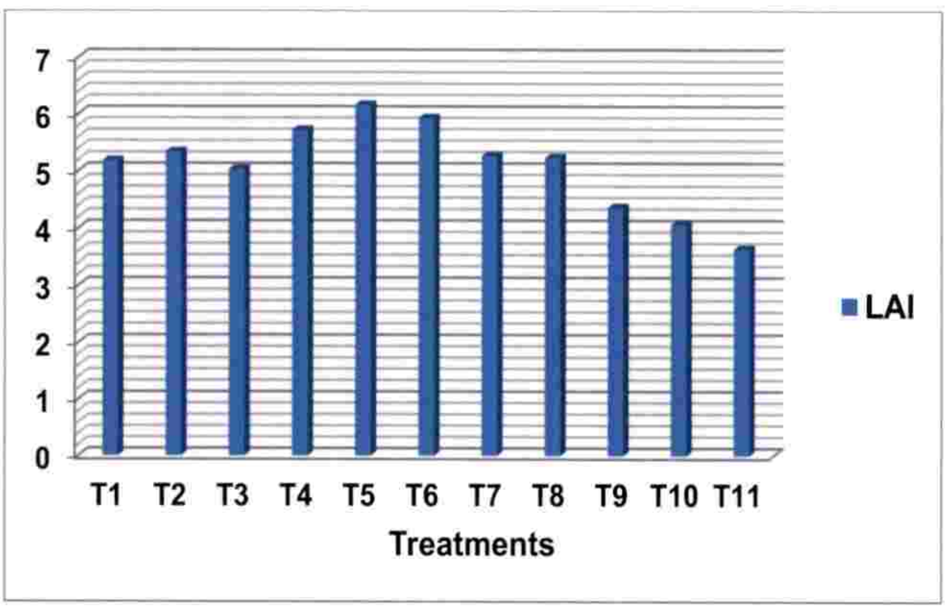

Fig4. Effect of seed priming and PGPR nutrition on LAI at 60 DAS

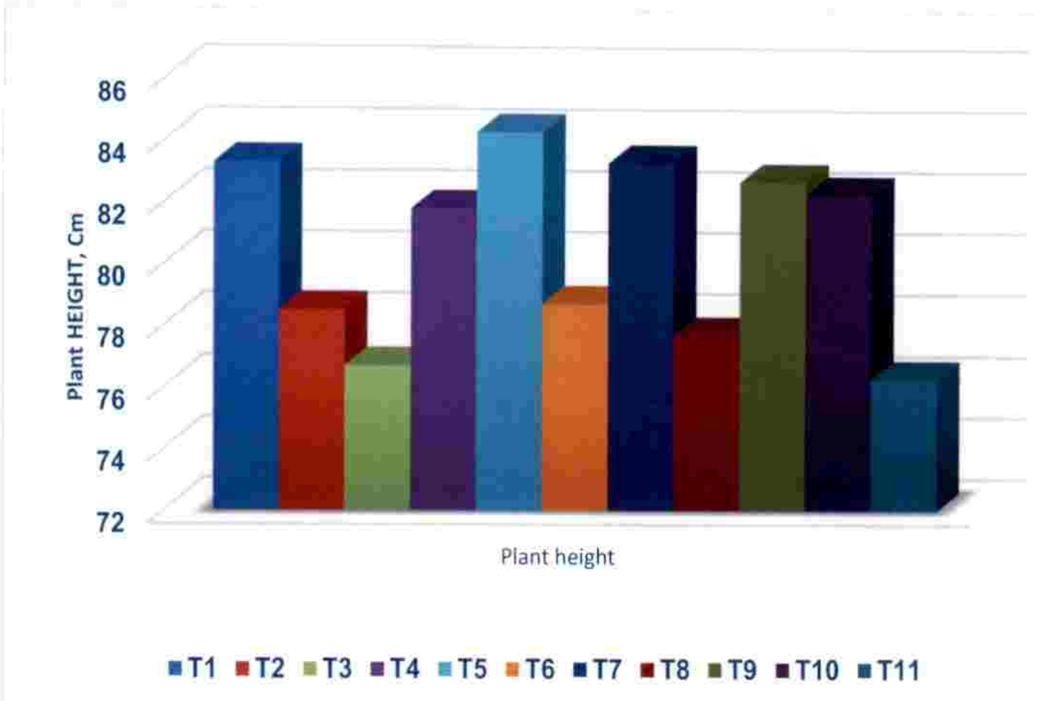

Fig 5. Effect of seed priming and PGPR mix I nutrition on plant height at 60 DAS

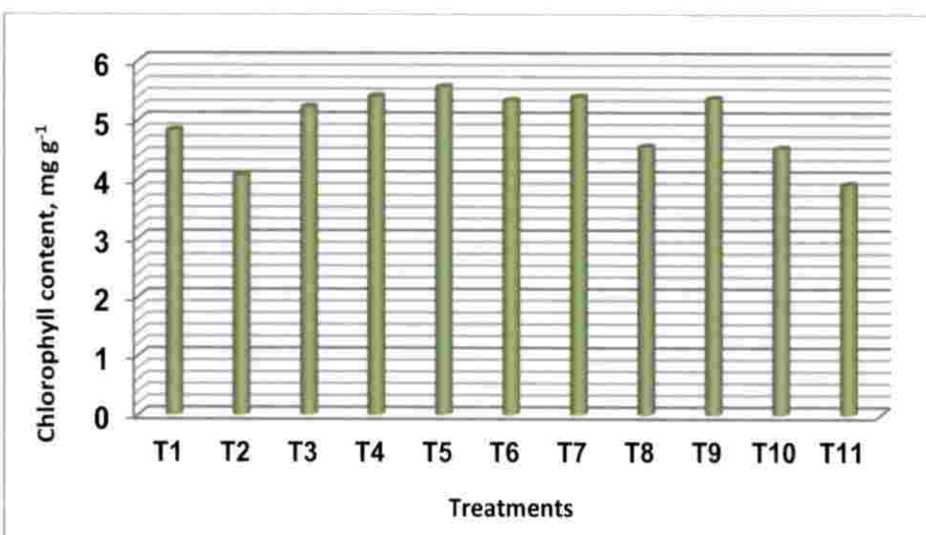

Fig.6. Effect of seed priming and PGPR mix I nutrition on chlorophyll content at 50 per cent flowering stage

Among the various yield attributes studied,days to 50 per cent flowering , number of panicles per m ^{2} ,filled grains panicle^{-1}, panicle weight and sterility percentage were significantly influenced by the seed priming and PGPR mix-I nutrition. Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with soil application of PGPR mix-I @ 2kg ha^{-1} at panicle initiation stage (T_5) recorded the highest values in number of panicles per m ^{2} ,filled grains panicle^{-1}, panicle weight. Increase in panicles m $^{-2}$ might be ascribed to adequate supply of zinc that might had increased the uptake and availability of other essential nutrients, which resulted in improvement of plant metabolic process and finally increased the crop growth. These results are in accordance with Naik and Das (2007) who reported that adequate supply of zinc produced more number of panicles per m $^{-2}$. The lowest sterility percentage was also recorded by T_5 (Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with soil application of PGPR mix-I @ 2kg ha^{-1} at PI stage). The improved nutrient and moisture supply from primed seeds might have resulted in enhanced fertilization, which ended in lower number of sterile spikelets as reported by Thakuria and Choudhary (1995) for direct seeded rice primed with salts of potassium. Seeds primed in ZnSO4 4.5 g kg-1 seed significantly improved the yield attributes in aerobic rice (Mukherjee and Pramanik, 2017).

5.2.6 Effect of Seed priming and PGPR mix-I on Yield and Harvest Index

Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with soil application of PGPR mix-I @ 2kg ha^{-1} at panicle initiation stage recorded higher grain yield and straw yield. Better production of yield attributes particularly panicles m^{-2} and fertile grains panicle^{-1} resulting from the better expression of growth attributes and better availability and uptake of nutrients might be the reason for higher grain yield in T_5. Higher yield due to zinc fertilization is attributed to its involvement in many metallic enzyme system ,regulatoryfunctions and auxin production (Sachdev et al., 1988),enhanced synthesis of carbohydrates and their transport to the site of grain production (Pedda Babu et al.,2007).Higher concentration of zinc concentration in the grain maintained by the application of zinc in the rhizosphere with constant supply coupled with more number of productive tillers per hill and higher zinc uptake might have increased the grain yield. Slaton et al. (2001) reported comparatively better dry matter production and higher tissue Zn concentration and grain yields from rice seeds primed with Zn than those fertilized via soil applied Zn. They also suggested that seed priming is an economic and better alternative to soil application (Slaton et al. 2001). Harris and his team, in their preliminary trials, demonstrated that seed priming with ZnSO4 (0.4%) was effective to meet Zn requirements of wheat with a mean yield (mean of eight on-farm trials) increase of 615 kg ha-1 (21%) compared with crops from non primed seed. Seed treatment with ZnSO4 (3.6 g kg-1 seed) with the recommended quantity of NPK significantly improved the grain yield of maize (Shabaz *et al.*, 2015). Maize seeds primed in 1 per cent ZnSO4 for 16 h resulted in 27.10 per cent increase in grain yield over control (Harris *et al.*, 2007).The enhancing effect of seed treatment with plant growth promoting rhizobacteria on grain and straw yield of rice was reported by many researchers(Raghu and MacRae,1996;Thakuria et al., 2004).Such an improvement might be attributed to N_2 fixing and P olubilising capacity of bacteria as well as the ability of these micro organisms to produce growth promoting substances (Salantur et al., 2006).

The increased straw yield recorded in T4(T2 + foliar application of PGPR mix –I at PI stage) might be due to higher plant height, tiller m^{-2} and dry matter production. Improved straw yield as a result of seed priming with boron might be due to earlier and uniform germination , which resulted in higher plant height , crop growth rate and leaf area index, which ended in increased straw yield. Grain and straw yields of *Basmati* rice significantly increased due to the inoculation of PGPR, and BGA with compost @ 5.0 t/ha, and chemical N fertilizer (2/3 N through urea) over control (Meena et al., 2013).Harvest index was not significantly influenced but shown higher values compared to control Improved harvest index by seed priming in direct seeded rice might be result of enhanced dry matter partioning towards the panicles that resulted in improved kernel yield.

5.2.9 Effect of Seed Priming Treatments on Nutrient Uptake by Crop

Seed priming and PGPR mix-1 nutrition had significant effect on N, P, K, Zn and B uptake by rice crop. Among the treatments , T_5 (Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with soil application of PGPR mix-I @ 2kg ha^{-1} at PI stage) recorded higher N, , K and Zn uptake by crop. P uptake was highest for T_9 (Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with foliar application of PGPR mix-I @ 2 per cent at AT & PI stage).. Seed priming enhanced the uptake of N and the results are supported by Mohammad et al.(2005) who concluded that improved nitrogen uptake and increased total reductive sugar content in rice have been related to improved root proliferation and enhanced α-amylase activity due to seed priming with $ZnSO_4$.Increased zinc uptake within the plant system and accumulation in grains from soil solution is regulated by the increased availability of Zn in the rhizosphere from where the roots receive nutrients.Khosravi(2018) reported that PGPR inoculation significantly increased shoot N uptake,P uptake and K uptake by 8%,16%,18 % respectively, compared to control treatments. Better availability of nutrients with improved root volume and root growth which consequently resulted in the better uptake of nutrients. Patten and Glick (2002) reported that PGPR enhanced nutrients uptake by increase of root elongation and growth due to IAA production and other plant growth promoting activities. Sharma et al .,2014 reported that PGPR application resulted in the increase in plant vigor and improvement in the plant's growth conditions and in the higher yield of rice. PGPR application also improved the plants zinc status which resulted in an increase in the zinc content of rice plants which correlated to the higher yield of the treated plants. The treatment, T_{10} (T2+soil application of PGPR at AT and PI stage) recorded the highest B uptake. Arif *et al*. (2012) revealed that soil application of B and Zn @ 3 and 6 kg acre-1 recorded higher B and Zn content in rice.

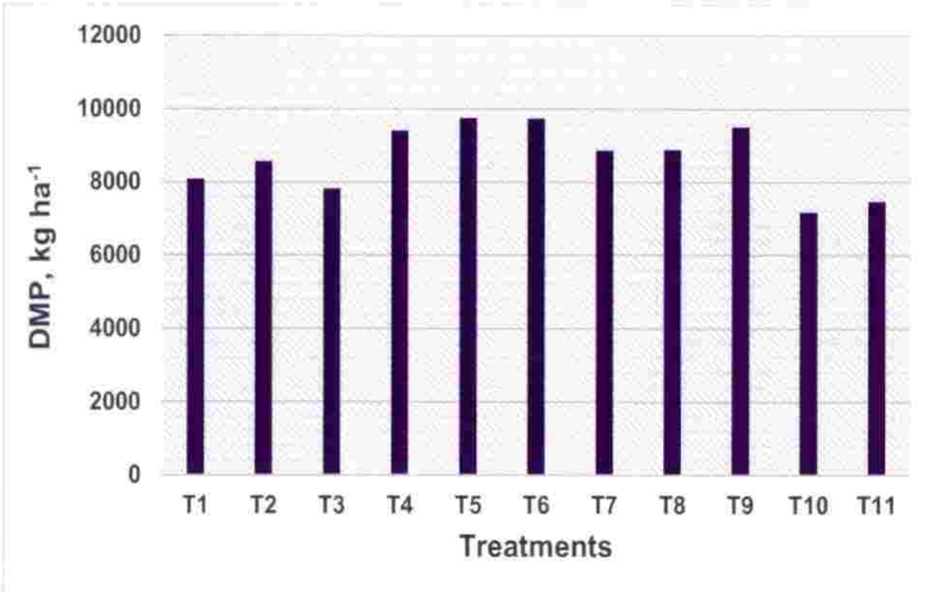

Fig.7. Effect of seed priming and PGPR nutrition on dry matter production, kg ha^{-1}

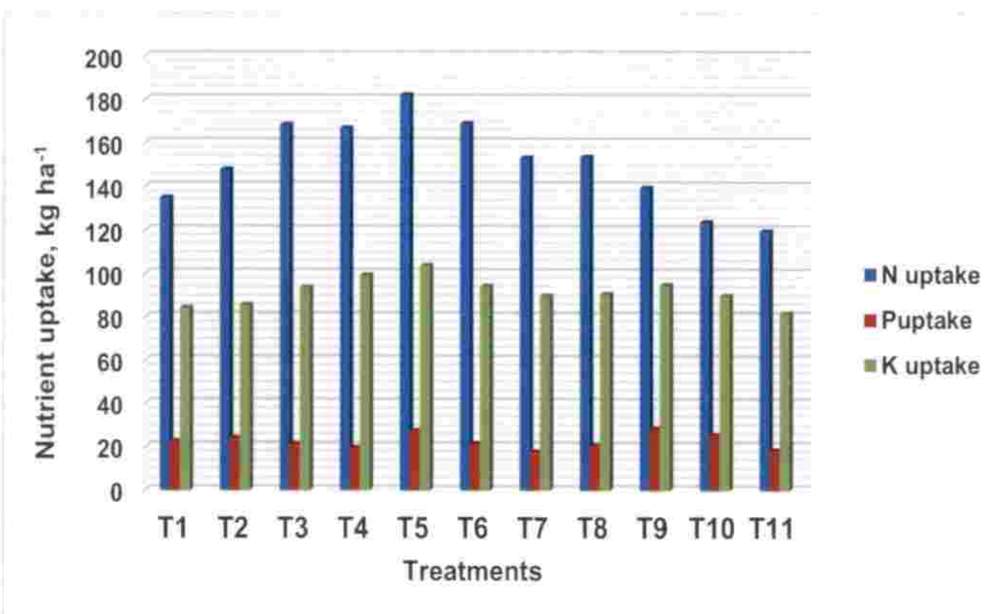

Fig. 8. Effect of seed priming and PGPR mix nutrition on N, P and K uptake at harvest, kg ha^{-1}

5.2.11 Effect of Seed priming on Post Harvest Organic Carbon and Available N, P, K, Zn and B Content in the Soil

Post-harvest soil analysis data revealed that all treatments recorded higher organic carbon content compared to initial soil status.But it was not significantly influenced by seed priming treatments. Similar to organic carbon, available N, P and K content in the soil also increased compared to the initial status.This might be due to the N fixation ,P solubilastion and K solubisation by plant growth promoting rhizobacteria(PGPR). Noshin et al., (2008) reported that the beneficial effect of Azospirillum can be accured from its nitrogen fixation and stimulating effect on root development().EL-Komy(2004) reported that Azospirillum spp. have multiple effect on plants including synthesis of phytohormones,nitrogen fixation,nitrate reductase activity and enhancing mineral uptake which ultimately enhance plant growth. Azotobacter spp. are non-symbiotic heterotrophic bacteria capable of fixing an average of 20 kg N/ha/year.Bacterization helps to improve plant growth and to increase soil nitrogen through nitrogen fixation by utilizing carbon for its metabolism (Monib et al.,1979). The P solubilizers isolated from Kerala soils were highly efficient in releasing the soil phosphorus(Meenakumari et al.,2008).

5.2.10 Effect of Seed priming Treatments on Economics

Results revealed that net return was found to increase with incremental rate of N up to 90 and K up to 45 kg ha^{-1}, respectively. The highest B:C ratio obtained in T_5 (Seed priming with $ZnSO_4$ @ 2 g kg^{-1} seed +PGPR mix-I @ 10 g kg^{-1} seed along with soil application of PGPR mix-I @ 2kg ha^{-1} at PI stage) was due to significantly higher grain and straw yield (Fig.15 and 16) registered in the treatment. The lowest net returns and B:C ratio recorded in T11(Control) was due the low grain and straw yield (Fig. 15) registered at this treatment. Similar findings were reported by Sinha *et al.*,(2018) in which the highest net returns (₹40,959 ha^{-1}) and B:C ratio (1.51)

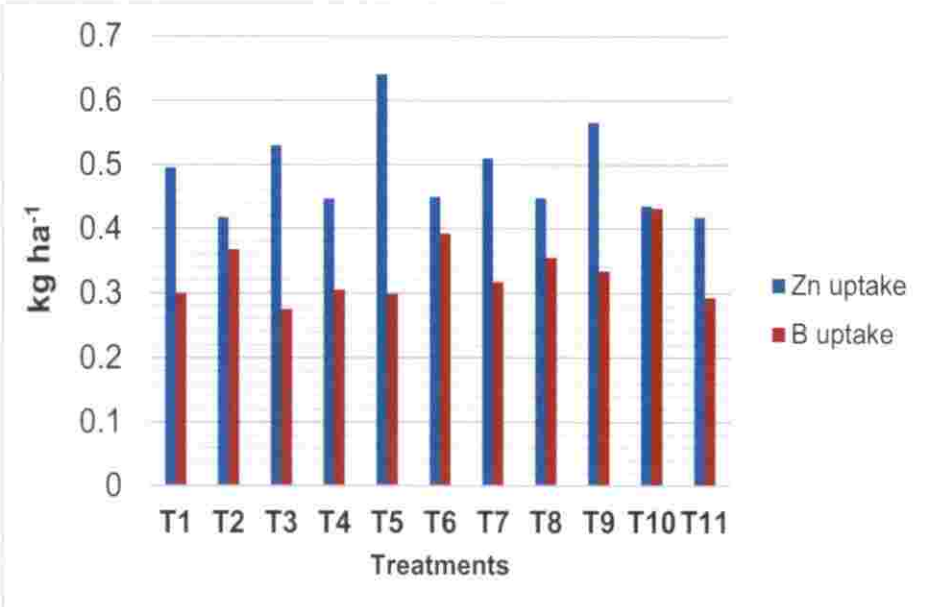

Fig.9 Effect of seed priming and PGPR mix I nutrition on Zn and B uptake at harvest, kg ha^{-1}

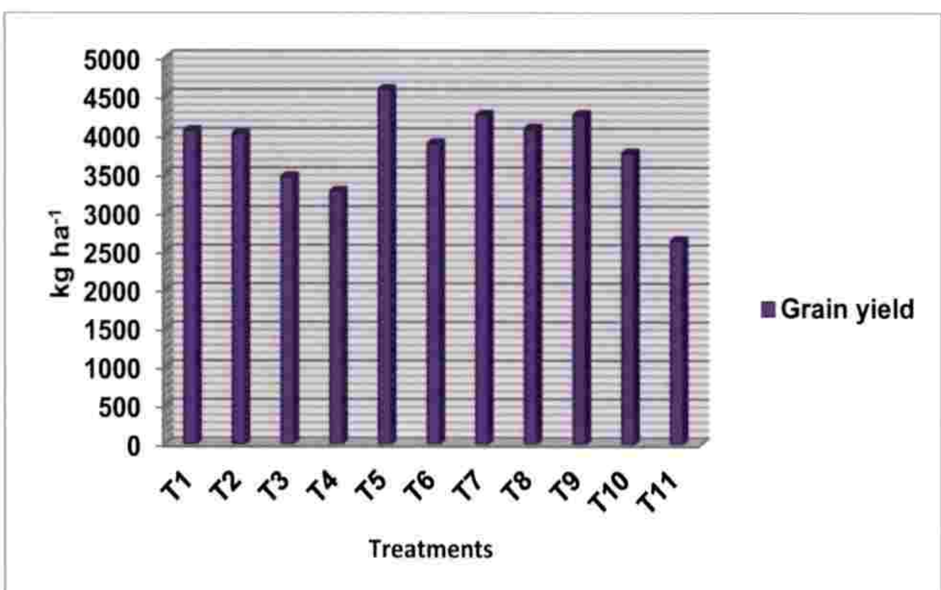

Fig.10. Effect of seed priming and PGPR mmix I nutrition on grain yield, kg ha^{-1}

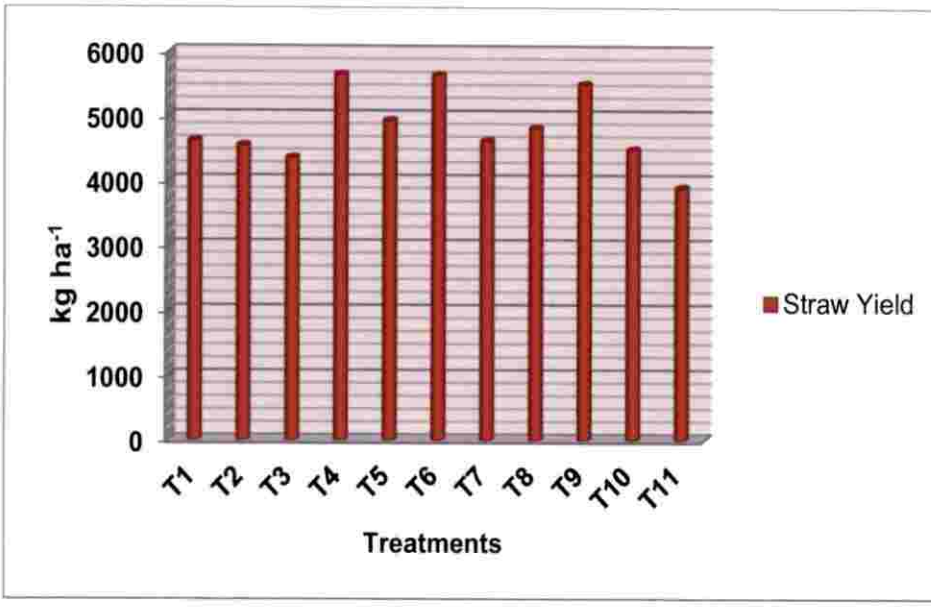

Fig.11. Effect of seed priming and PGPR mix I nutrition on straw yield, kg ha^{-1}

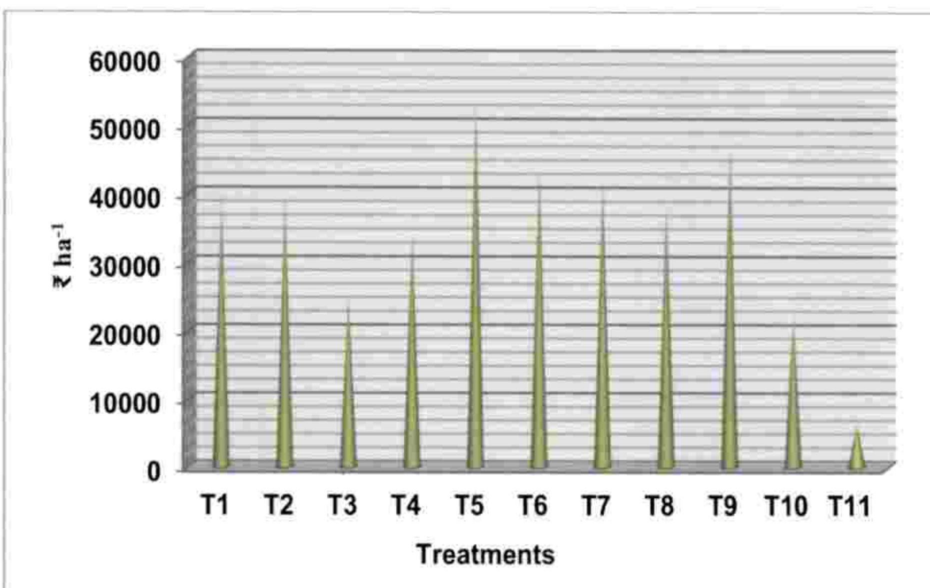

Fig. 12. Effect of seed priming and PGPR mix I nutrition on net returns, ₹ ha^{-1}

were recorded with soil application of zinc sulphate @ 25 kg ha^{-1} followed by foliar spray of 0.2 per cent zinc sulphate at panicle initiation stage and flowering stage. Seed priming was also cost effective compared with soil application with benefit:cost ratio of 8 and 360 from soil application and seed priming, respectively (Harris *et al.*, 2005).

SUMMARY

6. SUMMARY

Experiments were carried out during *Kharif* 2018 (May-September 2018) at Coconut Research Station, Balaramapuram with an objective to to standardize the ideal seed priming practice and to assess the influence of foliar application of PGPR mix I on growth and yield of upland rice raised as intercrop in coconut garden. The salient findings of the pot culture and field experiment were summarized below.

A pot culture experiment was carried out during May 2018 to study the influence of seed priming on germination and seedling vigour of paddy. Experiment was conducted in CRD with 17 treatments and three replications. Treatments were $ZnSO_4$ 2.0 g kg^{-1} seed (T_1), 3.0 g kg^{-1} seed (T_2), 4.0 g kg^{-1} seed (T_3), 5.0 g kg^{-1} seed (T_4), T_5 (T_1 + PGPR mix I 10 g kg^{-1} seed), T_6 (T_2 + PGPR mix I 10 g kg^{-1} seed), T_7 (T_3 + PGPR mix I 10 g kg^{-1} seed), T_8 (T_4 + PGPR mix I 10 g kg^{-1} seed), seed priming with borax 0.5 g kg^{-1} seed (T_9), 1.0 g kg^{-1} seed (T_{10}), 1.5 g kg seed (T_{11}), 2.0 g kg^{-1} seed (T_{12}), T_{13} (T_9 + PGPR mix I 10 g kg^{-1} seed), T_{14} (T_{10}+ PGPR mix I 10 g kg^{-1} seed), T_{15} (T_{11} + PGPR mix I 10 g kg^{-1} seed), T_{16} (T_{112} + PGPR mix I 10 g kg^{-1} seed) and control (T_{17}).

Seed priming treatments significantly influenced the germination parameters *viz*., GP, SG, GI, SVI. Among the seed priming treatments, the treatments, T_{13} (seed priming with borax 0.5 g kg $^{-1}$ seed + PGPR mix I @ 10 g kg^{-1} seed) and T_5 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @ 10 g kg^{-1} seed) recorded higher values for GP, GI, SVI and SG and lesser T_{50}. Hence, T_{13} and T_5 which recorded higher GP, GI, SG, SVI and lesser T_{50} were selected as the two best seed priming treatments for field experiment.

The field experiment was laid out in RBD with 11 treatments and 3 replications during *Kharif* 2018 (June to September 2018). The treatments comprised of seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @10 g kg^{-1} seed (T_1),seed priming with borax 0.5 g kg^{-1} seed + PGPR mix I @10 g kg^{-1} seed (T_2), T_1 + foliar application of PGPR mix I @ 2 per cent at PI stage (T_3),T_2+ foliar application of PGPR mix I @ 2 per cent at PI stage (T_4), T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_5), T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_6),T_1 + foliar application of PGPR mix I @ 2 per cent at AT and PI stage (T_7),T_2 + foliar application of PGPR mix I @ 2 per cent at AT and PI stage (T_8),T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI stage (T_9), T_2 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI stage (T_{10}) and a control (POP) (T_{11}).

The results of the study revealed that the seed priming had significant effect on growth characters. Seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I 2 kg ha^{-1} at PI stage recorded higher values for seedling emergence index, plant height, tillers m^{-2}, LAI, root shoot ratio and DMP.

The physiological parameters *viz*., relative water content, stomatal conductance and proline content at 50 per cent flowering were not significantly influenced by seed priming and PGPR nutrition. However, total chlorophyll content at 50 percent flowering and CGR were significantly influenced by the treatments. Seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_5) recorded the highest total chlorophyll content. Crop growth rate from 40 to 60 DAS and from 60 DAS to harvest was also the highest in T_5.

Similar to that of growth attributes, yield attributes were significantly influenced by seed priming and PGPR nutrition. The period for 50 per cent flowering was the shortest in T_7 (74 days) followed by T_5 (75 days). Seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_5) recorded higher values for number of panicles m^{-2} and filled grains per panicle and the lowest sterility percentage.

Data on grain yield revealed that seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_5) recorded the highest grain yield (4583.5 kg ha^{-1}) which was statistically on par with T_7 (seed priming with $ZnSO_4$ 2 g

kg^{-1} seed + foliar spray of PGPR mix I 2 per cent at AT and PI stage) and T_9 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I 2 kg ha^{-1} at AT and PI stage). The grain yield was the lowest (2637.2 kg ha^{-1}) in control. However, the highest straw yield (5644.5 kg ha^{-1}) was recorded by the treatment T_4 (seed priming with borax 0.5 kg ha^{-1} + foliar application of PGPR mix I @ 2 per cent at PI). Harvest index was not significantly influenced by seed priming and PGPR mix I nutrition.

Uptake of N, P and K by crop was significantly influenced by seed priming and PGPR mix I nutrition. Seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_5) recorded the highest N and K uptake by crop. Seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI stages (T_9) recorded significantly higher P uptake (28.37 kg ha^{-1}). The lowest N, P and K was uptake by crop was recorded by T_{11} (control).

Seed priming and PGPR mix I nutrition significantly influenced the Zn uptake by crop. The highest Zn uptake (0.245 kg ha^{-1}) at flowering stage was recorded in the treatment T_9 (seed priming with $ZnSO_4$ + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI stages). However, at harvest, T_5 (seed priming with $ZnSO_4$ 2 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage) recorded the highest Zn uptake by the crop. The treatment T_{11} (control) recorded the lowest Zn uptake at flowering and harvest stage.

Boron uptake by crop was also significantly influenced by the treatments. Seed priming with borax 0.5 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI (T_6) recorded the highest B uptake (0.153 kg ha^{-1}) at flowering stage and at harvest stage seed priming with borax 0.5 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI stages (T_{10}) recorded the highest uptake. At both the stages, the lowest B uptake was observed in T_{11} (control).

Seed priming and PGPR nutrition significantly influenced the N, P, K and Zn status of post harvest soil. Seed priming with $ZnSO_4$ 0.5 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI stages (T_9) recorded significantly higher available soil N (384.6 kg ha^{-1}) and available P (23.00 kg ha^{-1}). However, available K was the highest in seed priming with 0.5 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_6). Among the different treatments, significantly higher available soil Zn (1.04 mg kg^{-1} soil kg ha^{-1}) was recorded with seed priming with $ZnSO_4$ 0.5 g kg^{-1} seed + foliar application of PGPR mix I @ 2 per cent at AT and PI stages (T_9). Available B status in soil was not significantly influenced by the treatments.

Results on net income and B: C ratio indicated that seed priming with $ZnSO_4$ 0.5 g kg^{-1} seed + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_5) recorded significantly higher net income (₹ 53205 ha^{-1}) and B: C ratio (1.80) compared to other treatments.

Considering the growth, physiological parameters, yield attributes, nutrient uptake, grain yield, straw yield and economics, seed priming with $ZnSO_4$ 2g + PGPR mix I @ 10 g kg^{-1} seed followed by soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_5) is found effective for higher grain yield and returns in upland rice intercropped in coconut garden.

FUTURE LINE OF WORK

- Seed priming can be compared with other seed invigouration methods.
- Experiment can be repeated for two or more seasons and with different varieties for confirmation.
- Experiments can be conducted to study the effect of seed priming and PGPR nutrition on grain yield under wet land situation

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Appendix

APPENDIX 1

Weather data during the crop season (May 2018- September 2018)

Standard week	Temperature, ^{0} C		RH, %		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
23	31.08	21.07	93.17	79.1	69
24	31.2	20.84	96.43	85.7	127.6
25	31.18	19.65	90	80.5	64.5
26	31.74	19.91	92	83.1	57.1
27	31.47	20.18	89.4	80.4	26.8
28	30.64	18.67	90	75.2	13.4
29	29.24	19.71	86.1	85.2	70.2
30	30.2	19.27	91.2	79.2	56.8
31	31.42	19.24	88.5	74.5	12.9
32	29.4	19.52	90.4	80.9	137.8
33	30.38	19.58	91	85	107.1
34	29.61	18.84	93.3	89	206.8
35	31.08	21.02	89	77	2.9
36	31.12	19.87	89.1	71	0
37	32.62	20.71	87.1	72.9	0
38	33.71	19.47	84.2	70.7	0

Abstract

SEED PRIMING AND FOLIAR NUTRITION OF UPLAND RICE IN COCONUT GARDEN

by

GOPAKUMAR.A.T
(2017-11-018)

ABSTRACT

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ABSTRACT

The study entitled "Seed priming and foliar nutrition of upland rice in coconut garden" was undertaken during 2017-2019 at College of Agriculture, Vellayani,Thiruvananthapuram, with the objectives to standardize the ideal seed priming practice and to assess the influence of foliar application of PGPR mix 1 on growth and yield of upland rice raised as intercrop in coconut garden.

The research work was carried out at Coconut Research Station (CRS), Balaramapuram, Thiruvananthapuram. The variety used for the trial was Prathyasa. A pot culture experiment was carried out during May 2018 to study the influence of seed priming on germination and seedling vigour of paddy. It comprised 17 treatments and 3 replications done using completely randomized design.The treatments comprised of seed priming with different concentrations of zinc sulphate, borax and PGPR mix I. Seed priming with $ZnSO_4$ 2 g kg^{-1} seed + PGPR mix I @10 g kg^{-1} (T_5) and seed priming with borax 0.5 g kg^{-1} seed+ PGPR mix 1 @10 g kg^{-1} (T_{13}) were selected for field experiment.

The crop was raised as an intercrop in 55 year old coconut garden planted at a spacing of 7.6 m ×7.6 m. The field experiment was laid out in randomized block design with 11 treatments and 3 replications during *kharif* 2018 (June to September 2018) .The treatments comprised of seed priming with Zinc sulphate 2 g kg^{-1} seed + PGPR mix I ix I @10 g kg^{-1} seed(T_1),seed priming with Borax 0.5 g kg^{-1} seed + PGPR mix I @10 g kg^{-1} seed (T_2),T_1 +Foliar spray of PGPR mix I 2 per cent at PI stgae (T_3),T_2+foliar spray of PGPR mix I @ 2 per cent at PI stgae (T4), T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage(T_5) ,T_2+ soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage (T_6),T_1 + foliar spray of PGPR mix I @ 2 per cent at AT and PI stage (T_7),T_2 + foliar spray of PGPR mix I @ 2 per cent at AT and PI stage (T_8),T_1 + soil application of PGPR mix I @ 2 kg ha^{-1} at AT and PI stage (T_9), T_2 + soil application of PGPR mix-1@ 2 kg ha^{-1} at active tillering and panicle initiation stage(T_{10}) and a control (T_{11}).

The results of the study revealed that seed priming had significant influence on most of the growth characters, physiological parameters, yield attributes and yield of upland rice intercropped in coconut garden.

The treatment T_5 (T_1+ soil application of PGPR mix I @ 2 kg ha^{-1} at PI stage) recorded highest plant height at 40, 60 DAS and at harvest. Seedling emergence index was highest for T_5 and it was on par with T_2, T_3, T_4 and T_{10}. The highest number of tillers m^{-2} was recorded in T_5 at 40 and 60 DAS and at harvest and the lowest was observed in T_{11} (control) .The highest leaf area index was observed in T_5 at 40 DAS and 60 DAS but it was on par with T_6 (T_2+ soil application of PGPR mix-1@ 2 kg ha^{-1} at panicle initiation stage) at 60 DAS.

The treatment T_5 also recorded highest root shoot ratio at 50 per cent flowering and was comparable with T_2,T_6 and T_7.Chlorophyll content at 50 percent flowering was the highest for T_5 and comparable with all other treatments except T_2 and T_{11}.

Crop growth rate (CGR) at 40 to 60 DAS was higher in T_5, which was on par with T_3 and T_8 but at harvest higher CGR observed in T_5 was comparable with T_3, T_8 and T_9.

The period for 50 per cent flowering was the shortest in T_7 (74 days) followed by T_5 (75 days). T_5 recorded higher values for yield attributes. However, it was on par with T_4, T_7 and T_9 for number of panicles m^{-2}, with T_7 and T_9 for number of filled grains per panicle. The lowest sterility percentage recorded in T_5 was on par with T_4,T_7 and T_9 .

Data on grain yield revealed that the treatment T_5 (T_1+ soil application of PGPR mix 1@ 2 kg ha^{-1} at PI stage) recorded the highest grain yield which was statistically on par with T_7 (T_1 + foliar spray of PGPR mix I @ 2 per cent at AT and PI stage) and T_9 (T_1 +soil application of PGPR mix I @ 2 kg ha-1 at active tillering and panicle initiation stage). The grain yield was the lowest in the control. The highest straw yield was recorded by the treatment T_4 which was statistically on par with T_6, T_5, T_1, T_{11} and T_8.

Hence it could be concluded that seed priming with $ZnSO_4$ @ 2g + PGPR mix1 10 g kg $seed^{-1}$ followed by soil application of PGPR mix 1 @ 2 kg ha^{-1} at panicle initiation stage is found effective for higher grain yield and returns in upland rice intercropped in coconut garden.

സംഗ്രഹം

തെങ്ങിൻ തോപ്പിലെ കരനെല്ല് കൃഷിയുടെ വിത്ത് പ്രൈമിങ്ങും ഇലകളുടെ പോഷണവും എന്ന വിഷയത്തെ ആസ്പതമാക്കിയ ഗവേഷണ പഠനം 2017 - 19 കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. ഇതിനായുള്ള വിളഭൂമി പരീക്ഷണം ബാലരാമപുരത്തുള്ള തെങ്ങു ഗവേഷണ കേന്ദ്രത്തിൽ 2018 ജൂൺ മുതൽ സെപ്തംബര് വരെയാണ് നടന്നത്. തെങ്ങിൻ തോട്ടത്തിൽ ഇടവിളയായി വളർത്തുന്ന നെല്ലിന്റെ അനുയോജ്യമായ വിത്ത് പ്രൈമിംഗ് പ്രാക്ടീസ് മാനദണ്ഡമാക്കുന്നതിനും, വളർച്ചയ്ക്കും വിളവിനും പിജിപിആർ മിക്സ് I ന്റെ ഇലകളുടെ പ്രയോഗത്തിന്റെ സ്വാധീനം വിലയിരുത്തുക എന്നിവയാണ് പ്രധാന ലക്ഷ്യങ്ങൾ

പ്രത്യാശ എന്ന നെല്ലിനമാണ് പഠനത്തിനായി ഉപയോഗിച്ചത്.പതിനൊന്ന് രീതികളിലാണ് ഗവേഷണം നടത്തിയത് . രണ്ട് ഗ്രാം സിങ്ക് സൾഫേറ്റ്+ പിജിപിആർ മിക്സ് I 10 ഗ്രാം ഉപയോഗിച്ച് വിത്ത് പ്രൈമിങ്,അര ഗ്രാം ബോറാക്സ് + പിജിപിആർ മിക്സ് I 10 ഗ്രാം ഉപയോഗിച്ച വിത്ത് പ്രൈമിങ് , വിത്തു പ്രിമിങ്ങിന്റെ കൂടെ വ്യത്യസ്ത ഘട്ടങ്ങളിൽ പി.ജി.പി.ആർ മിക്സ് I മണ്ണിൽ പ്രയോഗിക്കൽ,ഇല പ്രയോഗം തുടങ്ങിയ രീതികളാണ് പരീക്ഷണത്തിന് ഉപയോഗിച്ചത്.

രണ്ട് ഗ്രാം സിങ്ക് സൾഫേറ്റ്+ പിജിപിആർ മിക്സ് I 10 ഗ്രാം ഉപയോഗിച്ച് വിത്ത് പ്രൈമിങ്+ പിജിപിആർ മിക്സ് I രണ്ടു കിലോ ഒരു ഹെക്ടറിൽ എന്ന അളവിൽ മണ്ണിൽ പ്രയോഗം നൽകുന്ന രീതിയാണ് കൂടുതൽ ധാന്യ വിളവ് നൽകുന്നതും കൂടുതൽ വരുമാനം നൽകുന്നതുമായ രീതിയെന്ന് ഗവേഷണത്തിലൂടെ കണ്ടെത്തി