Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut

By

VANAM JOSHNA

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled "**Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut**" is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Joshna. V

Vellayani

VANAM JOSHNA

Date: 30-01-2023

(2020-11-128)

CERTIFICATE

Certified that the thesis entitled "**Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut**" is a record of research work done independently by **Ms. Vanam Joshna** (2020-11-128) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associateship, or fellowship to her.

Vellayani

Date 30.01.23

Dr. Sharu S R

(Major advisor and advisory committee)

Assistant Professor

Department of Agronomy

College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. **Vanam Joshna** (2020-11-128), a candidate for the degree of **Master of Science in Agriculture**, with major field Agronomy, agree that this thesis entitled **"Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut"** may be submitted by **Ms. Vanam Joshna** in partial fulfilment of the requirement for the degree.

Dr. Sharu S R
(Major advisor, Advisory committee)
Assistant Professor
Department of Agronomy
College of Agriculture, Vellayani
Thiruvananthapuram-695522

Dr. Shalini Pillai P
(Member, Advisory committee)
Professor and Head
Department of Agronomy
College of Agriculture, Vellayani
Thiruvananthapuram-695522

Dr. Sheeja K Raj
(Member, Advisory committee)
Assistant Professor
Department of Agronomy
College of Agriculture, Vellayani
Thiruvananthapuram-695522

Dr. N. V. Radhakrishnan
(Member, Advisory committee)
Professor and Head
Department of Pathology
College of Agriculture, Vellayani
Thiruvananthapuram-695522

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation/ Symbol	**Expansion**
%	Per cent
@	At the rate of
₹	Indian rupee
BCA	Biocontrol agents
BCR	Benefit cost ratio
CD	Critical difference
CGR	Crop growth rate
DAP	Diammonium phosphate
DAS	Days after sowing
DMP	Dry matter production
$dS\ m^{-1}$	Deci siemens per meter
EC	Electrical conductivity
et al.	Co-workers
fb	followed by
Fig.	Figure
FYM	Farm yard manure
g	gram
$g\ kg^{-1}$	Gram per kilogram
ha-1	Per hectare
IAA	Indole acetic acid
ISR	Induced systemic resistance
K	Potassium
KAU	Kerala Agriculture University
KCl	Potassium chloride
kg	Kilogram
kg	kilogram
$kg\ ha^{-1}$	Kilogram per hectare

KSB	Potassium solubilizing bacteria
L	Litre
LAD	Leaf area duration
LAI	Leaf area index
LER	Land equivalent ratio
m	Metre
m^2	Square metre
m-2	Per square metre
mg	Milligram
mg kg^{-1}	Milligram per kilogram
Mha	Million hectares
MSL	Mean sea level
N	Nitrogen
NAA	Naphthalene acetic acid
NAR	Net assimilation rate
NS	Non-significant
No.	Number
^oC	Degree Celsius
OC	Organic carbon
P	Phosphorous
PGPR	Plant growth promoting rhizobacteria
pH	Potenz hydrogen
POP	Package of practices
ppm	Parts per million
PSB	Phosphorous solubilizing bacteria
RBD	Randomised block design
RDA	Recommended dietary allowances
RDF	Recommended dose of fertiliser
RGR	Relative growth rate

S	Sulphur
SE m	Standard error of mean
t ha^{-1}	Tonne per hectare
VC	Vermicompost
Viz.	Namely
WSF	Water soluble fertilisers
Zn	Zinc

LIST OF APPENDIX

INTRODUCTION

1. INTRODUCTION

Pulses being an inseparable ingredient in Indian vegetarian diet and soil ameliorative values, remained an integral component of subsistence farming. Pulses are promising legume crop for controlled ecological support system, since foliage, green pod and seeds are edible with low fat, high complex carbohydrate and proteins and adequate minerals.

Pulses are excellent source of protein as well as a wide range of vitamins and minerals. They are rich in lysine. Pulses are also rich sources of Vitamin A, Vitamin B_1, Vitamin C and better source of minerals like iron, calcium, magnesium, zinc and potassium. In addition to, amusing source of protein, pulses are an incredible gift from nature with incomparable capabilities like deep root system, biological nitrogen fixation and mobilization of insoluble soil nutrients. They are called as soil fertility restorers as they bring qualitative variations in soil properties (Kumar *et al.*, 2018). Hence it is regarded as potential crop for soil as well as human health.

About 33 per cent of the world's area and 22 per cent of the world's production of pulses is contributed by India, covering an area of about 28.78 Mha with an annual production of 25.75 million tonnes, with a productivity of 885 kg ha^{-1} (IIPR 2020). India imported nearly 5.6 million tonnes of pulses worth ₹18748 crores during 2017-18 (Singh *et al*., 2022).

The current per capita availability of pulses is 47.2 g d^{-1} in the country against the RDA (Recommended Dietary Allowances) of 60 g and 55 g d^{-1} for adult male and female (Tiwari and Shivhare, 2016). Average per capita consumption of pulses in India has increased to 56 g d^{-1} in 2018 from 35 g d^{-1} in 2011 (Deol *et al.*, 2018).

In Kerala, pulses are cultivated in an area of 1738 ha with a production of 1711 t (Farm guide, 2019). Despite a steady increase in the area under pulse crops, productivity is falling every year. The causes include the uneven application of fertilisers, the occurrence of physiological disorders such as ineffective assimilate partitioning, poor pod setting, excessive flower abscission, and nutrient deficiency during the crucial stages of crop growth, which results in nutrient stress, poor growth, and productivity, as well as the occurrence of pests and diseases.

PGPR have the ability to enhance the growth, yield and quality of various agricultural crops under low input agricultural systems (Rocha *et al*., 2020). Plant growth-promoting rhizobacteria (PGPR) use has been demonstrated as an effective, environmentally benign method of managing plant diseases and boosting agricultural yield (Jiao *et al.*, 2021). PGPR are known to increase crop yield by producing phytohormones, metabolites, volatile chemicals and inducing systemic resistance.

Foliar nutrition is a technique of feeding plants by applying fertilizer directly to their leaves. Plants are capable of absorbing all essential nutrients through leaves and nutrient sprays can be given at any point of time during the growing season to improve the appearance, color, size and quality of yield (Pooja and Ameena, 2021).

The lack of nutrients especially at critical stage may result in flower abscission, flower drop leading to poor pod setting and reduced yield (Mahala *et al.*, 2001). Foliar application of nutrients helps to translocate the nutrients from leaves to all parts thereby helps in synchronizing flowering as well as pod setting. Foliar applications of nutrients can delay leaf senescence due to their better absorption efficiency, which boosts photosynthetic efficiency. To make nutrients available at critical period of requirement, foliar application of nutrients is vital.

Cowpea [*Vigna unguiculata* (L.) *Walp*] is a tropical and subtropical annual legume generally referred to as lobia that is widely farmed in India's dry and semi-arid tropics. It is a crop that can withstand drought and is ideally suited for the drier tropical climates. Cowpea is rich in nutrients and fibre and is regarded as poor man's source of protein. It has a dry weight content of 23.4 per cent protein, 1.8 per cent fat, 60.3 per cent carbohydrates, and is a good source of calcium and iron. Cowpea has gained more attention worldwide due to its exerted health beneficial properties including antidiabetic, anti-cancerous, anti-hyperlipidemic, anti-inflammatory and anti-hypertensive properties.

A sole crop of coconut at the recommended spacing (7.5 x 7.5 m) does not fully utilize the available soil, air space and incident solar radiation. Moreover, from the land utilization point of view only 22 per cent of the area is being utilized by coconut and the remaining area can be utilized for growing a variety of other useful crops. Being a nutrient rich crop and having the ability to grow well in scarce rainfed areas, cowpea is well suited for intercropping in rainfed coconut garden. Additionally, it works well in agroforestry systems.

Hence, the present study entitled as "Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut" was proposed with an objective to evaluate the effect of seed treatment with plant growth promoting rhizobacteria and foliar nutrition on the seed yield of cowpea.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Pulses form a crucial part of maintaining agricultural production due to their high versatility to fit into different cropping systems. They are considered as a reliable crop under marginal growing conditions due to their adaptability to low rainfall regimes and under fertile soils. They are also an ideal choice for contingency crop planning as they are well adapted to short growing seasons. Intercropping is one of the environmental friendly agricultural technology for optimum utilization of resources. As pulses have the ability to grow in scarce rainfall and rainfed areas, cowpea can be well intercropped in rainfed coconut garden. The literature pertaining to effect of seed treatment and foliar spray of nutrients is reviewed in this chapter. Wherever sufficient literature on cowpea is not available, results on related crops are also reviewed.

2.1 INTERCROPPING IN COCONUT GARDEN

Coconut garden offers a wide opportunity for fodder production. About 30 per cent of the active roots are found in the soil between 25 and 60 cm and two metres around the palm, leaving 70 to 75 per cent of the soil open for exploitation by other crops. Regardless of the plant's age, intercropping is possible in coconut gardens that are more than 7.6 m apart. But intercropping is typically not an option for closely spaced palms between the ages of 8 and 25. It is possible to intercrop in mature plantations with palms that are over 25 years old because they enable enough light to reach the under storey. The study conducted by Tarigans (2002) revealed that monoculture of coconut is not a profitable practice for farmers.

2.2 SUITABILITY OF PULSES IN INTERCROPPING

Growing two or more crops in the same field at the same time is known as intercropping, which promote increased productivity and yield, effective resource use, and functional diversity (Nigade *et al.*, 2012). To close the gap between supply and demand of oilseeds and pulses in India, appropriate cropping system adjustments that can handle both oilseeds and pulses will be a better option (Bindhu *et al.*, 2014).

Contrasting maturities, plant heights, growth and rooting patterns, as well as variable pest and disease associated with component crops, are the main factors to take into account when intercropping, because they protect against weather adversities and complement each other rather than compete for resources (Singh *et al*., 2009).

Intercropping is more stable and reliable than producing a single crop under rainfed settings, where crop failure risks are higher (Rao and Willey, 1980). Pulses can be intercropped with cereals, oilseeds and commercial crops. When compared to monocrops, interspecific facilitation and niche complementarity have been proposed as mechanisms behind the overall yield gain in intercrops (Soltani *et al.*, 2013; Xue *et al.,* 2016). Kermah *et al*. (2017) reported increased LER with decreasing levels of soil N, suggesting increased performance of legume-based intercropping systems in poor soils.

2.3 COWPEA AS INTERCROP

Dahmardeh *et al.* (2010) manifested that intercropping with cowpea increased the amount of N, P and K content in the soil compared to sole crop of maize. The maize-cowpea intercropping system recorded the highest LER values (Adeniyan *et al.,* 2011; Dube *et al.*, 2014).

According to Oseni (2010), intercropping of sorghum with cowpea in the ratio of 2:1 provided greater income, better land use efficiency and improved agricultural sustainability compared to sole crop.

2.4 SEED TREATMENT

Optimal crop stand, robust plants, a delay in the onset of diseases and enhanced yield can be achieved with seed treatment. Additionally, it produced short-term gains from increased yields more than offset treatment expenses, as well as medium and long-term gains from balanced production systems. Therefore, seed treatment is viewed as a low-cost protection against various crop failure **(**Gadotti *et al.,* 2012).

Biofertilizer is a substance which consists of living organisms. Rhizosphere colonization aids growth by increasing the availability of essential nutrients. Nagananda *et al.* (2010) demonstrated that using bio fertilizers boosted crop output by utilizing root nodule bacteria and fungus which increased nutrient availability from soil. Biofertilizer increased the nutritional content in plants, improved the seed germination and increased the soil microbial population, which ultimately increased the nutrient transfer from soil to plants

(Ritika and Utpal, 2014). Biofertilizers, when applied to soil increased the availability of nutrients to the plants and increased yield by 10-20 per cent without any negative impact on the environment when applied to soil. Growth parameters such as plant height, shoot length, dry matter accumulation in plant organs and vigour index were also found to be increased significantly **(**Bhattacharjee and Dey, 2014).

The term, biocontrol agents (BCA) refers to naturally occurring adversaries that use parasitism, predation or other strategies to manage pests (Hokkanen and Pimentel, 1984). They can be bacteria, fungi, viruses, insects, etc. Since bacteria are safe to use, easy to employ, narrow spectrum, sustainable, logical and do not harm the environment like chemical pesticides or insecticides, using bacteria as BCA is an effective method for managing diseases (Kumar *et al.,* 2010; Cawoy *et al.,* 2011). *Xanthomonas, Bacillus, Pseudomonas, Burkholderia* and *Rhizobium* species are recognised to be antagonists of pests and diseases (Kumar *et al*., 2010; Satya *et al*., 2011). In addition to fostering the growth and development of plants, endophytic and rhizospheric bacteria can also stop the spread of diseases within plants. Bacteria can either directly or indirectly support plant growth. Nitrogen fixation, the mobilisation of minerals including phosphorus and iron, generation of phytohormones influence plant growth directly (Bahroun *et al.*, 2018).

PGPR cell suspensions were effective against a number of diseases when applied to seeds. The complex interrelated processes promoted by *Pseudomonas* and *Bacillus* include production of siderophores, antibiotics, hydrogen cyanide, and volatile compounds, the synthesis of metabolites like auxin, cytokinin, gibberellins and the induction of 1 - amino cyclopropane - 1 -carbocylate deaminase which ultimately resulted in growth improvement and control of diseases (Abbasdokht and Gholami, 2010).

2.4.1 PGPR

The area of soil surrounded and influenced by plant roots is known as the rhizosphere, whereas the surface of plant roots and closely bound soil particles is known as the rhizoplane (Kennedy, 2004)

According to Pinton *et al.* (2000), studies of the rhizosphere's microbial ecology usually include the rhizoplane. In the rhizosphere, there are significant, extensive biochemical interactions and signal molecule exchanges between the plant, soil, bacteria and soil micro fauna.

The growth of plants can be influenced by PGPR either directly or indirectly, according to Holguin *et al*. (1999) Phosphorus solubilization, nitrogen fixation, iron sequestration using siderophores, auxin, cytokinin, and gibberellin synthesis, as well as the stimulation of disease resistance mechanisms, are only a few of the direct methods that improve plant nutrient status. Indirect effects occur when PGPR acts as a biocontrol agent, lowering the disease and stimulating other beneficial symbioses.

PGPR strains were very effective in protecting cowpea against bean common mosaic virus (BCMV) by inducing resistance and also by enhancing the crop growth (Shankar *et al.,* 2009). PGPR is commonly referred to as yield-increasing bacteria, due to its contributory effect on plant growth.

2.4.1.1 Effect of PGPR on growth attributes

Increased in germination rate, seedling vigour index, emergence, plant stand, root and shoot growth, total plant biomass, seed weight, early blooming, and grain production were seen after seed inoculation with PGPR (Ramamoorthy *et al.,* 2001). Kaur *et al.* (2015) opined that co-inoculation of *Mesorhizobium* sp. and PGPR (*Pseudomonas* sp.) increased germination percentage from 91.0 to 96.1 per cent in desi PBG1 and 91.3 to 94.9 per cent in kabuli BG 1053. Seed biopriming with a combination of PGPR-1 and Rhizobium strain B1 produced higher emergence and plant growth in french bean (Negi *et al.,* 2021).

Kumari *et al.* (2018) observed that mung bean plants inoculated with PGPR strains (*Pseudomonas aeruginosa* BHU B13-398 and *Bacillus subtilis* BHUM) increased shoot length, root length and dry weight of the plant, 35 days after sowing.

Geetha *et al*. (2014) identified PGPR strains exhibiting considerable boost of plant growth in terms of increased root and shoot length and number of secondary roots in green gram. *Pseudomonas* isolates showed increase in root length, shoot length and shoot biomass compared to control in red gram (Kumar *et al.,* 2015). Ma *et al*. (2019) reported that cowpea inoculated with *Pseudomonas libanensis* significantly increased shoot and whole plant dry weight, as well as shoot to root dry weight ratio, compared to the control treatment, by 111 per cent, 101 per cent, and 83 per cent respectively.

2.4.1.2 Effect of PGPR on nodule parameters

Parmar and Dadarwa (1999) asserted that PGPR strains improved growth, nodulation, nitrogen fixation and nodule dry weight in chickpea. Tilak *et al.* (2006) also reported increased growth and nodule characters by PGPR strains in pigeonpea.

In a field experiment conducted in Manipur by Devi *et al*. (2013) to investigate the effects of inorganic, biological, and organic manures on nodulation, yield, and soil characteristics in soybean, the integration of 75 per cent RDF with VC@ 1 t/ha and PSB produced higher number of nodules per plant and dry weight of nodules per plant. The effect of inoculation with *Enterobacter kobei*, *Bacillus subtilis*, *Enterobacter species*, *Bacillus species* and *Pseudomonas fluorescence* on nodulation were significantly increased compared to control plants in lentil under greenhouse conditions (Mulissa *et al.*, 2015).

2.4.1.3 Effect of PGPR on yield and yield parameters

Adsul *et al.* (2019) conducted field experiment at Dapoli and observed that *Paceilomyces lilacinus*, *Pseudomonas fluorescnce* and *Bacillus subtilis* were found to be superior than other treatments for yield attributing characters in *Lablab purpureus.* El-Dabaa and Abd-El-Khair (2020) observed that shoot length, shoot fresh weight, shoot dry weight and leaf number, could be improved by *Pseudomonas flourencens*, *Bacillus subtilis*, *Bacillus pumilus*, *Trichoderma harzianum*, *Trichoderma viride*, and *Trichoderma vierns* in faba bean. The co-inoculation of *Rhizobium tropici* + *Azospirillum brasilense* + *Pseudomonas fluorescens* without NPK treatments, *Rhizobium tropici* + *Pseudomonas fluorescens* and *Rhizobium tropici* + *Azospirillum brasilense* + *Bacillus subtilis* with the recommended dose of NPK fertiliser (50%) and co-inoculation of *Rhizobium tropici* + *Bacillus subtilis* with the recommended dose of NPK fertiliser (100%) increased the grain yield of common bean (Mortinho *et al.*, 2022).

Shabayey *et al.* (1996) noticed the combined inoculation of *Bradyrhizobium japonicum* and *Pseudomonas fluorescens* significantly increased crop productivity in soybean. The result of the experiment conducted by Wani *et al.* (2007) to assess the synergistic impact of nitrogen-fixing bacteria and phosphate-solubilizing bacteria, revealed that the seed treatment with *Mesorhizobium ciceri* + *Azotobacter chroococcum* + *Bacillus* sp. resulted in the highest yield, DMP, N and P uptake compared to the treatment that received either single strain or 100 per cent RDF in chickpea. *Rokhzadi et al.* (2008) concluded that the combined inoculation of four soil rhizospheric microorganisms, *Azospirillum, Azotobacter, Mesorhizobium and Pseudomonas* increased the pod number, grain yield and DMP in soybean. Over non-inoculated control plants, seed coating with PGPR significantly increased the number of pods per plant and grain yield in cowpea (Rocha *et al.*, 2020).

2.4.1.4 Effect of PGPR on physiological parameters

According to Khangarot *et al.* (2022), PROM + PSB + VA + PF produced the highest LAI (5.74) and chlorophyll content (3.18 mg g^{-1}) in mung bean, followed by PROM + PSB + VAM (5.72) and PROM + PSB + PF (5.52). Experiment conducted in a field, to study the effect of biofertilizer inoculation [control, *Mesorhizobium* only, *Mesorhizobium* + *Pseudomonas argentinensis* and *Mesorhizobium* + *Bacillus aryabhattai*] and different levels of phosphorus recorded considerably higher CGR at 30-60 DAS and 60-90 DAS in chickpea (Singh *et al.*, 2017).

2.4.1.5 Effect of PGPR on nutrient uptake

Rhizobium with *Pseudomonas striata* and *Bacillus megaterium* dramatically boosted P absorption in legumes compared to the uninoculated control (Elkoca *et al.*, 2007). The microbial study conducted by Sahai and Chandra (2010) established that the inoculation of PGPR increased the uptake of N and P by grain and straw by 53.2 and 51.2 per cent, 28.1 and 62.7 per cent, respectively. According to Egamberdieva *et al.* (2013) *Pseudomonas* strains were used in leguminous plants for better absorption of nutrients and development of root system.

2.4.1.6 Effect of PGPR on economic returns

In an experiment conducted in pigeonpea, Singh *et al*. (1993) found that dual seed inoculation with *Bacillus polymyxa-Rhizobium-Pseudomonas florencenses* produced the higher gross returns, net returns and B: C ratio.

2.4.2 Trichoderma

Endophytic plant symbionts known as *Trichoderma* sp. are frequently employed as seed treatments to prevent disease and boost plant growth and productivity (Mastouri *et al.*, 2010). An alternative to chemical fungicides for the management of diseases transmitted by seeds is to treat the seeds with biological material (Rajkonda and bhale, 2011). The biological fungicides not only shield the seed but also invade the rhizosphere and benefit the plants (Callan *et al.*, 1997).

Trichoderma sp. is a well-known biological control agent against several phytopathogens. Seed treatment with both *Trichoderma viride* and *Trichoderma harzianum* improved the seedling emergence in chickpea by reducing the wilt disease (Rehman *et al.*, 2013). Treating the seeds with *Trichoderma viride* @ 50g kg^{-1} seed was effective for the management of wilt and root rot disease in chickpea (Pandey *et al.*, 2017)

2.4.2.1 Effect of Trichoderma on growth attributes

The result of the experiment proposed by Prasad *et al.* (2002) revealed taller plants with higher seed germination and root growth on treatment with *Trichoderma* in redgram. According to Kumar *et al.* (2014), *Trichoderma* sp. considerably decreased the incidence of wilt and improved seed germination and plant growth attributes. When pea seeds were bioprimed with *Trichoderma asperellum*, the germination of the seeds were accelerated in the first stage, and the seedlings were protected from soilborne phytopathogens. (Singh *et al.*, 2016). Seed microbiolization with *Trichoderma asperellum* and *Trichoderma harzianum* reduced the incidence of fungi, and had antimicrobial activity comparable to synthetic fungicides, and promoted seed vigour (Cruz *et al.*, 2022).

Seed germination, plant height, branch count, and DMP were improved in chickpea by combining the inoculation of *rhizobium*, a phosphate-solubilizing *Bacillus megaterium* sub sp. *phospaticum* and a biocontrol fungus called *Trichoderma* sp. (Rudresh *et al.*, 2005). Trichoderma treatment exhibited greater influence on leaves than pods in *Phaseolus vulgaris* (El-Khair *et al.*, 2010). Kapri and Tewari (2010) established that under glasshouse settings inoculation with *Trichoderma* sp. improved shoot length, root length, fresh and dry weight of shoots and roots in chickpea. In comparison to the control, various isolates of *Trichoderma* sp. (*Trichoderma asperelloides* GJS 04-217) demonstrated greater potential as a growth promoter increasing plant height and total dry matter production at 45 days after planting in cowpea. (Chagas *et al.,* 2015). The dual inoculation of *Trichoderma viride* and *Pseudomonas fluorescence* increased plant height, fresh weight, and dry weight in lentil (Kumari *et al.*, 2018).

2.4.2.2 Effect of Trichoderma on nodule parameters

Application of *Trichoderma harzianum, Trichoderma hamatum, Trichoderma viride* and carbendazim resulted in significant increase in the number of nodules compared to the control in chickpea. (Khan *et al.,* 2014). In mungbean, *Trichoderma viride* infested plots revealed that functional nodules and total nodules were significantly increased compared to the control (Khan *et al.,* 2019).

2.4.2.3 Effect of Trichoderma on yield and yield parameters

Khan *et al.* (2004) reported that inoculation with *Trichoderma harzianum* in chickpea, increased the yield by 44 per cent over the control plots. Dual application of *Trichoderma harzianum* with PSB and *Rhizobium* resulted in higher in growth and yield parameters (Rudresh *et al.,* 2005). Daniel *et al.* (2011) reported that on application of *Trichoderma viride* as seed dresser at a concentration of 4 g kg^{-1} enhanced the yield in blackgram. Combined application of microbial consortium *Pseudomonas fluorescens* and *Trichoderma asperellum*, resulted in increased nutritional quality of seed, pericarp, and foliage in chickpea (Yadav *et al.,* 2017).

2.4.2.4 Effect of Trichoderma on physiological parameters

Behera *et al.* (2021) noted that plants grown with hydrogel with improved practice and seed treatment with nano solution and *Trichoderma* at 30 - 45 days stage, resulted in maximum CGR and RGR in green gram. Cowpea seeds treated with *Trichoderma* showed a significant increase in relative growth rate when compared to control (Mendes *et al.,* 2020).

2.5 Foliar application of nutrients

When soil conditions are unfavourable for nutrient absorption or the quick supply of nutrients is negatively impacted, foliar treatment is regarded as the recommended remedy (Salisbury and Ross, 1985).

The soil application is the most efficient way to apply fertilisers to plants. Although foliar application is not a substitute for soil application, it is becoming more important and preferred in plant nutrition for increasing production and productivity of crops because very small amounts of fertiliser are applied per hectare, resulting in no waste and a quick supply, and thus reducing the requirement of fertilisers. Foliar application is also less likely to pollute ground water (Hamayun *et al.*, 2011). During times of acute nutrient scarcity and nutrient imbalance, foliar nutrition outperforms soil application (Maalhotra, 2016). Foliar application of fertilisers can be viewed as a temporary or emergency solution, but it has produced excellent results in some crops (Krishnasree *et al.,* 2022)

Active nodulation of any pulse crop ceases 45-50 days after sowing, and for legume plants, leaf senescence begins earlier before maturity, breaking the source-sink relationship and reducing yield if nutrients are supplied via foliar spray and found to have advantageous effects on improving growth, seed yield and quality parameters (Bhavya *et al.*, 2020).

Foliar application of urea at 50 per cent flowering enhanced seed yield and protein content of seed (Palta *et al.,* 2005). According to Sharifi *et al*. (2018) RDF + foliar application of water-soluble fertilisers @ 2 per cent during the flowering and pod filling stages resulted in higher growth parameters.

2.5.1 Foliar nutrition of water-soluble macro nutrient fertilizers on growth parameters

According to Senthilkumar *et al.* (2008) application of 1 per cent urea through foliar in blackgram at 35 and 55 days after sowing was superior in terms of growth parameters such as plant height and number of leaves.

Bhowmick *et al.* (2013) ascertained that foliar spraying with 2 per cent urea solution increased growth attributes such as plant height and number of branches per plant in chickpea. According to Parimala *et al*. (2013) foliar spray of urea at 2 per cent increased the number of branches and biomass yield in chickpea. Venkatesh and Basu (2011) observed that under rainfed conditions in chickpea, application of 2 per cent urea showed significant increase in the number of branches per plant. Foliar fertiliser of 2 per cent urea application recorded the highest plant height and number of branches in cowpea at harvest (Dey *et al.*, 2017).

Choudhary and Yadav (2011) reported increased plant height and number of branches at harvest with foliar spray of 2 per cent DAP spray in cowpea. Basavarajappa *et al.* (2013) found that combined foliar sprays of 40 ppm NAA, 0.5 per cent chelated micronutrient and 2 per cent DAP applied in blackgram at 35 and 50 DAS resulted in improved growth attributes such as plant height (37.11 cm) and number of branches (8.27). When compared to the control, combined foliar spray of DAP and NAA significantly enhanced plant height and seed yield in cowpea (Meyyappan and Sivakumar, 2020).

In mung bean, urd bean, cowpea and horse gram, foliar treatment of 2 per cent DAP dramatically enhanced plant height and the number of branches per plant (Maheswari *et al.*, 2017).

Foliar application of 1 per cent potassium chloride (KCl) along with 25 ppm benzyladenine increased plant height significantly in soyabean (Ramesh and Thirumurugan, 2001). Fayed *et al*. (2019) stated that foliar spray of potassium improved plant height and leaf number in cowpea.

According to Vaibhav *et al.* (2019), foliar spray of neem coated urea 2 per cent in cowpea followed by NPK (19:19:19) @ 2 per cent spray at flower formation resulted in the highest values of all growth parameters *viz.,* plant height, number of branches, leaves and dry weight per plant, CGR, RGR and LAI**.**

Plant growth was substantially influenced by foliar nutrition of RDF + 00:52: 34 @ 1.0 per cent at the flowering stage, which resulted in significantly higher plant height and branches per plant in chickpea (Takankhar *et al.,* 2017). Application of 2 per cent DAP + 1 per cent KCl spray enhanced the plant height and DMP in blackgram (Geetha, 2003).

2.5.2 Foliar nutrition of water-soluble macro nutrient fertilizers on nodule parameters

Foliar application of NPK increased the number of nodules per plant in lentil (Hamayun and Chaudhary, 2004). Foliar application of monopotassium phosphate and 19:19:19 each @ 1 per cent at 30 and 45 DAS, along with the recommended practices, resulted in higher number of nodules at 45 DAS in green gram (Bhavya *et al.,* 2020)

Dixit and Elamathi (2007) opined that application of DAP through foliar spray produced the greatest number of nodules in green gram. Maximum number of nodules per plant was observed with foliar nutrition of DAP in groundnut (Reddy *et al.*, 2020).

Irshad *et al.* (2022) noticed an increase in number of nodules per plant, dry weight of each nodule, number of branches and pods per plant, 100 grain weight and grain yield on application of potassium as foliar spray both in normal and late sown chickpea.

2.5.3 Foliar nutrition of water-soluble macro nutrient fertilizers on yield components

Fayed (2019) concluded that in cowpea plants that received potassium spray showed the highest numbers of pods (33.11 and 34.13), seeds per pod (10.99 and 11.56), dry seed yield per plant (25.22 and 25.67 g), as well as dry seed yield (882.73 and 904.17) kg, while the control plants had the lowest numbers of pods (24.36 and 24.92) and dry seed yield (821.16 and 841.98 kg).

Mamathashree *et al.* (2014) opined that foliar nutrition of 19:19:19 at 2 per cent concentration yielded considerably greater grain yield in red gram compared to other soluble fertilizers. Foliar application of NPK (20:20:20) @ 2.5 kg ha^{-1} and pinching significantly enhanced the number of pods (115.36), and plant height (59.48 cm) in bengal gram compared to the control (Khan *et al.*, 2018).

According to Palta *et al.* (2005), direct application of urea at 50 per cent blooming enhanced yield of gram. Mondal *et al*. (2012) stated that foliar spraying of 1.5 per cent urea three times at the reproductive stage boosted seed yield in soybean (3.19 t ha^{-1}). Maximum number of seeds per pod, number of pods per plant, and seed weight per plant were observed when urea was applied as 1 per cent foliar spray at pre flowering stage in moth bean (Kandpal *et al.*, 2013)

Kocon (2010) concluded that foliar feeding with urea was preferable to soil top dressing in fababean. Das and Jana (2015) asserted that maximum grain yield (1325 kg ha^{-1}) was reported in greengram, lathyrus, lentil, and chickpea with application of 2 per cent urea spray compared to basal dose of fertiliser application, though it was on par with 2 per cent NPK (19:19:19) spray and 2 per cent DAP spray. Dewangan *et al.* (2017) conducted experiment at Varanasi, and reported that the application of 100 per cent RDF + 2 per cent urea spray resulted in the maximum seed yield and stover yield in chickpea.

At pre flowering stage, maximum growth, grain production, and financial benefit were obtained with foliar application of 2 per cent urea and 0.25 per cent multiplex in late-sown chickpea (Ganga *et al.*, 2014)

In an experiment performed in Coimbatore, Radhamani *et al.* (2003) found that applying 2 per cent DAP as foliar spray at 50 per cent flowering produced noticeably higher seed yield than the control due to an increase in pods per plant and the number of seeds per pod, in greengram. Ramesh *et al.* (2007) reported that with foliar nutrition of DAP @ 2 per cent twice (pre-flowering + blooming), rice fallow pulses have the maximum reproductive efficiency and grain output. It was observed that foliar spray of DAP @ 2 per cent during the flower and pod formation stages of crop growth led to larger numbers of pods (62.50), seeds per pod, seed index, and grain yield (1460 kg ha^{-1}) in soybean (Kumar *et al.*, 2013). Meena *et al.* (2018) stated that foliar nutrition of DAP @ 2 per cent at the flowering stage led to a greater number of pods per plant (32.44), increased seed index and grain yield in soybean.

According to Limbikai (2012), foliar spraying of 2 per cent DAP + 40 ppm NAA at 45 and 55 DAS resulted in greater seed yield (1202 kg ha^{-1}). Combined application of NAA @ 40 ppm, 0.5 per cent chelated micronutrient, along with 2 per cent DAP at flowering and pod formation stage increased seed yield in soyabean (Kumar *et al.*, 2013). To maximise the genetic potential and increase the production of black gram, it is advised to apply the full suggested dose of nitrogen, phosphorous and potassium, 2 per cent DAP and TNAU pulse wonder at 45 DAS (Marimuthu and Surendran, 2015).

The application of 75 per cent RDF, foliar applications of 2 per cent DAP + 2 per cent urea + 2 per cent WSF at 60 DAS and 80 DAS in chickpea resulted in the largest number of pods per plant (51.89), number of seeds per pod (2.13), and seed index (12.30 g) when compared to control (Singh *et al.*, 2021)

Combined application of 100 ppm salicylic acid, two per cent DAP, one per cent KCl, and NAA @ 40 ppm resulted in higher grain yield in greengram (Chandrasekhar and

Bangarusamy, 2003). Parimala *et al*. (2013) opined that spray of 1 per cent KCl registered highest pods per plant and grain yield in chickpea.

2.5.4 Foliar nutrition of water-soluble macro nutrient fertilizers on physiological parameters

Kachlam *et al.* (2019) opined that basal and foliar administration of nutrients were found to have a substantial impact on leaf area index per plant under rhizobium, phosphorous solubilizing bacteria and multi micronutrient along with recommended dose of fertiliser at flower initiation and 1 per cent NPK 19:19:19 twice at branching and pod initiation in greengram. Sakthi *et al*. (2020) concluded that the higher LAI (1.91 and 3.21 on 30 DAS and 45 DAS respectively) was obtained with 1 per cent foliar spray applied at 13:0:45 on 45 DAS in blackgram.

With foliar nutrition of 2 per cent DAP and 1 per cent KCl, Sritharan *et al*. (2005) asserted that maximum chlorophyll content was observed by foliar spraying of 1 per cent urea in blackgram. In Coimbatore, foliar spraying with 2 per cent urea resulted in the highest RGR, NAR, CGR and LAD followed by 1 per cent KCl in blackgram (Sritharan *et al.*, 2015).

Blackgram leaves had the maximum chlorophyll content when treated with foliar sprays of 2 per cent DAP at 20, 30, and 45 DAS (Elayaraja and Angayarkanni, 2005). According to study by Choudhary and Yadav (2011), foliar application of 2 per cent DAP raised the chlorophyll content in cowpea (2.29 mg g^{-1}) as compared to the control. According to Basavarajappa *et al*. (2013) foliar spraying of 40 ppm NAA plus 0.5 per cent chelated micronutrient plus 2 per cent DAP at 35 and 50 DAS resulted in enhanced leaf area index (4.18). When pulse crops were in the blooming and pod setting stages, foliar applications of 2 per cent DAP and 1 per cent KCl and 1 per cent boron enhanced the leaf area index (Maheswari *et al.,* 2017).

2.5.5 Foliar nutrition of water-soluble macro nutrient fertilizers on quality parameters

According to Ashour and Thalooth (1983) soyabean seeds have more protein content when urea was administered as foliar spray. Foliar application of urea at various growth stages resulted in the highest level of nitrogen and protein content in the seeds in chickpea (Palta *et al.,* 2005). Bahr (2007) reported the highest protein content when urea was applied as 1 per cent spray at pod setting stage in high density planting in chickpea. The soyabean plants receiving 2 per cent urea as foliar spray at flowering and early pod development stage had the maximum protein content (Jyothi *et al.*, 2013).

Tahir *et al.* (2014) indicated that when (2% DAP + 1% K) was given as foliar spray, the highest protein content (23.80%) was reported in blackgram.

2.5.6 Foliar nutrition of water-soluble macro nutrient fertilizers on nutrient uptake

The overall uptake of N, P, K, S and Zn in chickpea was greatly enhanced by integrated nutrient management. Spraying 100 per cent RDF + 2 per cent urea exhibited positive result for N, P, K, S, and Zn (Dewangan *et al.*,2017). Combined application of recommended dose of fertilizer (RDF) and 2 per cent urea outperformed recommended dose of fertiliser along with water spray and RDF alone in terms of N and P uptake in soybean (Jaybhay *et al.*, 2021)

2.5.7 Foliar nutrition of water-soluble macro nutrient fertilizers on economics

The benefit cost ratio of growing chickpea plants was greatly improved by spraying water-soluble macro nutrient fertiliser (19:19:19) @ 1.5 per cent concentration at the blooming and pod development stages, in addition to the basal dose of fertilizer (Ali *et al.*, 2016). According to Banasode and Math (2018), in soybean, two foliar sprays of 1 per cent 19:19:19 produced higher gross and net returns and B: C ratio.

According to Gupta and Saxena (2015) 2 per cent urea spray produced the highest net returns (21892 ha^{-1}) and B:C ratio of 1.77 in cowpea. Dewangan *et al*. (2017) demonstrated that the use of 2 per cent urea spray along with 100 per cent RDF resulted in maximum B:C ratio and was found to be superior to other treatments. RDF + Urea + DAP + 2 per cent foliar spray produced the highest net returns and benefit cost ratio in soyabean (Jaybhay *et al.*, 2021).

The cost of cultivation, net return and benefit cost ratio were found higher, when DAP and NAA 40 ppm were applied twice at 25 and 35 days after sowing at a rate of 2 per cent per foliar spray in greengram (Nigamananda and Elamathi, 2007). Kavitha *et al.* (2019) opined that foliar nutrition of 2 per cent DAP coupled with RDF during blooming and pod development stage recorded higher returns in cowpea.

2.6 Interaction between the seed treatment and foliar application of nutrients on different growth and yield parameters

In an experiment carried out by Perumal *et al.* (2004), the impact of DAP and phosphobacteria on the growth and yield of rice fallow black gram was investigated and growth parameters like plant height and LAI were positively influenced by both the seed and soil application of phosphobacteria along with DAP 2 per cent foliar spray.

According to Lavanya and Ganapathy (2011), the application of 2 per cent DAP with Rhizobium and 3 per cent phosphobacteria, led to profused growth and yield parameters of greengram.

Dual inoculation of Rhizobium with PSB and application of sulphur at 30 kg ha^{-1} along with 2 per cent foliar spray of DAP pointedly increased fertility coefficient, number of pods per plant, number of seeds per pod, seed yield, stover yield, test weight and harvest index compared to control in green gram (Ghosh and Joseph, 2008).

Navaz *et al.* (2018) concluded that seed priming with sodium molybdate @ 0.5 g kg^{-1} seed in conjunction with foliar spray of NPK 19:19:19 @ 5 per cent at pre-flowering and at 15 days after the first spray observed higher uptake of P in seeds, stover yield and total dry matter production.

Higher uptake of N, P and K in grain and haulm yield as well as total uptake was noticed in seed priming with ammonium molybdate @ 0.5 g kg^{-1} seed followed by NPK (19:19:19) @ 0.5 per cent spray at pre-flowering stage in grass pea (Banerjee *et al.,* 2020).

The maximum leaf area index (LAI), total chlorophyll content and crop growth rate were obtained by seed priming with ammonium molybdate @ 0.5 g kg^{-1} seed along with two sprays of NPK (19:19:19) at pre-flowering and after 15 days of first spraying as reported by (Banerjee *et al.,* 2022)

Gupta *et al.* (2011) concluded that the treatment of 20 kg N ha^{-1}, rhizobium, PSB, PGPR and 2 per cent urea spray at flowering resulted in the highest nodule parameters in chickpea.

The plants treated with synergistic inoculation of PGPR and foliar K silicate were found to have higher N, P and K content in grain (Hafez *et al.*, 2021).

Literature search unveiled the nutritional importance and climate resilience of cowpea. The selection of suitable seed treatments and foliar application of nutrients are necessary for promising yield from cowpea. Existing literature explains the considerable influence of seed treatments and foliar application of nutrients on the growth, yield and quality parameters of other crops. The crop responds well to seed treatments and foliar nutrition, and the nutritional quality is enhanced by nutrient application. Such studies are limited in cowpea hence, the present study was proposed to evaluate the effect of seed treatment with plant growth promoting rhizobacteria and foliar nutrition on the seed yield of cowpea.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut" was carried out at the Coconut Research Station (CRS), Balaramapuram, Kerala, India during *Rabi* 2021. The main objective of the study was to evaluate the seed treatment with plant growth promoting rhizobacteria and foliar nutrition on seed yield of cowpea. The materials and methods adopted during the course of research work are presented below.

3.1. EXPERIMENTAL SITE

The experiment was conducted at the Coconut Research Station (CRS), Balaramapuram, Kerala, India, located at 8° 22’ 52’’ North latitude and 77° 1’ 47’’ East longitude, at an altitude of 9 m above MSL.

3.1.1 Soil

The soil of the experimental site was red sandy loam, acidic in reaction, medium in organic carbon, low in available nitrogen, high in available phosphorus and medium in available potassium status. A composite soil sample was taken from a depth of 0-15 cm and analysed for its chemical properties. The data obtained are presented in Table 1.

3.1.2 Climate and Season

The field experiment was conducted during the period from December 2021 to April 2022. The data on weather parameters (mean temperature, relative humidity (RH), rainfall and evaporation) were collected from the agrometeorological observatory located at CRS, Balaramapuram. The data during the cropping period are given in Appendix I and graphically presented in Fig. 1.

3.1.3. Cropping History of the Experimental Site

The crop was raised in the inter row space of 58 years old coconut planted at spacing of 7.5 m x 7.5 m having more than 70 per cent light transmission. In the previous year, finger millet was grown in the inter row space of coconut.

Table 1. Chemical properties of soil of the experimental site

Sl. No.	Parameters	Content	Rating	Method
1	Soil reaction	4.52	Strongly acidic	pH meter (1:2.5 soil water ratio) (Jackson, 1973)
2	EC (dS m^{-1})	0.10	Normal	Conductivity meter (1:2.5 soil water ratio) (Jackson, 1973)
3	Organic carbon (%)	0.5	Medium	Walkley and Black rapid titration method (Walkley and Black, 1934)
4	Available N (kg ha^{-1})	201.2	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available P (kg ha^{-1})	27.9	High	Bray colorimetric method (Jackson, 1973)
6	Available K (kg ha^{-1})	162.82	Medium	Ammonium acetate method (Jackson, 1973)

3.2 MATERIALS

3.2.1 Crop Variety

The cowpea variety Bhagyalakshmy was used for the study. It is a short duration variety (80 days) released from College of Agriculture, Vellanikara, Thrissur. The variety is characterized by bushy growth habit with light green, medium sized pods. This variety has seed yield with 1.0 – 1.5 t ha^{-1}. This variety is highly resistant to anthracnose disease caused by *Colletotrichum lindemuthianum* of cowpea.

3.2.2 Source of Seed

The seeds for the experiment were procured from Coconut Research Station, Balaramapuram, Kerala, India.

3.2.3 Manures and Fertilizers

Dried cow dung (0.45% N, 0.17% P_2O_5, and 0.5% K_2O content) was used as manure. DAP (18% N, 46% P_2O_5), Urea (46% N), Rajphos (20% P_2O_5), and KCl (60% K_2O) were used as the fertiliser sources of N P K for the experiment.

3.3 METHODS

3.3.1 Design and Lay out

Design	: RBD
Treatments	: (3 x 6) =18
Replication	: 03
Spacing	: 30 cm x15 cm
Plot size	: 3 m x 3 m
Crop	: Bush cowpea
Variety	: Bhagyalakshmy
Season	: Rabi 2021-22

3.3.2 Treatment details

Factor A: Seed treatment (S)

s_1- seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed

s_2- seed treatment with PGPR Mix II @ 20 g kg^{-1} seed

s_3- control (No seed treatment)

Factor B: Foliar application of nutrients (F)

f_1 -foliar application of urea 2% at 40 DAS

f_2 -foliar application of DAP 2% at 40 DAS

f_3 -foliar application of KCl 2% at 40 DAS

f_4 -foliar application of urea 2% *fb* DAP 2% at 40 DAS

f_5- foliar application of KCl 2% + DAP 2% at 40 DAS

f_6- Control (POP)

Treatment combinations (18)

s_1f_1 s_1f_2 s_1f_3 s_1f_4 s_1f_5 s_1f_6

s_2f_1 s_2f_2 s_2f_3 s_2f_4 s_2f_5 s_2f_6

s_3f_1 s_3f_2 s_3f_3 s_3f_4 s_3f_5 s_3f_6

Two biocontrol agents were used in the experiment, PGPR Mix II is microbial consortium of *Pseudomonas flourescens* and *Bacillus subtilis*. KAU isolate *Trichoderma sp*. is recognised as *Trichoderma asperellum.* Apart from treatments, all other management practices followed package of practices recommended by Kerala Agriculture University (KAU, 2016).

3.3.3 Land Preparation and Lay Out

The experimental area was cleared by removing weeds and stubbles. After thorough ploughing land was brought to fine tilth and divided into plots of 3 m x 3 m. The layout plan is shown in Fig. 2.

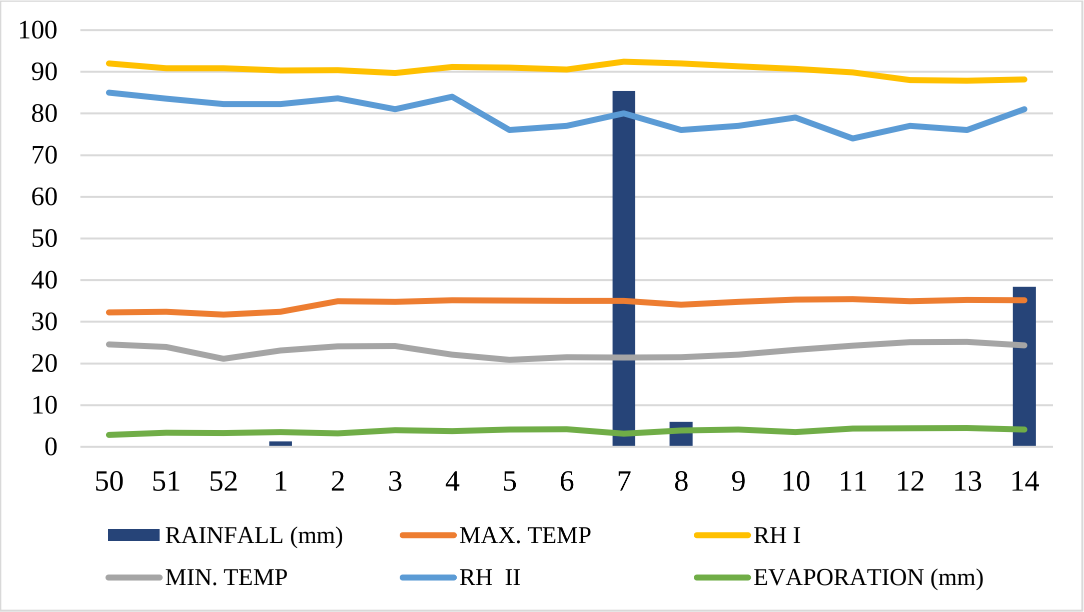

Fig. 1. Weather data during the cropping period

Plate 1. Layout of field before sowing of crop

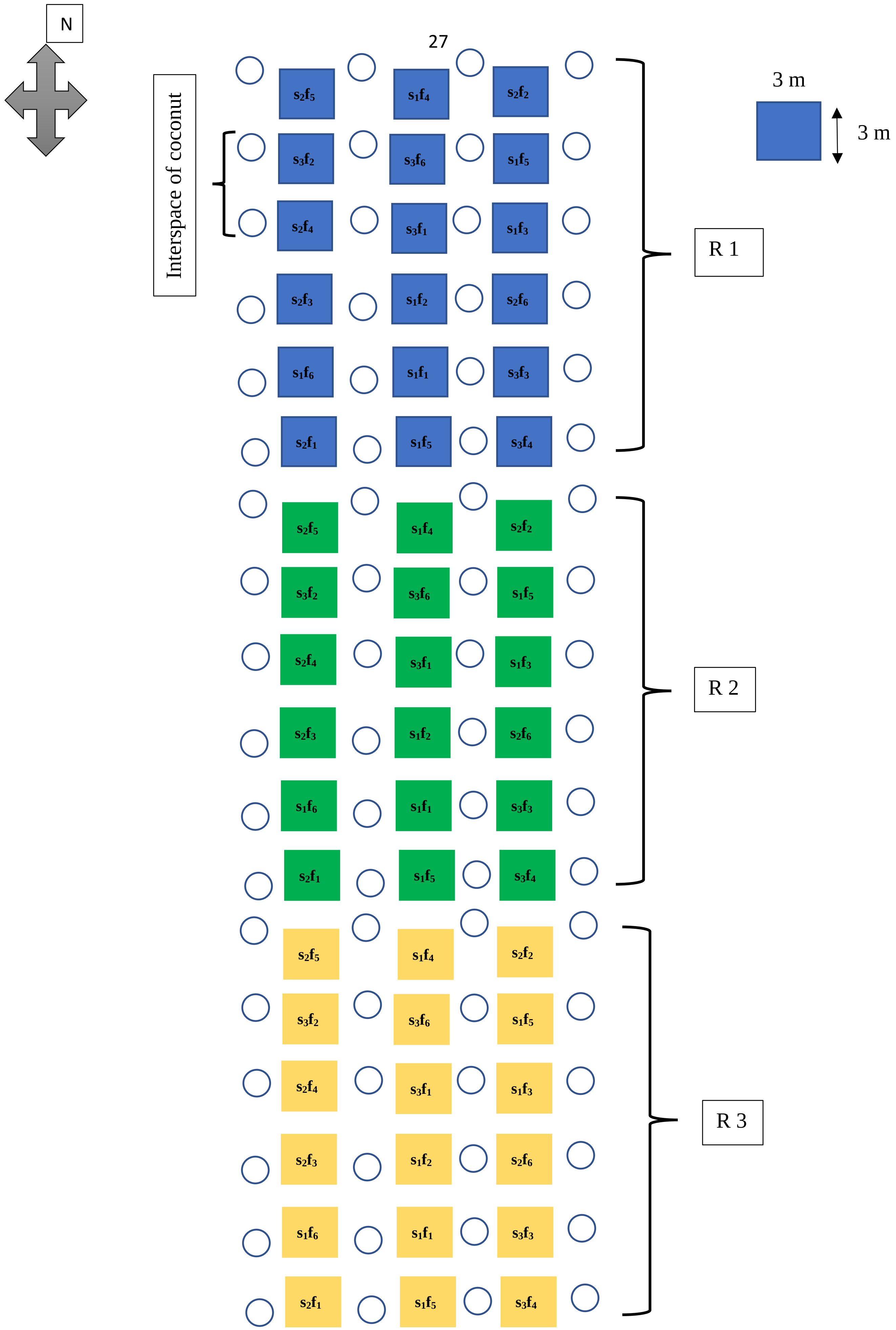

Fig. 2. Layout of experimental field

Plate 2. Sowing of seeds using seed drill

Plate 3. General view of experimental field

3.3.4 Lime Application

Lime @ 250 kg ha^{-1} was uniformly applied to the treatment plots at the time of ploughing.

3.3.5 Manure and Fertilizer Application

FYM @ 20 t ha^{-1} was uniformly applied to all plots. NPK was applied @ 20:30:10 kg ha^{-1}. Foliar application of urea, DAP and KCl were done at 40 DAS as per the treatments. Half N and full P and K were applied as basal dose. The remaining half nitrogen was applied as topdressing at 20 DAS. The treatment foliar application of urea 2% *fb* DAP 2% at 40 DAS was given as two separate sprays, whereas the foliar application of DAP 2% + KCl 2% at 40 DAS was given as single spray.

3.3.6 Seed Treatment and Sowing

As part of treatments, seed treatment was done in s_1, s_2 and s_3. Seeds were sown with the help of seed drill at the rate of one seed per hill at a spacing of 30 cm x 15 cm on 22/12/2021.

3.3.7 After Cultivation

Resowing was done one week after sowing and uniform population was maintained. The crop was given two weedings at 15 and 30 DAS.

3.3.9 Plant Protection

Mild incidence of maruca pod borer was noticed at 30 DAS and flowering stage. Coragen (chlorantraniliprole 18.5% SC) @ 3 mL10 L^{-1} was applied and a repeated spray was given 15 days after the first spray. Incidence of anthracnose was also noticed at 30 DAS and was controlled by spraying Saaf (carbendazim 12% + mancozeb 63% WP) @ 3 g L^{-1} uniformly to all treatments.

3.3.10 Harvest

Harvesting was done in five pickings from 60 to 90 DAS once in a week. The dry pods from each plot were picked, sun dried and threshed separately plot wise and seed yield and halum yield were recorded and expressed as kg ha^{-1}.

3.4 GROWTH PARAMETERS

3.4.1 Emergence Percentage

Emergence percentage was recorded at 4 DAS. Resowing was done to maintain the optimum population.

3.4.2 Plant Height

Plant height was measured from five tagged plants at 20, 40, 60 DAS and at harvest. The average plant height, stated in centimetres, was calculated by measuring the plant's height from the base to the tip.

3.4.3 Number of Branches Per Plant

Number of primary branches in the sample plants at 20,40 and 60 DAS was counted and the average was worked out and recorded as the number of branches plant^{-1}.

3.4.4 Number of Green Leaves Per Plant

Number of leaves in the sample plants were counted at 20, 40 and 60 DAS and the average was worked out.

3.4.5 Dry Matter Production (DMP) Per Plant

For recording the DMP at 20, 40, 60 DAS and at harvest, five plants were selected randomly and uprooted from outside the net plot area leaving border row. The plant samples were shade dried for two days to reduce the moisture content and then oven dried at 65 ±5 °C till constant weight was attained. The average was worked out and expressed in g per plant.

3.4.6 Nodule Parameters (50 DAS)

3.4.6.1 Total Number of Nodules Per Plant

Total number of nodules per plant was recorded at 50 DAS. Five plants were uprooted from outside the net plot area without causing any damage to the roots. The roots of plant were washed and made free of soil particles. The nodules were removed from plants and counted separately and expressed as total number of nodules per plant.

3.4.6.2 Number of Effective Nodule Per Plant

The separated nodules were observed for colour by cutting the nodules using a sharp blade. The nodules with pink colour were identified as effective and recorded as effective nodules per plant. Nodules with green colour were considered as ineffective (Jordan, 1962).

3.4.6.3 Nodule Fresh Weight Per Plant

Fresh weight of the nodules from each plant was recorded, average was worked out and expressed in g per plant

3.5 YIELD PARAMETERS

3.5.1 Days to 50 per cent Flowering

Days to 50% flowering was recorded by counting the number of days taken for 50 per cent of plants to reach flowering stage in each treatment plot and expressed in days.

3.5.2 Number of Pods Per Plant

Pods from the observational plants were recorded at each harvest. Mean was worked out and expressed as number of pods per plant.

3.5.3 Pod Girth

Five pods were randomly selected from the observational plants at each harvest for measuring the pod girth from each treatment. Pod girth was measured from the middle of the pod by using a thread and scale, mean was worked out and expressed in cm.

3.5.4 Pod Length

Five pods were randomly selected from the observational plants on each harvest for measuring the pod length from each treatment. Pod length was measured from base to the tip of the pod, the mean was calculated and expressed in cm.

3.5.5 Pod Weight

Pods were harvested from observational plants and recorded the pod weight from each treatment, average weight was worked out and expressed in g per plant.

3.5.6 No of Seeds Per Pod

Separate pods used for measuring length were threshed, and the average was calculated by counting the number of seeds in each pod.

3.5.7 Seed Yield Per Plant

Seed from the observational plants were collected and weighed. Average was worked out to obtain the pod yield per plant and expressed in g per plant.

3.5.8 Total Seed Yield Per Hectare

Seeds from each harvest from the net plot area of each treatment was weighed and recorded and expressed in kg ha^{-1}.

3.5.9 Haulm Yield Per Plant

The observational plants were uprooted after harvesting the pods, sun dried and weighed and average was calculated and expressed in g per plant.

3.5.10 Total Haulm Yield Per Hectare

The plants were uprooted from the net plot area of each treatment, pods were picked and sun dried and weighed and expressed in kg ha^{-1}.

3.5.11 Harvest Index

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

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.6 PHYSIOLOGICAL PARAMETERS

3.6.1 Total Chlorophyll Content

Chlorophyll content of the leaves at 20, 40 and 60 DAS was determined by the method suggested by Yoshida *et al.* (1976).

3.6.2 Leaf Area Index (LAI)

Leaf area index of trifoliate leaves was calculated by using linear method (length x breadth method) at 20, 40 and 60 DAS and expressed in cm^2.

Leaf area = L x B x K x n

Where,

L = length of the leaf (cm)

B=breadth of the leaf (cm)

K (constant value) = 0.631 (Montgomery, 1911)

n=number of leaves

Then LAI was computed based on the recorded leaf area per plant by using the formula,

$$LAI = \frac{\text{Leaf area of plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

3.6.3 Crop Growth Rate (CGR)

Crop growth rate was calculated at growth phases from 20 to 40 DAS and 40 to 60 DAS and 60 DAS to harvest using the formula suggested by Watson (1958) and expressed in g m^{-2} day^{-1}

$$CGR = \frac{w_2 - w_1}{P\,(t_2 - t_1)}$$

where w_2 and w_1 are the dry weight of the plant (g) at time t_1 and t_2 respectively,

t_2-t_1 – time interval in days,

P- Ground area on which w_1 and w_2 has been estimated.

3.6.4 Relative crop growth rate (RGR)

Relative growth rate was also calculated growth phases from 20 to 40 DAS and from 40 to 60 DAS and 60 DAS to harvest using the formula proposed by Evans (1972) and expressed in mg $g^{-1}day^{-1}$.

$$RGR = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1}$$

where w_2 and w_1 are the dry weight of the plant (g) at time t_1 and t_2 respectively,

t_2-t_1 – time interval in days,

3.7 QUALITY PARAMETER

3.7.1 Protein Content of Grain

Protein content of grain was calculated by multiplying N per cent with the factor 6.25 (Simpson *et al.*, 1965) and expressed in percentage.

3.8 CHEMICAL ANALYSIS

3.8.1 Soil Analysis

For analysis of soil before experiment, soil samples were collected from the experimental area to a depth of 15 cm, dried under shade and composite soils were prepared by quartering. After the harvest of crop the composite samples were drawn from each plot and were shade dried for the analysis of organic carbon, N, P and K content.

3.8.1.1 Organic Carbon

For the estimation of soil organic carbon, soil was sieved through 0.2 mm sieve and analyzed by rapid titration method (Walkley and Black, 1934) and expressed in %.

3.8.1.2 Available Nitrogen

Alkaline potassium permanganate method (Subbaiah and Asija, 1956) was adopted for the estimation of available N and expressed in kg ha^{-1}.

3.8.1.3 Available Phosphorus

Dickman and Brays molybdenum blue method (Jackson, 1973) was adopted for the determination of available phosphorous and expressed in kg ha^{-1}.

3.8.1.4 Available Potassium

Available potassium was determined by the procedure suggested by Jackson (1973) and expressed in kg ha^{-1}.

3.8.2 Plant Analysis

Plant samples at harvest were analysed for total N, P and K content. For two days, the plant samples were shade dried to lower their moisture content, and then they were oven dried at 65±5 °C. After drying, samples were ground to fine powder. The finely ground samples were weighed accurately, subjected to acid digestion and used for the determination of N, P and K.

3.8.2.1 Nitrogen uptake

The total N content in shoot and grain was calculated by modified microkjeldahl method (Jackson, 1973). The uptake was estimated by multiplying the N content of shoot and grain with their total DMP and expressed as kg ha^{-1}

3.8.2.2 Phosphorous uptake

The total phosphorous content in the shoot and grain were estimated colorimetrically, after wet digestion and colour development using vanadomolybdate phosphoric yellow colour method and intensity of colour was read using spectrophotometer (Jackson, 1973). The total P uptake was calculated by multiplying with the DMP and expressed as kg ha^{-1}

3.8.2.3 Potassium uptake

The total K content in shoot and grain were estimated using flame photometer (Jackson, 1973). The uptake was estimated by multiplying the K content of shoot and grain with their total DMP and expressed as kg ha^{-1}.

3.9 ECONOMIC ANALYSIS

3.9.1 Net Return

Net return was worked out by the formula

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

3.9.2 Benefit Cost Ratio

B:C ratio was worked out as the ratio of gross income to cost of cultivation.

$$\text{BCR} = \frac{\text{Gross return (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

3.10 STASTICAL ANALYSIS

The data were statistically analysed using analysis of variance technique (F – test) as per methods suggested by (Panse and Sukhatme, 1985). Wherever significant differences among the treatments were observed, CD values at 5 percent level of significance were calculated for comparison of means.

3.11 EXPERIMENT NO. 2: CONFIRMATION EXPERIMENT TO STUDY INFLUENCE OF SEED TREATMENT METHODS ON GERMINATION AND SEEDLING VIGOUR OF GRAIN COWPEA

Confirmation experiment was conducted in the laboratory of College of Agriculture, Vellayani for period of eight days from 3/12/2022 to 11/12/2022 using paper towel germination method.

3.11.1 Outline of this experiment

Variety : Bhagyalakshmy

Replications : 3

Treatments : 3

3.11.2 Treatment details

s_1- Seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed

s_2- Seed treatment with PGPR Mix II @ 20 g kg^{-1} seed

s_3- Control (No seed treatment)

Biocontrol agents were applied to the seeds before they were placed for germination testing. The seeds were placed between wet paper towels that were individually wrapped, placed upright in plastic buckets, and kept at room temperature to determine the percentage of germination. Following the guidelines of the International Seed Testing Association, percent germination was assessed after 4 and 8 days (ISTA, 1985). After 8 days of growth, root and shoot elongation as well as their dry weights were measured.

3.11.3 Observations on Seed Germination and Seedling Growth

3.11.3.1 Number of Seeds Germinated on each day

Number of seeds germinated on each day was counted and recorded. Count was recorded up to 8^{th} day

3.11.3.2 Seedling Root length and Shoot length

On the eighth day, five seedlings were randomly selected. Root length and shoot length were measured from five seedlings, average was worked out and expressed in cm.

3.11.3.3 Seedling Shoot and Root Dry weight

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

3.11.4 Germination Parameters

Based on the above observations, the following germination parameters were worked out.

3.11.4.1 Germination Percentage

Germination percentage was calculated by using the formula suggested by Jones and Sanders (1987).

3.11.4.2 Seedling Vigour Index I

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

3.11.4.3 Seedling Vigour Index II

Seedling vigour index II was also calculated by the formula developed by Abdul-baki and Anderson (1973).

RESULTS

4. RESULTS

The field experiment entitled "Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut" was conducted during the period from December 2021 to April 2022, at Coconut Research Station, Balaramapuram, Kerala, India. The main objective of the study was to evaluate the effect of seed treatment with plant growth promoting rhizobacteria and foliar nutrition on the grain yield of cowpea. The results of present study are presented in this chapter.

4.1 GROWTH AND GROWTH ATTRIBUTES

4.1.1 Emergence Percentage

The data on the emergence percentage at 4 DAS by the effect of seed treatment, foliar application of nutrients and their interaction is depicted in Tables 2a and 2b.

Seed treatment significantly influenced the emergence percentage. The highest emergence percentage was recorded in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed). The lower emergence percentage was observed in treatment s_3 (control) and was found to be on par with s_1 (seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed). There was no significant interaction of foliar nutrition on emergence percentage at this stage.

No significant interaction was found on emergence percentage at 4 DAS

4.1.2 Plant Height

The data on plant height at different growth stages as affected by treatments and their interactions are presented in Tables 3a and 3b.

Seed treatment significantly influenced the plant height at all stages of growth. The tallest plants were recorded in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) at 20, 40, 60 DAS and at harvest. At 20 DAS, shorter plants (16.03 cm) were recorded in s_3 (control). At 40 and 60 DAS, and at harvest s_3 (control) was found to be on par with s_1 (seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed).

Foliar application of nutrients had significant influence on plant height at 60 DAS and at harvest. The tallest plants were observed in f_4 (foliar application of urea 2% *fb* DAP 2% at

Table 2a. Effect of seed treatment and foliar application on emergence percentage, per cent.

Treatments	Emergence percentage
Seed treatment (S)	
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	52.19
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	64.64
s_3- control (no seed treatment)	54.26
SEm (±)	1.24
CD (0.05)	3.555
Foliar application (F)	
f_1- foliar application of urea 2% at 40 DAS	56.42
f_2- foliar application of DAP 2% at 40 DAS	57.69
f_3- foliar application of KCl 2% at 40 DAS	58.42
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	59.14
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	58.28
f_6- control	52.22
SEm (±)	1.75
CD (0.05)	NS

Table 2b. Interaction effect of seed treatment and foliar application on emergence percentage.

Treatments	Emergence percentage
S×F interaction	
s_1 f_1	53.89
s_1 f_2	58.68
s_1 f_3	50.89
s_1 f_4	56.89
s_1 f_5	54.89
s_1 f_6	50.29
s_2 f_1	62.67
s_2 f_2	61.47
s_2 f_3	69.26
s_2 f_4	66.26
s_2 f_5	66.46
s_2 f_6	61.67
s_3 f_1	52.69
s_3 f_2	52.89
s_3 f_3	55.09
s_3 f_4	54.29
s_3 f_5	53.49
s_3 f_6	44.71
SEm (±)	3.03
CD (0.05)	NS

Table 3a. Effect of seed treatment and foliar nutrition on plant height at different stages of crop, cm

Treatments	20 DAS	40 DAS	60 DAS	Harvest
Seed treatment (S)				
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	18.26	30.55	51.48	52.95
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	25.74	39.17	54.18	55.86
s_3- control (no seed treatment)	16.03	29.70	50.20	51.61
SEm (±)	0.38	0.47	0.67	0.68
CD (0.05)	1.094	1.359	1.936	1.956
Foliar application (F)				
f_1- foliar application of urea 2% at 40 DAS	20.22	33.15	54.43	56.08
f_2- foliar application of DAP 2% at 40 DAS	19.92	33.85	50.73	52.19
f_3- foliar application of KCl 2% at 40 DAS	20.72	32.45	48.93	50.43
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	19.78	33.02	57.89	59.09
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	20.72	33.71	55.22	56.77
f_6- control	18.72	32.66	44.82	46.29
SEm (±)	0.54	0.67	0.95	0.96
CD (0.05)	NS	NS	2.738	2.766

Table 3b. Interaction effect of seed treatment and foliar application on plant height at different stages of the crop, cm

Treatments	20 DAS	40 DAS	60 DAS	Harvest
S×F interaction				
s_1 f_1	17.88	30.57	55.90	57.42
s_1 f_2	19.55	32.09	51.80	53.61
s_1 f_3	18.83	29.76	48.93	50.85
s_1 f_4	17.33	28.63	54.97	55.98
s_1 f_5	18.25	32.17	53.60	55.30
s_1 f_6	17.74	30.07	43.69	44.55
s_2 f_1	26.62	39.28	54.48	56.44
s_2 f_2	25.75	40.64	52.45	53.91
s_2 f_3	26.43	38.86	51.51	53.49
s_2 f_4	24.91	40.18	62.97	64.20
s_2 f_5	26.99	37.52	57.72	59.06
s_2 f_6	23.75	38.55	45.95	48.04
s_3 f_1	16.15	29.60	52.91	54.37
s_3 f_2	14.46	28.83	47.95	49.07
s_3 f_3	16.89	28.74	45.46	46.94
s_3 f_4	17.08	30.23	55.74	57.09
s_3 f_5	16.92	31.44	54.32	55.92
s_3 f_6	14.66	29.37	44.83	46.26
SEm (±)	0.93	1.16	1.64	1.66
CD (0.05)	NS	NS	NS	NS

40 DAS) which was on par with f_5 (foliar application of DAP 2% + KCl 2% at 40 DAS) and the shortest plants were observed in f_6 (control) at 60 DAS and at harvest. No significant interaction among treatment combinations was observed between seed treatment and foliar application of nutrients at all stages of growth.

4.1.3 Branches per plant

The impact of seed treatment and foliar nutrition and their interactions on number of branches per plant at all stages of growth was documented and depicted in Tables 4a and 4b.

Seed treatment had significantly influenced the number of branches per plant at every stage of plant growth. The highest number of branches was observed in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) at 20, 40 and 60 DAS. At 20 and 40 DAS, the lower number of branches was observed in s_1 (seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed) which was comparable with s_3 (control). At 60 DAS, lower number of branches (4.89) per plant was recorded in s_3 (control) which was found to be on par with s_1 (4.94).

A significant response on number of branches by the treatments of foliar nutrition was noticed only at 60 DAS. Maximum branches at 60 DAS (5.44) was registered in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was on par with f_1 (foliar application of urea 2% at 40 DAS), f_2 (foliar application of DAP 2% at 40 DAS) and f_5 (foliar application of DAP 2% + KCl 2% at 40 DAS). The treatment f_6 (control) recorded the lowest number of branches per plant (4.24).

Significant interaction between the seed treatment and foliar nutrition on count of branches was observed only noticed at 60 DAS. Higher number of branches per plant (6.13) was observed in treatment combination of s_2f_4 which was found to be on par with s_2f_2 (5.73). The lowest count of branches (3.73) was observed in s_3f_6.

4.1.4 Number of leaves

The result of the effect of treatments (seed treatment and foliar application of nutrients) and their interactions with respect to number of leaves at different growth stages of the crop are contemplated in Tables 5a and 5b.

Seed treatment significantly influenced the number of leaves per plant at all stages of growth. The highest number of leaves per plant were observed in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) at 20, 40 and 60 DAS. The number of leaves per plant was found to be lower in s_3 (control) at both 20 and 40 DAS. The lower number of leaves per plant (18.58) was observed in s_1 (seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed) at 60 DAS which was comparable to s_3 (18.76).

The results indicated that foliar spray of nutrients at 40 DAS had significant impact on number of leaves per plant only at 60 DAS. The treatment f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) was recorded the highest number of leaves per plant (23.13). The lowest number of leaves per plant (16.51) was observed in f_6 (control).

No significant interaction effects were noticed on number of leaves per plant at all stages of plant growth.

4.1.5 Dry matter production

The data on DMP at different stages of the crop growth as influenced by the seed treatment and foliar nutrition and their interactions are depicted in Tables 6a and 6b.

Seed treatment had significant influence the DMP at every stage of plant growth. Higher dry matter production per plant was registered in the treatment s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed). However, at 20 and 40 DAS, whereas s_2 was found to be on par with $s_{1.}$ Lower DMP per plant was observed in s_3 at all stages of growth.

At 60 DAS and at harvest, foliar spray of nutrients had significant influence on DMP per plant. At both 60 DAS and at harvest, higher DMP per plant was registered in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS), while the lowest DMP per plant was observed in f_6. Interaction between the seed treatment and foliar nutrition at 40 DAS was found to be non-significant at all stages of crop growth on DMP.

Table 4a. Effect of seed treatment and foliar application on number of branches at different stages of crop

Treatments	20 DAS	40 DAS	60 DAS
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	1.50	2.36	4.94
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	1.79	2.80	5.46
s_3- control (no seed treatment)	1.64	2.40	4.89
SEm (±)	0.07	0.09	0.07
CD (0.05)	0.217	0.267	0.191
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	1.76	2.56	5.36
f_2- foliar application of DAP 2% at 40 DAS	1.78	2.64	5.36
f_3- foliar application of KCl 2% at 40 DAS	1.73	2.60	4.98
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	1.62	2.51	5.44
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	1.47	2.36	5.20
f_6- control	1.51	2.44	4.24
SEm (±)	0.11	0.13	0.09
CD (0.05)	NS	NS	0.270

Table 4b. Interaction effect of seed treatment and foliar application on number of branches at different stages of the crop

Treatments	20 DAS	40 DAS	60 DAS
S×F interaction			
s_1 f_1	1.47	2.13	5.00
s_1 f_2	1.73	2.53	5.20
s_1 f_3	1.80	2.53	4.93
s_1 f_4	1.47	2.53	5.07
s_1 f_5	1.33	2.13	5.13
s_1 f_6	1.20	2.27	4.33
s_2 f_1	1.80	2.80	5.53
s_2 f_2	1.87	3.00	5.73
s_2 f_3	1.80	2.80	5.27
s_2 f_4	1.80	2.73	6.13
s_2 f_5	1.67	2.67	5.40
s_2 f_6	1.80	2.80	4.67
s_3 f_1	2.00	2.73	5.53
s_3 f_2	1.73	2.40	5.13
s_3 f_3	1.60	2.47	4.73
s_3 f_4	1.60	2.27	5.13
s_3 f_5	1.40	2.27	5.07
s_3 f_6	1.53	2.27	3.73
SEm (±)	0.11	0.23	0.16
CD (0.05)	NS	NS	0.468

Table 5a. Effect of seed treatment and foliar application on number of leaves at different growth stages of the crop

Treatments	20 DAS	40 DAS	60 DAS
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	5.46	11.49	18.58
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	6.58	14.02	21.33
s_3- control (no seed treatment)	5.37	10.64	18.76
SEm (±)	0.11	0.36	0.24
CD (0.05)	0.330	1.022	0.696
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	5.98	11.84	20.29
f_2- foliar application of DAP 2% at 40 DAS	5.58	12.51	18.87
f_3- foliar application of KCl 2% at 40 DAS	5.64	12.49	17.82
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	5.80	11.82	23.13
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	6.04	12.13	20.71
f_6- control	5.76	11.51	16.51
SEm (±)	0.16	0.50	0.34
CD (0.05)	NS	NS	0.984

Table 5b. Interaction effect of seed treatment and foliar application on number of leaves at different stages of the crop

Treatments	20 DAS	40 DAS	60 DAS
S×F interaction			
s_1 f_1	5.40	12.00	18.60
s_1 f_2	5.33	12.07	17.67
s_1 f_3	5.20	11.00	17.53
s_1 f_4	5.33	11.33	22.00
s_1 f_5	5.80	10.60	19.07
s_1 f_6	5.67	11.93	16.60
s_2 f_1	7.07	13.87	22.73
s_2 f_2	6.47	14.2	21.13
s_2 f_3	6.53	15.13	18.87
s_2 f_4	6.60	13.20	25.00
s_2 f_5	6.27	14.40	23.27
s_2 f_6	6.53	13.27	17.00
s_3 f_1	5.47	9.67	19.53
s_3 f_2	4.93	11.20	17.80
s_3 f_3	5.20	11.33	17.07
s_3 f_4	5.47	10.93	22.40
s_3 f_5	6.07	11.40	19.80
s_3 f_6	5.07	9.33	15.93
SEm (±)	0.28	0.87	0.59
CD (0.05)	NS	NS	NS

Table 6a. Effect of seed treatment and foliar application on dry matter production on different growth stages of crop, g per plant

Treatments	20 DAS	40 DAS	60 DAS	Harvest
Seed treatment (S)				
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	4.40	14.78	32.42	39.15
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	4.48	15.42	35.66	43.03
s_3- control (no seed treatment)	3.95	13.15	29.93	37.54
SEm (±)	0.12	0.36	0.66	0.42
CD (0.05)	0.353	1.029	1.895	1.220
Foliar application (F)				
f_1- foliar application of urea 2% at 40 DAS	4.38	15.02	35.35	41.49
f_2- foliar application of DAP 2% at 40 DAS	4.18	14.47	32.37	40.02
f_3- foliar application of KCl 2% at 40 DAS	4.08	14.08	30.30	36.93
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	4.32	14.33	35.73	45.18
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	4.29	14.77	35.50	44.53
f_6- control	4.41	14.04	26.76	31.28
SEm (±)	0.17	0.51	0.93	0.60
CD (0.05)	NS	NS	2.680	1.726

Table 6b. Interaction effect of seed treatment and foliar application on dry matter production at different stages of the crop, g per plant.

Treatments (DMP)	20 DAS	40 DAS	60 DAS	Harvest
S×F interaction				
s_1 f_1	4.60	15.60	37.00	41.26
s_1 f_2	4.30	15.23	32.76	39.66
s_1 f_3	4.23	13.96	28.06	35.66
s_1 f_4	4.16	14.86	36.33	45.76
s_1 f_5	4.66	15.33	36.16	44.83
s_1 f_6	4.43	13.73	24.20	27.70
s_2 f_1	4.26	15.03	36.83	44.30
s_2 f_2	4.30	15.64	35.33	43.60
s_2 f_3	4.10	14.63	33.33	40.20
s_2 f_4	4.76	15.26	38.80	46.46
s_2 f_5	4.36	15.46	38.30	47.03
s_2 f_6	5.10	16.53	31.36	36.63
s_3 f_1	4.30	14.44	32.23	38.90
s_3 f_2	3.96	12.53	29.03	36.80
s_3 f_3	3.91	13.66	29.50	34.93
s_3 f_4	4.03	12.86	32.06	43.33
s_3 f_5	3.83	13.53	32.03	41.73
s_3 f_6	3.70	11.86	24.73	29.53
SEm (±)	0.30	0.88	0.61	1.04
CD (0.05)	NS	NS	NS	NS

4.2 NODULE PARAMETERS

4.2.1 Number of Nodules per Plant

The perusal of data stating the impact on number of nodules per plant at flowering by seed treatment and foliar application of nutrients is cited in Tables 7a and 7b.

Seed treatment had significant influence the no. of nodules per plant at flowering. Higher no. of nodules per plant at flowering (9.87) was recorded in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). The lowest number of nodules per plant at flowering (7.95) was recorded in s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed).

Foliar application of nutrients had significant influence the no. of nodules per plant at flowering. The highest no. of nodules at flowering (10.81) was recorded in f_3 (foliar application of KCl 2% at 40 DAS) which was statistically comparable with f_2 (foliar application of DAP 2% at 40 DAS) and minimum (7.96) was recorded in f_6 (control).

Among the treatment combinations, significant interactions were found between the seed treatment and foliar application of nutrients. The highest no. of nodules per plant (12.99) was documented in treatment combination s_3f_3 which was on par with s_2f_2, s_2f_3 and s_3f_1 whereas lower no. of nodules per plant (5.88) was registered in s_1f_6.

4.2.2 No. of Effective Nodules per Plant

The result on number of effective nodules per plant at flowering by the effect of seed treatment and foliar nutrition and their interactions are presented in Tables 7a and 7b.

The results showed that both seed treatment and foliar application had significant influence on the number of effective nodules per plant at flowering. The highest no. of effective nodules per plant at flowering (6.01) was recorded in s_2. The lowest no. of effective nodules per plant at flowering (4.75) was recorded in s_1.

Foliar nutrition at 40 DAS had no significant influence on effective nodules.

Interaction between the seed treatment and foliar application of nutrients had significant influence on number of effective nodules per plant at flowering. Maximum number of effective nodules per plant at flowering (7.84) was recorded in treatment combination of s_2f_2. Lower number of effective nodules per plant (3.33) was recorded in s_1f_6.

4.2.3 Fresh Nodule weight

The data pertaining to fresh nodule weight are presented in the Tables 7a and 7b. No significant interaction was found with respect to fresh nodule weight.

4.3 YIELD AND YIELD PARAMETERS

4.3.1 Days to 50 per cent flowering

The observations on days to 50% flowering was contemplated in Tables 8a and 8b.

Seed treatment had significant influence on days to 50 per cent flowering. The lowest number of days to 50 per cent flowering (45.66) was recorded in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed) whereas the highest number of days to 50 per cent flowering (48.16) was noticed in s_3 (control).

Foliar application of nutrients did not influence the no. of days to 50% flowering.

Interaction between the treatment factors had no significant influence on no. of days to 50% flowering.

4.3.2 Number of pods per plant

The data on number of pods per plant at harvest as influenced by the seed treatment and foliar nutrition at 40 DAS and their interaction were documented and are presented in Tables 8a and 8b.

Seed treatment had significant influence on number of pods per plant at harvest. The highest number of pods per plant (30.63) was recorded in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). The treatment s_3 (control) recorded the lower number of pods per plant (25.43).

Table 7a. Effect of seed treatment and foliar application on total no. of nodules per plant, total no. of effective nodules per plant and fresh nodule weight

Treatments	Nodules per plant (nos)	Effective nodules per plant (nos)	Fresh nodule weight (g per plant)
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	7.96	4.75	0.61
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	9.87	6.00	0.64
s_3- control (no seed treatment)	9.69	5.86	0.56
SEm (±)	0.26	0.34	0.04
CD (0.05)	0.739	0.978	NS
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	8.40	5.84	0.55
f_2- foliar application of DAP 2% at 40 DAS	10.01	6.57	0.71
f_3- foliar application of KCl 2% at 40 DAS	10.81	6.07	0.71
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	8.62	5.14	0.54
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	9.22	4.70	0.55
f_6- control	7.96	4.92	0.57
SEm (±)	0.36	0.48	0.05
CD (0.05)	1.045	NS	NS

Table 7b. Interaction effect of seed treatment and foliar application on total no. of nodules per plant, total no. of effective nodules per plant and fresh nodule weight

Treatments	Nodules per plant (nos)	Effective nodules per plant (nos)	Fresh nodule weight (g per plant)
S×F interaction			
s_1 f_1	8.440	5.99	0.60
s_1 f_2	8.53	5.33	0.70
s_1 f_3	8.33	5.66	0.53
s_1 f_4	7.55	3.66	0.52
s_1 f_5	8.99	4.55	0.67
s_1 f_6	5.88	3.33	0.67
s_2 f_1	5.33	4.10	0.53
s_2 f_2	12.43	7.84	0.80
s_2 f_3	11.10	5.77	0.86
s_2 f_4	9.55	6.77	0.65
s_2 f_5	10.30	4.77	0.52
s_2 f_6	10.44	6.77	0.52
s_3 f_1	11.44	7.44	0.54
s_3 f_2	9.07	6.55	0.63
s_3 f_3	12.99	6.77	0.74
s_3 f_4	8.77	4.99	0.45
s_3 f_5	8.33	4.77	0.45
s_3 f_6	7.55	4.66	0.53
SEm (±)	0.63	0.83	0.09
CD (0.05)	1.809	2.394	NS

Foliar spray of nutrients at 40 DAS had significant influence on the number of pods per plant at harvest. The maximum number of pods per plant (31.87) was registered in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was statistically comparable with f_5. However, lower number of pods (22.44) was noted in f_6.

Interaction between the seed treatment and foliar nutrition at 40 DAS had no significant influence on the no. of pods per plant at harvest.

4.3.3 Pod Girth

The outcome of seed treatment and foliar spray of nutrients at 40 DAS and their interactions on pod girth at harvest are shown in Tables 8a and 8b.

Seed treatment had significant influence on the pod girth at harvest. Maximum pod girth (1.88 cm) was recorded in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). However, the treatment s_3 (control) resulted in minimum pod girth (1.48 cm).

Foliar spray at 40 DAS had significant influence on the pod girth at harvest. The treatment f_1 (foliar application of urea 2% at 40 DAS) registered the maximum pod girth (1.82 cm) were found to be on par with all other treatments except f_6.

Interaction between the seed treatment and foliar nutrition at 40 DAS had no significant impact on the pod girth at harvest.

4.3.4 Pod Length

Tables 9a and 9b summarise the influence of seed treatment and foliar application of nutrients and their interactions on length of the pods per plant at harvest.

Seed treatment had significant influence on the length of pod per plant at harvest. The longest pods (18.22 cm) were recorded in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). The treatment s_3 (control) resulted in smaller pods (16.8 cm) and was found comparable with s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed) of 17.2 cm.

Table 8a. Effect of seed treatment and foliar application on days to 50 per cent flowering, No. of pods per plant and Pod girth

Treatments	Days to 50% flowering	Pods per plant (nos)	Pod girth (cm)
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	46.89	26.98	1.72
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	45.66	30.63	1.88
s_3- control (no seed treatment)	48.16	25.43	1.48
SEm (±)	0.18	0.38	0.03
CD (0.05)	0.521	1.080	0.101
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	46.77	28.56	1.82
f_2- foliar application of DAP 2% at 40 DAS	46.78	26.68	1.71
f_3- foliar application of KCl 2% at 40 DAS	46.67	25.99	1.7
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	46.89	31.87	1.71
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	46.67	30.66	1.67
f_6- control	47.67	22.44	1.56
SEm (±)	0.26	0.53	0.05
CD (0.05)	NS	1.527	0.142

Table 8b. Interaction effect of seed treatment and foliar application on days to 50 percent flowering, pods per plant and pod girth

Treatments	Days to 50% flowering	Pods per plant (nos)	Pod girth (cm)
S×F interaction			
s_1 f_1	47.33	28.37	1.87
s_1 f_2	46.33	26.10	1.73
s_1 f_3	46.00	24.90	1.73
s_1 f_4	47.33	30.50	1.67
s_1 f_5	46.67	30.30	1.67
s_1 f_6	47.67	21.70	1.67
s_2 f_1	45.33	30.77	1.67
s_2 f_2	45.67	29.83	2.06
s_2 f_3	45.33	28.17	1.87
s_2 f_4	45.33	36.20	1.9
s_2 f_5	45.67	33.00	1.93
s_2 f_6	46.67	25.83	1.87
s_3 f_1	47.67	26.53	1.67
s_3 f_2	48.33	24.10	1.53
s_3 f_3	48.67	24.90	1.53
s_3 f_4	48.00	28.90	1.47
s_3 f_5	47.67	28.67	1.53
s_3 f_6	48.67	19.80	1.47
SEm (±)	0.44	0.92	0.09
CD (0.05)	NS	NS	NS

Foliar nutrition at 40 DAS also had significant influence on the length of pod per plant at harvest. The longer pods (18.52 cm) were recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was comparable with par (17.87 cm) with f_1 (foliar application of urea 2% at 40 DAS). Smaller pods (16.29 cm) were produced in f_6 (control) which was on par with f_2 (foliar application of DAP 2% at 40 DAS) and f_3 (foliar application of KCl 2% at 40 DAS) of 17.24 cm and 17.17 cm respectively.

Interaction between the seed treatment and foliar application of nutrients had no significant influence on the length of pod per plant at harvest.

4.3.5 Pod Weight

The data on weight of pods per plant at harvest were recorded and presented in Tables 9a and 9b.

Seed treatment had significant influence on the weight of the pods at harvest. The highest weight of pods (23.37 g) was observed in treatment s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). The lowest weight of pods (19.64 g) was noted in s_3 (control).

Foliar nutrition at 40 DAS had significant influence on the weight of pods per plant at harvest. The treatment f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) registered the maximum weight of pods per plant at harvest (24.84 g) which was statistically comparable with f_5 (foliar application of DAP 2% +KCl 2% at 40 DAS) whereas the lowest pod weight per plant at harvest (16.82 g) was recorded at f_6 (control).

No significant interaction between the seed treatment and foliar spray had significant impact on the pod weight per plant at harvest.

4.3.6 Seeds per pod

Tables 9a and 9b depicts the seed treatment and foliar nutrition at 40 DAS and their interaction effects on no. of seeds per pod at harvest.

Seed treatment had significant influenced the no. of seeds per pod at harvest. The highest no. of seeds per pod (15.63) was documented in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). The lowest no. of seeds per pod (12.68) was enumerated in s_1 (Seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed) which was comparable (12.98) with s_3(control).

Foliar application of nutrients had significant influence on the number of seeds per pod at harvest. The treatment f_2 (foliar application of DAP 2% at 40 DAS) registered significantly higher number of seeds per pod (14.4) which was statistically comparable with f_1 (foliar application of urea 2% at 40 DAS), f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) and f_5 (foliar application of KCl 2% + DAP 2% at 40 DAS) respectively. Minimum no. of seeds per pod (12.63) was recorded in f_6 (control) which was found to be on par (13.22) with f_3 (foliar application of KCl 2% at 40 DAS).

Interaction between the two factors on no. of seeds per pod at harvest had significantly influenced. The treatment combination of s_2f_4 registered the higher no. of seeds per pod (17.67) which was on par with s_2f_5 (16.11) whereas the lowest no. of seeds per pod at harvest (11.44) was recorded in treatment combination s_1f_6 which was statistically comparable with s_3f_1, s_3f_3 s_3f_4 s_3f_5 s_1f_2 s_1f_3 and s_1f_4.

4.3.7 Seed Yield per Plant

The inspection on seed treatment and foliar application of nutrients and their interactions on seed yield per plant was documented and depicted in Tables 10a and 10b.

Seed treatment had significant influence on the grain yield per plant at harvest. The highest grain yield per plant (19.57 g) was registered in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed) and the bottom seed yield per plant (15.69 g) was recorded in s_3.

Foliar application of nutrients had significant influence on the seed yield per plant at harvest. The highest seed yield per plant at harvest (21.11 g) was registered in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) whereas the lowest seed yield per plant at harvest (14.48 g) was observed in f_6 (control).

No significant interaction was observed between treatment combinations.

4.3.8 Seed Yield per hectare

The results of the data on the seed treatment and foliar nutrition at 40 DAS and their interactions with respect to seed yield per hectare are presented in Tables 10a and 10b.

Seed treatment had significant influence on the seed yield per hectare at harvest. Maximum seed yield (1451.67 kg ha^{-1}) was recorded in s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). Minimum seed yield (1178.88 kg ha^{-1}) was recorded in s_3 (control) which was comparable with s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed).

Foliar application of nutrients also had significant influence on the seed yield per hectare at harvest. The highest seed yield (1631.38 kg ha^{-1}) was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS). The lowest seed yield (1155.40 kg ha^{-1}) was recorded in f_6 (control). Among treatment combinations, no significant interaction was found between treatments.

4.3.9 Haulm Yield per Plant

The data on haulm yield per plant at harvest as influenced by the seed treatment and foliar application of nutrients at 40 DAS and their interactions was documented and depicted in Tables 10a and 10b.

Seed treatment had significant influence on the haulm yield per plant at harvest. The treatment s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed) registered the maximum haulm yield per plant (27.53 g) whereas lower haulm yield per plant (23.73 g) was recorded in s_1 (Seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed) which was comparable with (23.83 g) s_3 (control).

Foliar nutrition had significant impact on the haulm yield per plant at harvest. Maximum haulm yield per plant at harvest (27.25 g) was recorded in f_5 (foliar application of KCl 2% + DAP 2% at 40 DAS) which was statistically comparable with f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS). The lowest haulm yield per plant at harvest (22.49 g) was recorded in f_6 (control).

Table 9a. Effect of seed treatment and foliar application on pod length, pod weight and number of seeds per pod

Treatments	Pod length (cm)	Pod weight (g per plant)	Number of seeds per pod
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	17.2	21.39	12.68
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	18.22	23.37	15.63
s_3- control (no seed treatment)	16.8	19.64	12.98
SEm (±)	0.25	0.34	0.78
CD (0.05)	0.711	0.979	2.032
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	17.87	22.07	14.22
f_2- foliar application of DAP 2% at 40 DAS	17.24	20.44	14.41
f_3- foliar application of KCl 2% at 40 DAS	17.17	19.95	13.22
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	18.52	24.84	13.89
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	17.35	24.70	14.22
f_6- control	16.29	16.82	12.63
SEm (±)	0.35	0.48	0.38
CD (0.05)	1.005	1.384	1.098

Table 9b. Interaction effect of seed treatment and foliar application on pod length, pod weight and number of seeds per pod

Treatments	Pod length (cm)	Pod weight (g per plant)	Number of seeds per pod
S×F interaction			
s_1 f_1	17.8	22.03	13.89
s_1 f_2	17.13	20.46	13.00
s_1 f_3	16.46	19.21	12.11
s_1 f_4	18.76	25.55	11.78
s_1 f_5	17.13	25.19	13.67
s_1 f_6	15.93	15.94	11.67
s_2 f_1	18.5	24.26	15.33
s_2 f_2	17.83	22.64	15.33
s_2 f_3	18.13	21.61	14.56
s_2 f_4	19.10	26.45	17.67
s_2 f_5	18	26.16	16.11
s_2 f_6	17.77	19.13	14.78
s_3 f_1	17.3	19.94	13.44
s_3 f_2	16.77	18.21	14.89
s_3 f_3	16.93	19.04	13.00
s_3 f_4	17.7	22.55	12.22
s_3 f_5	16.93	22.74	12.89
s_3 f_6	15.16	15.40	11.44
SEm (±)	0.60	0.83	1.90
CD (0.05)	NS	NS	2.032

Interaction between seed treatment and foliar nutrition at 40 DAS had significant impact on the haulm yield per plant at harvest. The treatment combination, s_2f_5 was observed significantly the highest haulm yield per plant (31.73 g) and the lower haulm yield per plant was recorded in treatment combination of s_3f_6.

4.3.10 Haulm Yield ha^{-1}

Data furnished in Tables 10a and 10b represents the effect of seed treatment and foliar nutrition at 40 DAS and their interactions on haulm yield ha^{-1} at harvest.

Seed treatment had significant influence on the haulm yield at harvest. The highest haulm yield (3355.29 kg ha^{-1}) was recorded in the treatment s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed). Lower haulm yield (3093.70 kg ha^{-1}) was recorded in the treatment s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed) which was on par with s_3 (control).

Foliar nutrition at 40 DAS had significant influence on the haulm yield ha^{-1} at harvest. The treatment f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) recorded the maximum haulm yield at harvest (3408.66 kg ha^{-1}) and was statistically comparable with f_5 (foliar application of KCl 2% + DAP 2 % at 40 DAS). However, the lowest haulm yield at harvest (2920.55 kg ha^{-1}) was recorded in f_6 (control) which was found to be on par with f_3 (foliar application of KCl 2% at 40 DAS). No significant interaction was found between treatment combinations.

4.3.11 Harvest Index

The data on effect of seed treatment, foliar nutrition and their interaction on harvest index is presented in Tables 11a and 11b.

Seed treatment had no significant influence on the harvest index of crop.

Foliar application had significant influence on harvest index. Higher harvest index was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was on par with all parameters except f_3 and f_6. There was no significant interaction among treatment combinations.

Table 10a. Effect of seed treatment and foliar application on seed yield per plant, seed yield ha^{-1}, haulm yield per plant and haulm yield ha^{-1}

Treatments	Seed yield (g per plant)	Seed yield (kg ha^{-1})	Haulm yield (g per plant)	Haulm yield (kg ha^{-1})
Seed treatment (S)				
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	17.51	1257.62	23.73	3093.70
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	19.57	1451.67	27.53	3355.29
s_3- control (no seed treatment)	15.69	1178.88	23.83	3108.06
SEm (±)	0.40	33.69	0.22	57.64
CD (0.05)	1.153	96.838	0.637	165.55
Foliar application (F)				
f_1- foliar application of urea 2% at 40 DAS	18.37	1343.23	25.40	3204.68
f_2- foliar application of DAP 2% at 40 DAS	16.52	1276.54	24.57	3078.13
f_3- foliar application of KCl 2% at 40 DAS	16.03	1183.70	23.41	3070.84
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	21.11	1493.68	27.05	3431.23
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	19.01	1389.29	27.25	3408.66
f_6- control	14.48	1089.90	22.49	2920.55
SEm (±)	0.56	47.65	0.31	81.52
CD (0.05)	1.630	136.950	0.901	234.286

Tables 10b. Interaction effect of seed treatment and foliar application on seed yield per plant, seed yield per hectare, haulm yield per plant and haulm yield per hectare

Treatments	Seed yield per plant (g per plant)	Seed yield (kg ha^{-1})	Haulm yield per plant (g per plant)	Haulm yield (kg ha^{-1})
S×F interaction				
s_1 f_1	18.11	1301.52	24.94	3209.55
s_1 f_2	16.23	1244.54	24.05	3092.86
s_1 f_3	16.05	1133.76	22.43	2888.92
s_1 f_4	21.43	1449.96	25.42	3227.73
s_1 f_5	19.63	1385.09	25.07	3275.77
s_1 f_6	13.60	1030.87	20.46	2867.40
s_2 f_1	20.41	1510.69	27.18	3265.27
s_2 f_2	18.67	1431.31	26.98	3239.96
s_2 f_3	17.92	1374.07	25.96	3126.18
s_2 f_4	23.15	1635.78	29.29	3854.16
s_2 f_5	21.19	1568.33	31.73	3538.50
s_2 f_6	16.09	1189.84	24.05	3107.65
s_3 f_1	16.61	1217.47	24.09	3139.23
s_3 f_2	14.67	1153.79	22.68	2901.58
s_3 f_3	14.14	1043.26	21.86	3197.44
s_3 f_4	18.75	1395.29	26.43	3211.80
s_3 f_5	16.21	1214.46	24.95	3411.71
s_3 f_6	13.76	1048.99	22.97	2786.61
SEm (±)	0.98	82.53	0.54	141.19
CD (0.05)	NS	NS	1.561	NS

Table 11a. Effect of seed treatment and foliar application on harvest index

Treatments	Harvest index
Seed treatment (S)	
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	0.28
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	0.30
s_3- control (no seed treatment)	0.28
SEm (±)	0.005
CD (0.05)	NS
Foliar application (F)	
f_1- foliar application of urea 2% at 40 DAS	0.29
f_2- foliar application of DAP 2% at 40 DAS	0.29
f_3- foliar application of KCl 2% at 40 DAS	0.28
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	0.31
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	0.30
f_6- control	0.27
SEm (±)	0.01
CD (0.05)	0.021

Table 11b. Interaction effect of seed treatment and foliar application on harvest index

Treatments	Harvest index
S×F interaction	
s_1 f_1	0.28
s_1 f_2	0.28
s_1 f_3	0.28
s_1 f_4	0.31
s_1 f_5	0.29
s_1 f_6	0.26
s_2 f_1	0.31
s_2 f_2	0.30
s_2 f_3	0.30
s_2 f_4	0.30
s_2 f_5	0.31
s_2 f_6	0.27
s_3 f_1	0.28
s_3 f_2	0.28
s_3 f_3	0.28
s_3 f_4	0.31
s_3 f_5	0.29
s_3 f_6	0.27
SEm (±)	0.01
CD (0.05)	NS

4.4 PHYSIOLOGICAL PARAMETER

4.4.1 Total chlorophyll content

The response of the results to seed treatment and foliar application of nutrients and their interactions with respect to total chlorophyll content in plant at different growth stages of crop are presented in Tables 12a and 12b

Seed treatment had significant influence on the total chlorophyll content at all stages of crop growth. The highest total chlorophyll content was recorded in treatment s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed) at 20, 40 and 60 DAS. Minimum total chlorophyll content was recorded in treatment s_3 (control) at 20 and 40 DAS. However, at 60 DAS s_3 (control) was found to be on par with s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed).

Foliar application of nutrients had significant impact on the total chlorophyll content only at 60 DAS. Maximum total chlorophyll content (1.97 mg g^{-1}) was observed in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) and f_1 (foliar application of urea 2% at 40 DAS) which was comparable with f_2 (foliar application of DAP 2% at 40 DAS) and f_5 (foliar application of KCl 2% + DAP 2% at 40 DAS). The treatment f_6 (control) registered lower total chlorophyll content (1.71 mg g^{-1}) which was statistically comparable with f_3 (foliar application of KCl 2% at 40 DAS). Interaction between the seed treatment and foliar nutrition at 40 DAS had no significant effect on the total chlorophyll content.

4.4.2 Leaf area index

The persual of data stating the impact of seed treatment and foliar nutrition at 40 DAS and their interactions on leaf area index at different growth stages of the crop are presented in Tables 13a and 13b.

Seed treatment had significant influence on the LAI at 20, 40 and 60 DAS. Maximum LAI was recorded in treatment s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed) at 20, 40 and 60 DAS. The treatment s_3 (control) recorded the lowest leaf area index at 20 and 40 DAS whereas s_3 (control) registered the lower LAI at 60 DAS.

Table 12a. Effect of seed treatment and foliar application on total chlorophyll content at different growth stages of growth, mg g^{-1}

Treatments	20 DAS	40 DAS	60 DAS
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	1.93	2.61	1.77
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	2.18	2.89	2.05
s_3- control (no seed treatment)	1.76	2.37	1.74
SEm (±)	0.05	0.03	0.04
CD (0.05)	0.144	0.083	0.123
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	1.98	2.61	1.97
f_2- foliar application of DAP 2% at 40 DAS	1.99	2.63	1.88
f_3- foliar application of KCl 2% at 40 DAS	1.98	2.56	1.78
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	1.94	2.59	1.97
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	1.91	2.69	1.80
f_6- control	1.95	2.62	1.71
SEm (±)	0.07	0.04	0.06
CD (0.05)	NS	NS	0.173

Table 12b. Interaction effect of seed treatment and foliar application on total chlorophyll content at different stages of crop, mg g^{-1}

Treatments	20 DAS	40 DAS	60 DAS
S×F interaction			
s_1 f_1	1.97	2.55	1.92
s_1 f_2	1.99	2.60	1.77
s_1 f_3	1.87	2.62	1.69
s_1 f_4	1.96	2.55	1.87
s_1 f_5	1.89	2.66	1.73
s_1 f_6	1.93	2.64	1.65
s_2 f_1	2.20	2.98	2.16
s_2 f_2	2.23	2.79	2.04
s_2 f_3	2.20	2.91	1.96
s_2 f_4	2.09	2.86	2.19
s_2 f_5	2.11	2.96	2.02
s_2 f_6	2.27	2.86	1.95
s_3 f_1	1.77	2.29	1.84
s_3 f_2	1.77	2.49	1.83
s_3 f_3	1.86	2.25	1.69
s_3 f_4	1.78	2.36	1.86
s_3 f_5	1.72	2.45	1.67
s_3 f_6	1.66	2.35	1.53
SEm (±)	0.12	0.07	0.10
CD (0.05)	NS	NS	NS

LAI was significantly influenced by foliar application only at 60 DAS. The result revealed that significantly the highest leaf area index (4.26) was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was on par with f_4 (foliar application of DAP 2% + KCl 2% at 40 DAS) and the lowest (3.25) was recorded in f_6 (control).

Interaction between the seed treatment and foliar application of nutrients had no significant influence.

4.4.3 Crop Growth Rate

The data on effect of seed treatment, foliar nutrition at 40 DAS and their interaction on crop growth rate at different growth stages is depicted in Tables 14a and 14b.

Seed treatment significantly influenced the crop growth rate at all stages of crop growth. At 20-40 DAS and 40-60 DAS significantly the highest crop growth rate (10.41 and 18.51 g m^{-2} d^{-1} respectively) was observed in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed). The lowest crop growth rate (8.71 and 15.32 g m^{-2} d^{-1} respectively) was recorded in s_3 (control) at both 20-40 DAS and 40-60 DAS which was found to be on par with s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed).

Foliar application of nutrients had significant influence on the crop growth rate at 40-60 DAS and 60 DAS-harvest. At 40-60 DAS, higher crop growth rate (19.80 g m^{-2} d^{-1}) was observed in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was on par with f_5 and f_1. At 60 DAS-harvest higher crop growth rate (5.48 g m^{-2} d^{-1}) was observed in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was on par with f_5 and f_2. However, the lowest crop growth rate (11.16 and 1.54 g m^{-2} d^{-1} respectively) was recorded in f_6 (control) at both 40-60 DAS and at 60 DAS-harvest.

Interaction between seed treatment and foliar spray of nutrients was found to be non-significant.

Table 13a. Effect of seed treatment and foliar application on leaf area index at different growth stages of growth

Treatments	20 DAS	40 DAS	60 DAS
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	0.38	1.78	3.49
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	0.95	2.41	3.97
s_3- control (no seed treatment)	0.32	1.60	3.67
SEm (±)	0.02	0.06	0.05
CD (0.05)	0.07	0.171	0.156
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	0.62	1.91	3.78
f_2- foliar application of DAP 2% at 40 DAS	0.49	1.97	3.55
f_3- foliar application of KCl 2% at 40 DAS	0.53	1.96	3.40
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	0.56	1.87	4.26
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	0.58	1.96	4.03
f_6- control	0.51	1.90	3.25
SEm (±)	0.03	0.08	0.08
CD (0.05)	NS	NS	0.221

Table 13b. Interaction effect of seed treatment and foliar application on leaf area index at different stages of crop

Treatments	20 DAS	40 DAS	60 DAS
S×F interaction			
s_1 f_1	0.44	1.58	3.75
s_1 f_2	0.34	1.61	3.41
s_1 f_3	0.37	1.56	3.30
s_1 f_4	0.38	1.64	4.27
s_1 f_5	0.39	1.73	4.13
s_1 f_6	0.34	1.47	3.18
s_2 f_1	1.13	2.37	3.96
s_2 f_2	0.88	2.37	3.99
s_2 f_3	0.93	2.56	3.73
s_2 f_4	0.97	2.25	4.48
s_2 f_5	0.88	2.48	4.23
s_2 f_6	0.91	2.41	3.43
s_3 f_1	0.29	1.58	3.75
s_3 f_2	0.23	1.61	3.41
s_3 f_3	0.29	1.56	3.30
s_3 f_4	0.32	1.64	4.27
s_3 f_5	0.47	1.73	4.13
s_3 f_6	0.28	1.47	3.18
SEm (±)	0.06	0.14	0.13
CD (0.05)	NS	NS	NS

Table 14a. Effect of seed treatment and foliar application on crop growth rate at different growth stages of growth, g m^{-2} d^{-1}

Treatments	20-40 DAS	40-60 DAS	60 DAS -Harvest
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	9.83	15.99	3.12
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	10.41	18.51	3.41
s_3- control (no seed treatment)	8.71	15.32	4.28
SEm (±)	0.346	0.79	0.642
CD (0.05)	0.994	2.269	NS
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	9.54	18.66	2.20
f_2- foliar application of DAP 2% at 40 DAS	10.27	16.30	4.04
f_3- foliar application of KCl 2% at 40 DAS	9.44	14.64	3.26
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	9.92	19.80	5.48
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	9.64	19.08	5.08
f_6- control	9.15	11.16	1.54
SEm (±)	0.49	1.12	0.91
CD (0.05)	NS	3.209	2.610

Table 14b. Interaction effect of seed treatment and foliar application on CGR at different stages of crop, g m^{-2} d^{-1}

Treatments	20-40 DAS	40-60 DAS	60 DAS -Harvest
S×F interaction			
s_1 f_1	10.8	19.67	0.15
s_1 f_2	9.72	15.84	3.25
s_1 f_3	9.70	12.54	4.48
s_1 f_4	10.45	19.81	5.39
s_1 f_5	9.54	19.10	4.64
s_1 f_6	8.80	8.94	0.81
s_2 f_1	9.58	20.13	3.37
s_2 f_2	11.16	17.95	4.34
s_2 f_3	10.25	17.07	3.16
s_2 f_4	10.71	21.83	3.35
s_2 f_5	10.65	21.11	4.47
s_2 f_6	10.24	12.99	1.78
s_3 f_1	8.19	16.18	3.09
s_3 f_2	9.93	15.10	4.54
s_3 f_3	8.36	14.31	2.15
s_3 f_4	8.58	17.77	7.70
s_3 f_5	8.76	16.99	6.14
s_3 f_6	8.42	11.54	2.05
SEm (±)	0.85	1.93	1.57
CD (0.05)	NS	NS	NS

Table 15a. Effect of seed treatment and foliar application on relative growth rate at different growth stages of growth, mg $g^{-1}d^{-1}$

Treatments	20-40 DAS	40-60 DAS	60 DAS -Harvest
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	26.34	16.82	4.06
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	26.87	18.23	4.09
s_3- control (no seed treatment)	26.12	17.81	4.90
SEm (±)	0.73	0.71	0.39
CD (0.05)	NS	NS	NS
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	26.72	18.56	3.51
f_2- foliar application of DAP 2% at 40 DAS	26.78	17.64	4.71
f_3- foliar application of KCl 2% at 40 DAS	27.00	16.61	4.32
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	26.04	19.83	5.17
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	27.04	18.98	5.00
f_6- control	25.07	14.12	3.397
SEm (±)	1.04	1.01	0.56
CD (0.05)	NS	2.906	NS

Table 15b. Interaction effect of seed treatment and foliar application on relative growth rate at different stages of crop, mg $g^{-1}d^{-1}$

Treatments	20-40 DAS	40-60 DAS	60 DAS-Harvest
S×F interaction			
s_1 f_1	26.45	18.82	2.37
s_1 f_2	27.44	16.62	4.18
s_1 f_3	26.15	15.15	5.15
s_1 f_4	27.63	19.38	5.07
s_1 f_5	25.83	18.61	4.68
s_1 f_6	24.54	12.33	2.91
s_2 f_1	27.35	19.48	4.01
s_2 f_2	27.71	18.13	4.63
s_2 f_3	27.61	17.90	4.07
s_2 f_4	25.32	20.28	3.89
s_2 f_5	27.75	19.67	4.48
s_2 f_6	25.48	13.93	3.43
s_3 f_1	26.35	17.38	4.13
s_3 f_2	25.19	18.18	5.33
s_3 f_3	27.22	16.77	3.73
s_3 f_4	25.18	19.82	6.55
s_3 f_5	27.55	18.65	5.84
s_3 f_6	25.20	16.08	3.84
SEm (±)	1.79	1.75	0.97
CD (0.05)	NS	NS	NS

4.4.4 Relative Growth Rate

The response of results with respect to seed treatment, foliar nutrition at 40 DAS and their interaction on relative growth rate at different growth stages are presented in Tables 15a and 15b.

Seed treatment had no significant influence on the relative growth rate.

Foliar application of nutrients had significant impact on the relative growth rate only at 40-60 DAS. Higher relative growth rate (19.83 mg $g^{-1}d^{-1}$) was observed in f_4 (foliar application of urea 2% *fb* DAP 2 % at 40 DAS) which was statistically comparable with f_5 (foliar application of urea 2% *fb* DAP 2% at 40 DAS), f_1 (foliar application of urea 2% at 40 DAS) and f_2 (foliar application of DAP 2% at 40 DAS). Lower relative growth rate (14.12 mg $g^{-1}d^{-1}$) was observed in f_6 (control).

Interaction between seed treatment and foliar nutrients at 40 DAS had no significant effect on relative growth rate.

4.5 QUALITY PARAMETER

4.5.1 Crude Protein Content of the Grain

The effect of seed treatment and foliar application of nutrients and their interactions on crude protein of grain is presented in Tables 16a and 16b.

Seed treatment had significant effect on the protein content of grain at harvest. The treatment s_2 (seed treatment with PGPR Mix II @ 20 g kg^{-1} seed) recorded the highest crude protein of grain (28.23%) whereas the lowest crude protein of grain (25.86%) was recorded in s_3 (control).

Foliar application of nutrients had significant influence on the crude protein content of grain at harvest. Maximum crude protein content of grain (28.74%) was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS). The lowest crude protein content of grain (24.85%) was recorded in f_6 (control).

Table 16a. Effect of seed treatment and foliar application on crude protein, per cent

Treatments	Crude protein
Seed treatment (S)	
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	26.19
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	28.23
s_3- control (no seed treatment)	25.86
SEm (±)	0.08
CD (0.05)	0.218
Foliar application (F)	
f_1- foliar application of urea 2% at 40 DAS	27.73
f_2- foliar application of DAP 2% at 40 DAS	26.21
f_3- foliar application of KCl 2% at 40 DAS	25.86
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	28.74
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	27.18
f_6- control	24.85
SEm (±)	0.11
CD (0.05)	0.309

Table 16b. Interaction effect of seed treatment and foliar application on crude protein, per cent

Treatments	Crude protein
S×F interaction	
s_1 f_1	28.00
s_1 f_2	26.02
s_1 f_3	25.32
s_1 f_4	27.88
s_1 f_5	26.02
s_1 f_6	23.92
s_2 f_1	29.40
s_2 f_2	27.30
s_2 f_3	26.83
s_2 f_4	30.57
s_2 f_5	28.93
s_2 f_6	26.37
s_3 f_1	25.78
s_3 f_2	25.32
s_3 f_3	25.43
s_3 f_4	27.77
s_3 f_5	26.60
s_3 f_6	24.27
SEm (±)	0.19
CD (0.05)	0.535

Table17a. Effect of seed treatment and foliar application on available soil nitrogen, soil phosphorous, soil potassium and organic carbon

Treatments	Organic carbon (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorous (kg ha^{-1})	Available Potassium (kg ha^{-1})
Seed treatment (S)				
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	0.50	161.68	21.33	126.08
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	0.56	260.64	23.97	131.34
s_3- control (no seed treatment)	0.49	197.22	22.15	117.70
SEm (±)	0.01	4.13	0.51	3.15
CD (0.05)	0.04	11.876	1.458	9.107
Foliar application (F)				
f_1- foliar application of urea 2% at 40 DAS	0.51	224.39	22.34	125.30
f_2- foliar application of DAP 2% at 40 DAS	0.49	186.77	24.03	122.85
f_3- foliar application of KCl 2% at 40 DAS	0.53	177.01	21.02	132.67
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	0.51	255.06	24.77	122.05
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	0.50	206.28	22.74	133.77
f_6- control	0.52	189.55	20.01	113.61
SEm (±)	0.02	5.84	0.72	4.46
CD (0.05)	NS	16.795	2.062	12.879

Table 17b. Interaction effect of seed treatment and foliar application on available soil nitrogen, soil phosphorous, soil potassium and organic carbon

Treatments	Organic carbon (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorous (kg ha^{-1})	Available Potassium (kg ha^{-1})
S×F interaction				
s_1 f_1	0.46	183.98	18.87	121.48
s_1 f_2	0.53	121.26	21.63	123.60
s_1 f_3	0.59	142.16	19.91	135.30
s_1 f_4	0.47	213.25	23.46	123.79
s_1 f_5	0.48	150.53	24.00	135.34
s_1 f_6	0.46	158.89	20.14	117.00
s_2 f_1	0.56	271.79	24.91	133.06
s_2 f_2	0.48	255.06	25.52	129.80
s_2 f_3	0.53	213.25	22.31	138.42
s_2 f_4	0.56	317.78	26.21	127.16
s_2 f_5	0.57	271.79	23.24	142.63
s_2 f_6	0.62	234.15	21.63	116.97
s_3 f_1	0.51	217.43	23.24	121.37
s_3 f_2	0.46	183.98	24.96	115.13
s_3 f_3	0.48	175.62	20.86	124.30
s_3 f_4	0.49	234.15	24.64	115.21
s_3 f_5	0.47	196.52	20.98	123.35
s_3 f_6	0.48	175.62	18.25	106.85
SEm (±)	0.03	10.12	1.24	7.73
CD (0.05)	NS	NS	NS	NS

Interaction between seed treatment and foliar application of nutrients had significant influence on the crude protein content of grain at harvest. The highest crude protein content of grain (30.57%) was recorded in treatment combination of s_2f_4. Minimum crude protein content of grain (23.92%) was recorded in s_1f_6 which was on par with s_3f_6 (24.27%).

4.6 SOIL ANALYSIS

4.6.1 Organic Carbon

Tables 17a and 17b shows the soil analysis data as influenced by the seed treatment and foliar application of nutrients and their interactions was documented with regard to organic carbon, nitrogen, phosphorous and potassium.

Seed treatment had significant influence on the soil organic carbon content. The highest organic carbon (0.56 %) was recorded in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) while the lowest organic carbon content was recorded in s_3 (control) which was statistically comparable with s_1.

Foliar nutrition at 40 DAS had no significant influence on the soil organic carbon content.

No significant interaction between the seed treatment and foliar application of nutrients on the organic carbon content of the soil.

4.6.2 Available N

Seed treatment significantly influenced the N content of soil. The treatment s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) registered the highest N content (260.64 kg ha^{-1}) while the lowest N content (161.68 kg ha^{-1}) was recorded in s_3 (control).

Foliar nutrition at 40 DAS also had significant influence on the soil nitrogen content. The highest N content (255.06 kg ha^{-1}) was registered in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) whereas f_3 (foliar application of KCl 2% at 40 DAS) recorded the lower N content (177.01 kg ha^{-1}) which was found to be on par with f_2 (foliar application of DAP 2% at 40 DAS) and f_6 (control).

Interaction between the seed treatment and foliar nutrition at 40 DAS had no significant influence on the nitrogen content of the soil.

4.6.3 Available P

Seed treatment significantly influenced the phosphorous content of soil. The highest P content (23.97 kg ha^{-1}) was recorded in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) while the lowest P content was recorded in s_1 (seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed) which was statistically comparable with s_3 (control).

Foliar nutrition at 40 DAS also had significant influence on the soil phosphorous content. The treatment f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) registered the maximum P content (24.77 kg ha^{-1}) which was on par with f_2 and f_5. The lowest P content (20.01 kg ha^{-1}) was recorded in f_6 (control) which was found to be on par with f_3.

Interaction between the seed treatment and foliar nutrition had no significant impact on the phosphorous content of the soil.

4.6.4 Available K

Seed treatment had significant effect on the available K content of soil. The treatment s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) recorded the highest K content (131.34 kg ha^{-1}) while s_3 (control) recorded the lowest K content (117.10 kg ha^{-1}).

Foliar nutrition at 40 DAS had significant influence on the soil K content. Higher K content (133.77 kg ha^{-1}) was recorded in f_5 (foliar application of KCl 2% + DAP 2 % at 40 DAS) which was on par with all treatments except f_6 (control).

Interaction between the seed treatment and foliar application of nutrients had no significant influence on the K content of the soil.

Table 18a. Effect of seed treatment and foliar application on uptake of nitrogen by haulm, pod and total N content, kg ha^{-1}

Treatments	Haulm N uptake	Pod N uptake	Total N uptake
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	15.07	84.39	99.47
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	15.03	92.54	107.57
s_3- control (no seed treatment)	16.69	80.97	97.67
SEm (±)	0.45	1.72	1.75
CD (0.05)	1.301	4.932	5.039
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	16.75	87.88	104.65
f_2- foliar application of DAP 2% at 40 DAS	15.07	79.51	94.59
f_3- foliar application of KCl 2% at 40 DAS	12.68	79.35	92.03
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	18.44	106.37	124.82
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	16.46	102.18	118.56
f_6- control	14.16	60.56	74.73
SEm (±)	0.64	2.43	2.48
CD (0.05)	1.840	6.974	7.216

Table 18b. Interaction effect of seed treatment and foliar application on uptake of nitrogen by haulm, pod and total N content, kg ha^{-1}

Treatments	Haulm N uptake	Pod N uptake	Total N uptake
S×F interaction			
s_1 f_1	16.223	81.24	97.46
s_1 f_2	14.95	75.21	90.16
s_1 f_3	11.25	75.96	87.22
s_1 f_4	17.78	108.76	126.52
s_1 f_5	15.64	103.34	118.99
s_1 f_6	14.56	61.87	76.44
s_2 f_1	17.07	98.13	115.20
s_2 f_2	15.12	89.78	104.91
s_2 f_3	12.74	85.27	98.02
s_2 f_4	17.17	106.14	123.3
s_2 f_5	15.82	112.31	128.15
s_2 f_6	12.25	63.62	75.87
s_3 f_1	16.97	84.28	101.26
s_3 f_2	15.14	73.56	88.70
s_3 f_3	14.04	76.82	90.87
s_3 f_4	20.38	104.31	124.64
s_3 f_5	17.94	90.68	108.65
s_3 f_6	15.67	56.20	71.88
SEm (±)	1.11	4.20	4.29
CD (0.05)	NS	NS	NS

4.7 PLANT ANALYSIS

4.7.1 N uptake

Seed treatment showed significant effect on total N uptake and also N uptake by haulm and pod (Tables 18a and 18b). The treatment s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) recorded the highest total N uptake (107.57 kg ha^{-1}), nitrogen uptake by pod (92.54 kg ha^{-1}). The treatment s_3 (control) recorded lower in total N uptake (97.67 kg ha^{-1}) and N uptake by pod (80.97 kg ha^{-1}) and was comparable with s_1 (seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed).

Foliar application of nutrients had significant impact on the total N uptake and N uptake by haulm and pod. The treatment f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) registered the highest total N uptake (124.82 kg ha^{-1}), N uptake by the haulm (18.44 kg ha^{-1}) and pod (106.67 kg ha^{-1}). However, with respect to N uptake by pod f_4 was found to be on par with f_5. whereas, the lowest total N uptake (74.73 kg ha^{-1}), N uptake by haulm (14.16 kg ha^{-1}) and pod (60.56 kg ha^{-1}) was recorded in f_6 (control).

Interaction between the seed treatment and foliar nutrition at 40 DAS had no significant impact on total N uptake and N uptake by haulm and pod.

4.7.2 P uptake

Significant effect among the seed treatments with respect to the total P uptake and P uptake by haulm and pod are presented in the (Tables 19a and 19b). The treatment s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed) registered the highest total P uptake (68.48 kg ha^{-1}), P uptake by haulm (32.39 kg ha^{-1}) and pod (36.09 kg ha^{-1}) whereas, s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed) recorded the lower total P uptake (56.62 kg ha^{-1}). However, s_1 (seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed) was found to be on par with s_3 with respect to P uptake by haulm.

Foliar application of nutrients had significant influence on the total P uptake and P uptake by haulm and pod. The highest total P uptake (71.43 kg ha^{-1}) and P uptake by haulm

(32.98 kg ha^{-1}) was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was on par with f_5 (foliar application of KCl 2% + DAP 2 % at 40 DAS). Higher P uptake by pod (38.45 kg ha^{-1}) was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was found to be on par with f_5 (foliar application of DAP 2% +KCl 2%). The lowest total P uptake (48.53 kg ha^{-1}), P uptake by haulm (26.61 kg ha^{-1}) and pod (21.92 kg ha^{-1}) was recorded in f_6 (control). However, f_6 was found to be on par with f_3 (foliar application of KCl 2% at 40 DAS) with respect to P uptake by haulm.

Interaction between the seed treatment and foliar application of nutrients at 40 DAS had no significant influence on P uptake.

4.7.3 K uptake

The response of results on K uptake as influenced by the seed treatment and foliar application of nutrients and their interactions are depicted in the Tables 20a and 20b.

Seed treatment had significant impact on the total K uptake, K uptake by haulm and pod. The highest total K uptake (110.98 kg ha^{-1}), K uptake by haulm (65.90 kg ha^{-1}) and pod (45.07 kg ha^{-1}) was recorded in s_2 (seed treatment with PGPR mix II @ 20 g kg^{-1} of seed). The lowest total potassium uptake (85.12 kg ha^{-1}), K uptake by haulm (51.22 kg ha^{-1}) and pod (33.89 kg ha^{-1}) was recorded in s_3.

Foliar application of nutrients had significant influence on the total K uptake and uptake of K by haulm and pod. The treatment f_5 (foliar application of KCl 2% + DAP 2% at 40 DAS) recorded higher total K uptake (112.60 kg ha^{-1}), K uptake by haulm and pod. However, f_5 was found to be on par with f_4 with respect to K uptake by pod. The lowest total K uptake (78.69 kg ha^{-1}), K uptake by pod and haulm was recorded in f_6 (control).

Interaction between seed treatment and foliar nutrition at 40 DAS had no significant impact on uptake of K.

Table 19a. Effect of seed treatment and foliar application on uptake of phosphorus by haulm, pod and total P uptake, kg ha^{-1}

Treatments	Haulm P uptake	Pod P uptake	Total P uptake
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	28.16	29.89	58.05
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	32.39	36.09	68.48
s_3- control (no seed treatment)	28.63	27.99	56.62
SEm (±)	0.83	0.68	1.12
CD (0.05)	2.399	1.945	3.230
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	29.84	31.51	61.35
f_2- foliar application of DAP 2% at 40 DAS	31.36	31.53	62.90
f_3- foliar application of KCl 2% at 40 DAS	24.83	27.50	52.32
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	32.98	38.45	71.43
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	32.73	37.04	69.77
f_6- control	26.61	21.92	48.53
SEm (±)	1.18	0.96	1.59
CD (0.05)	3.393	2.751	4.567

Table 19b. Interaction effect of seed treatment and foliar application on uptake of phosphorus by haulm, pod and total P uptake, kg ha^{-1}

Treatments	Haulm P uptake	Pod P uptake	Total P uptake
S×F interaction			
s_1 f_1	28.15	31.87	60.02
s_1 f_2	28.03	30.60	58.63
s_1 f_3	24.14	26.56	50.71
s_1 f_4	30.69	39.15	69.84
s_1 f_5	32.80	33.30	66.10
s_1 f_6	25.13	17.87	43.01
s_2 f_1	31.95	35.91	67.86
s_2 f_2	35.50	36.67	72.18
s_2 f_3	26.10	32.11	58.21
s_2 f_4	33.16	40.94	74.11
s_2 f_5	37.83	42.57	80.41
s_2 f_6	29.78	28.34	58.12
s_3 f_1	29.43	26.74	56.18
s_3 f_2	30.54	27.34	57.88
s_3 f_3	24.23	23.81	48.05
s_3 f_4	35.09	35.25	70.35
s_3 f_5	27.55	35.23	62.79
s_3 f_6	24.90	19.57	44.48
SEm (±)	2.04	1.66	2.75
CD (0.05)	NS	NS	NS

Table 20a. Effect of seed treatment and foliar application on uptake of potassium by haulm, pod and total K uptake, kg ha^{-1}

Treatments	Haulm K uptake	Pod K uptake	Total K uptake
Seed treatment (S)			
s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	55.70	37.17	92.88
s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	65.90	45.07	110.98
s_3- control (no seed treatment)	51.22	33.89	85.12
SEm (±)	1.46	0.96	1.89
CD (0.05)	4.204	2.763	5.451
Foliar application (F)			
f_1- foliar application of urea 2% at 40 DAS	58.80	39.23	98.04
f_2- foliar application of DAP 2% at 40 DAS	56.21	35.71	91.93
f_3- foliar application of KCl 2% at 40 DAS	54.76	37.82	92.59
f_4- foliar application of urea 2% *fb* DAP 2% at 40 DAS	60.28	43.80	104.08
f_5- foliar application of DAP 2% + KCl 2% at 40 DAS	67.52	45.10	112.60
f_6- control	48.06	30.62	78.69
SEm (±)	2.07	1.36	2.68
CD (0.05)	5.945	3.907	7.709

Table 20b. Interaction effect of seed treatment and foliar application on uptake of potassium by haulm, pod and total K uptake, kg ha^{-1}

Treatments	Haulm K uptake	Pod K uptake	Total K uptake
S×F interaction			
s_1 f_1	58.09	38.05	96.15
s_1 f_2	52.63	32.00	84.64
s_1 f_3	54.55	35.26	89.81
s_1 f_4	61.19	41.37	102.54
s_1 f_5	63.48	46.79	110.24
s_1 f_6	44.27	29.58	73.85
s_2 f_1	66.24	46.26	112.55
s_2 f_2	67.00	41.74	108.75
s_2 f_3	61.07	43.36	104.43
s_2 f_4	64.50	50.58	115.05
s_2 f_5	76.50	50.07	126.54
s_2 f_6	60.10	38.43	98.54
s_3 f_1	52.08	33.38	85.46
s_3 f_2	49.00	33.40	82.41
s_3 f_3	48.67	34.86	83.53
s_3 f_4	55.14	39.45	94.60
s_3 f_5	62.60	38.43	101.03
s_3 f_6	39.82	23.85	63.67
SEm (±)	3.58	2.35	4.65
CD (0.05)	NS	NS	NS

4.8 ECONOMIC ANALYSIS

4.8.1 Net return

The computed data of net returns as influenced by different treatment combinations of seed treatment and foliar application of nutrients are presented in Table 21. The highest value of net return was registered in the treatment combination s_2f_4 (₹ 73805.97 ha^{-1}).

4.8.2 Benefit Cost Ratio

The benefit cost ratio (BCR) as affected by different treatment combinations of seed treatment and foliar application of nutrients at 40 DAS are presented in Table 21. The highest BCR of 1.60 was marked with the treatment combination s_2f_4 was followed by s_2f_5.

4.9 GERMINATION PARAMETERS

Mean data of germination parameters as influenced by different seed treatment methods is presented in the Table 22.

Seed treatment with PGPR mix II @ 20 g kg^{-1} of seed showed higher germination parameters *viz.*, germination percentage (86.67%), seedling length and vigour index. Lower germination parameters were recorded in control (without seed treatment) followed by seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed.

Table 21. Effect of seed treatment and foliar application on net income and BCR

Treatment combinations	Gross returns (₹ ha $^{-1}$)	Net income (₹ ha $^{-1}$)	BCR
S×F interaction			
s_1 f_1	156183	34084.99	1.27
s_1 f_2	149344.9	26926.87	1.21
s_1 f_3	136051.9	13897.91	1.11
s_1 f_4	173995.8	51497.81	1.42
s_1 f_5	166211.4	43657.41	1.35
s_1 f_6	123704.8	1686.81	1.01
s_2 f_1	181283.7	59195.71	1.48
s_2 f_2	171757.3	49349.33	1.40
s_2 f_3	164889.5	42745.49	1.34
s_2 f_4	196294	73805.97	1.60
s_2 f_5	188200.3	65656.29	1.53
s_2 f_6	142781.7	20773.69	1.17
s_3 f_1	146096.9	24048.93	1.19
s_3 f_2	138455.5	16087.47	1.13
s_3 f_3	125191.7	3087.73	1.02
s_3 f_4	167435.6	44987.57	1.36
s_3 f_5	145735.3	23231.31	1.18
s_3 f_6	125879.7	3911.69	1.03

Table 22. Effect of seed treatment methods on germination and seedling vigour index of grain cowpea

Germination parameters	s_1- seed treatment with *Trichoderma* sp. @ 20 g kg^{-1} of seed	s_2- seed treatment with PGPR mix II @ 20 g kg^{-1} of seed	s_3- control (no seed treatment)
Germination percentage (%)	73.33	86.67	70
Shoot length (cm)	12.35	14.32	12.11
Root length (cm)	6.12	7.13	6.12
Dry weight (g)	0.62	0.71	0.60
Vigour index I	1354.22	1859	1277.44
Vigour index II	44	59.93	43.39

DISCUSSION

5. DISCUSSION

The present experiment entitled “Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut” was conducted in Coconut Research Station, Balaramapuram, Kerala to evaluate the effect of seed treatment with plant growth promoting rhizobacteria and foliar nutrition on the grain yield of cowpea. The results of this study are discussed in this chapter.

5.1 EFFECT OF SEED TREATMENT ON COWPEA

Seed treatment had significant influence on the growth parameters, yield parameters, grain quality and nutrient content of cowpea.

5.1.1 Effect on growth characters

The results of the study indicated that seed treatment significantly improved the various growth attributing characters like emergence percentage, plant height, number of branches, number of leaves and dry matter production. Seed treatment with PGPR mix II with 20 g kg^{-1} of seed produced significantly the tallest plants at 20, 40, 60 DAS and at harvest with the highest emergence percentage at 4 DAS. Similarly, the highest number of branches and leaves were also recorded by seed treatment with PGPR mix II with 20 g kg^{-1} of seed. *Pseudomonas fluorescens* and *Bacillus subtilis* strains which are present in PGPR mix II were reported positive for production of ammonia, solubilization of phosphorous and production of IAA (Khan *et al.,* 2012). The increase in growth characters might be due to increased production of IAA, ammonia, solubilization of phosphorous and gibberellins. The tallest plants with increased number of branches and leaves per plant could be explained on the grounds of increased production of IAA, ammonia and increased availability of phosphorous by solubilization, extra cellular production of antibiotics, lytic enzymes and hydrocyanic acid. IAA increase the root and shoot length of plant by stimulating plant cell elongation or cell division. Improved root length might have enhanced the uptake of essential plant nutrients which plays a major role in regulation of plant development. Similar results were also reported by Siddiqui *et al.* (2009) in pea, Geetha *et al.* (2014) in green gram, Kaur *et al.* (2015) in chickpea, Kumari *et al.* (2018) in mung bean and Abd-El-Khair *et al.* (2019).

Seed treatment had significant influence on dry matter production shown in the Fig.3. There was an increase in dry matter production of 9.91 per cent and 14.62 per cent respectively for seed treatment with PGPR mix II 20 g kg^{-1} of seed when compared to seed treatment with *Trichoderma* sp. and control treatment. This might be due to better absorption of nutrients resulted from increased root length and better crop nutrition as a result of N fixation. These results are in conformity with the findings of Goel *et al.* (2002), Karimi *et al.* (2012) in chickpea and Manaf and Zayed (2015) in cowpea.

5.1.2 Effect of seed treatment on nodule parameters

Seed treatment had significant influence on number of nodules and number of effective nodules per plant. The highest number of nodules and effective nodules were recorded in seed treatment with PGPR mix II @ 20 g kg^{-1} of seed. This can be explained based on the improved biological nitrogen fixation resulted from enhanced nodulation through colonizing root system and suppressing growth of deleterious microorganisms. This increase in nodulation might be due to increased availability of P in soils by PGPR strains which are known to initiate nodule formation and increase the development and functioning of nodules. Similar findings were reported by Parmar and Dadarwal (1999), Goel *et al.* (2002), Bhattacharjee and Chandra (2013) in chickpea and Hafez *et al.* (2021) in faba bean.

5.1.3 Effect of seed treatment on yield parameters and grain quality

All yield attributing characters *viz.*, days to 50 per cent flowering, number of pods per plant and seeds per pod, pod girth, pod length, pod weight per plant, grain yield, haulm yield and harvest index were significantly influenced by seed treatment.

Seed treatment with PGPR mix II with 20 g kg^{-1} of seed recorded lesser number of days (45.66) for 50 per cent flowering compared to control (48.16).

Seed treatment with PGPR mix II with 20 g kg^{-1} of seed recorded higher number of pods per plant, pod girth, pod length, pod weight per plant, number of seeds per pod, seed yield and haulm yield compared to other treatments shown in the Fig.4. There was an increase of 23.14 per cent and 15.43 per cent respectively in seed treatment with PGPR mix II compared to control and seed treatment with *Trichoderma* sp. PGPR promoted plant growth and development *via* production and secretion of various regulatory chemicals in the vicinity of rhizosphere. They also increased nitrogen fixation and sequestration of iron by siderophores, solubilization of inorganic phosphate and mineralization of organic phosphate and/or other nutrients. All these factors might have resulted in increased yield. This enhanced yield may also be attributed to the augmented chlorophyll formation by IAA production resulting in developed photosynthetic rates leading to an increase in growth attributes conducive to better seed yield. A similar pattern of results were observed by Wani *et al.* (2007) in chickpea, Bhatia *et al.* (2008) in groundnut, El-Mohamedy and El-Baky (2008) in pea and Gupta *et al.* (2011) in red gram, Similar findings were also reported by Durga *et al.* (2013) in chickpea, Jain *et al.* (2014) in pea, Kalantari *et al.* (2018) in bean, Mogal *et al.* (2019) in mungbean and Rocha *et al.* (2020) in cowpea.

Protein content of grain was significantly influenced by the seed treatment. Seed treatment with PGPR mix II registered an enhancement of protein content of grain (9.16 per cent and 7.78 per cent respectively) compared to control and seed treatment with *Trichoderma* sp. Seed treatment with PGPR mix II with 20 g kg^{-1} of seed recorded significantly the highest protein content of grain (28.23 per cent) compared to the control. This might be possibly due to greater nutrient mobilization inside the plant by IAA and increase in N content in grain. The enhanced protein concentration in grain improved the nutritive value of cowpea. Similar findings were observed by Wani and Khan (2010) in chickpea, Mohamed and Gomaa (2012) in radish and Singh *et al.* (2015) in lentil.

5.1.4 Effect of seed treatment on nutrient uptake

At harvest plants were analysed for N, P and K content and uptake of these nutrients were computed. Seed treatment had significant influence on N, P and K uptake.

The highest total uptake of N, P and K were found in seed treatment with PGPR mix II with 20 g kg^{-1} of seed shown in the Fig.5. The development of lateral roots and subsequent increase in root proliferation might have increased the nutrient uptake. The higher dry matter accumulation also might have contributed to the increased nutrient uptake. The increases in total N content and plant uptake might result through PGPR's nitrate reductase activity, nitrogen fixation, or amino acid and $NH^{+\ 4}$ uptake. P uptake in cowpea might be due to the production of various organic acids by PGPR, which decreased the soil pH, leading to the conversion of the insoluble P into the soil solution P and also by producing chelating substances, which might have led to solubilization of phosphate. PGPR might have similar mechanism of action for release of K. Dey *et al.* (2004) in pea nut, Mohamed and Gomaa

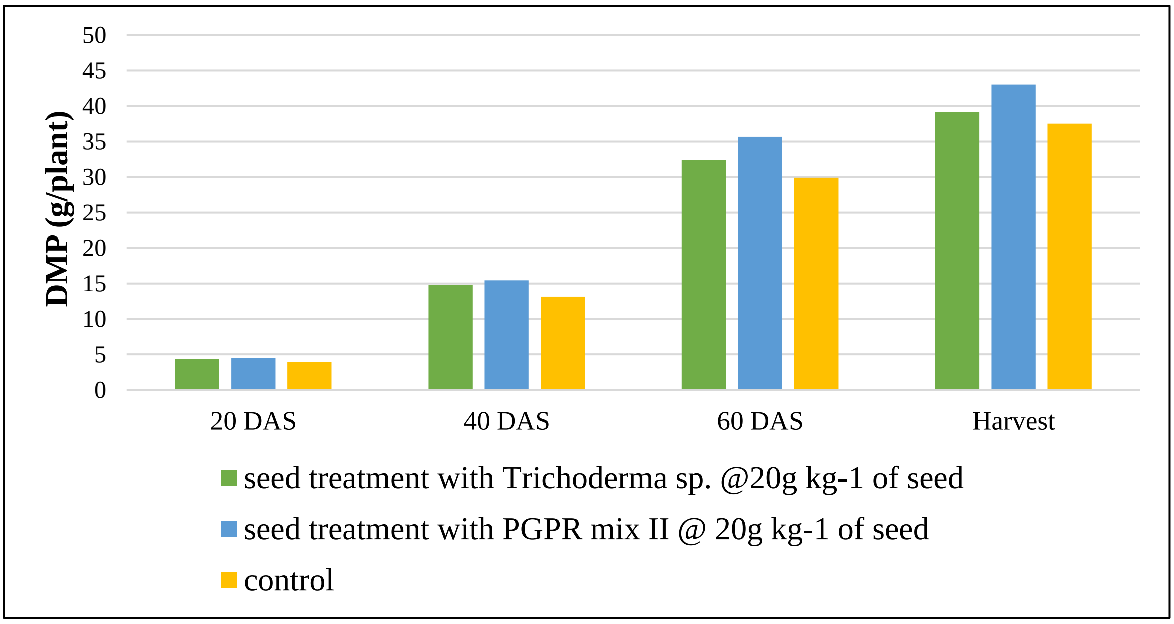

Fig 3. Effect of seed treatment on dry matter production (DMP) at different growth stages of crop

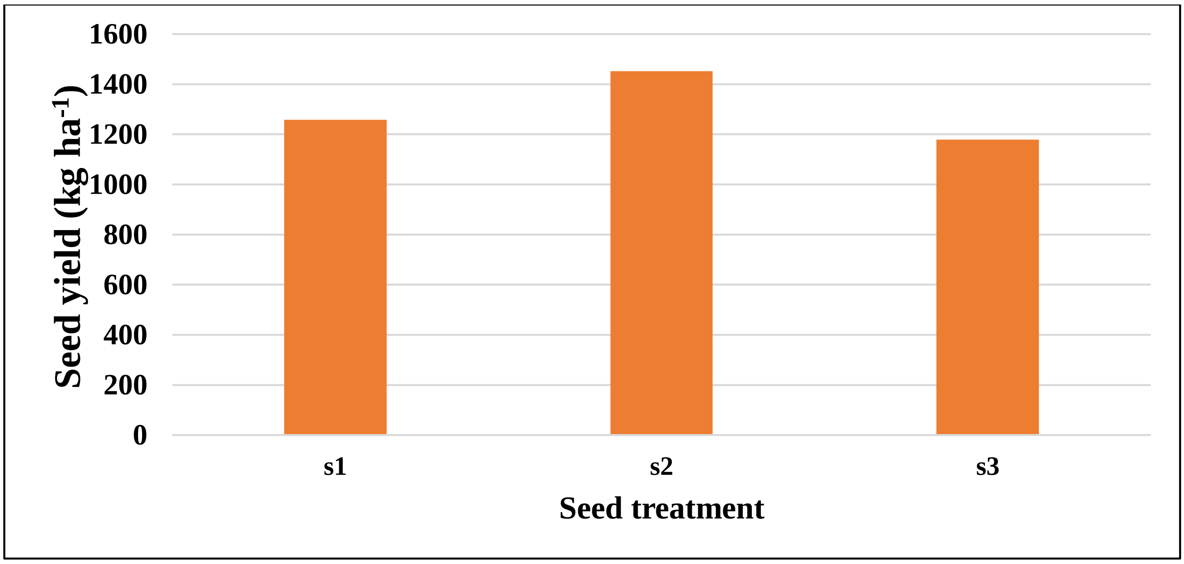

Fig 4. Effect of seed treatment and foliar application of nutrients on seed yield ha^{-1}

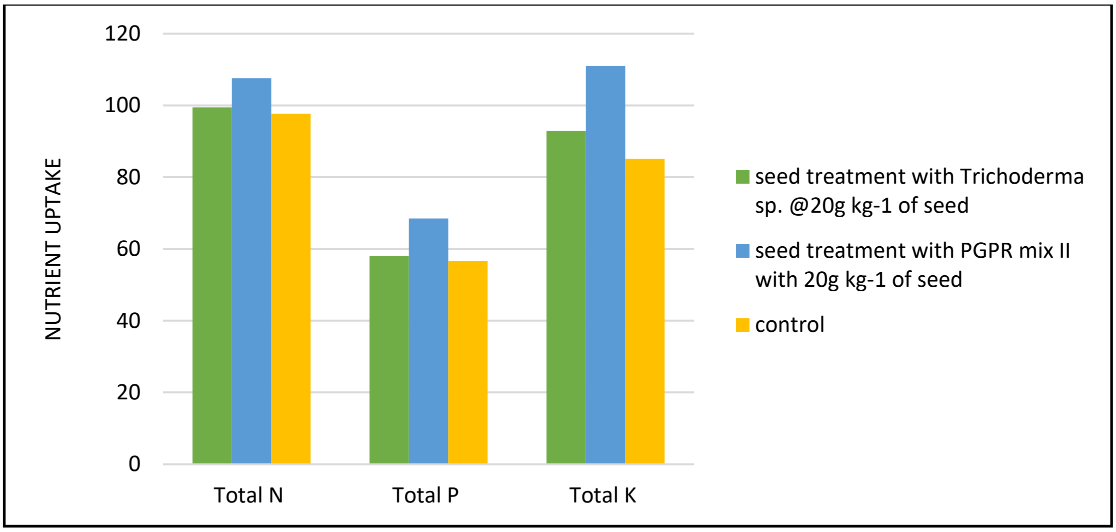

Fig 5. Effect of seed treatment on total nutrient uptake in kg ha^{-1}

Plate 4. Effect of seed treatment on seedling length of cowpea

(2012) in radish, Zafar *et al.* (2012) in lentil and Kumar *et al.* (2016) in bean, Israr *et al.* (2016) in chickpea also reported similar findings.

5.1.5 Effect of seed treatment on soil available nutrient status

Soil organic carbon, available nitrogen, phosphorous and potassium status of soil after harvest were profoundly influenced by seed treatment. Seed treatment with PGPR mix II with 20 g kg^{-1} of seed showed significantly the highest availability of soil OC, N, P and K. Rhizobium's ability to fix atmospheric nitrogen and PSB and KSB's ability to solubilize inaccessible phosphates and potassium in the soil (PGPR) may both contribute to the increased availability of N, P, and K in soil. Similar findings were reported by Ghosh and Joseph (2008) in soyabean and Lavanya and Ganapathy (2011) in green gram.

5.1.6 Effect of seed treatment on physiological parameters

Seed treatment had significant influence on physiological parameters *viz.*, chlorophyll content, leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR). Seed treatment with PGPR mix II with 20 g kg^{-1} of seed recorded higher chlorophyll, LAI, CGR and RGR.

The highest chlorophyll at 20, 40 and 60 DAS was recorded in treatment s_2. The reason for such increase might be attributed to synthesis of phytohormones such as IAA by PGPRs at various stages, resulting in increased root growth, stimulated production of chlorophyll, delayed leaf senescence followed by higher absorption of essential nutrients. Similar findings were documented by Jain *et al.* (2014) in pea and Mahmood *et al.* (2016) in mung bean.

The highest CGR at 20-40 and 40-60 DAS were recorded in treatment s_2 (seed treatment with PGPR mix II with 20 g kg^{-1} of seed). The promotion of CGR may be due to higher nodules, resulting in higher nitrogen fixation, leading to improved shoot as well as root growth. This might have further improved in better acquisition of P and other nutrients thereby increasing the crop growth rate. The higher light interception due to greater LAI may also have contributed to the enhanced CGR which might have ultimately registered in higher biomass. Similar findings were conveyed by Singh *et al.* (2016) in lentil and Yousef *et al.* (2020) in mung bean.

Seed treatment with PGPR mix II with 20 g kg^{-1} of seed recorded significantly higher LAI at 20, 40 and 60 DAS. This might be due to greater the accessibility to nutrients and their uptake by crop plants along with better amount of light interception by the crop plants with greater no. of leaves which might have contributed toward the vegetative growth of crop plants under all treatments. Similar findings were found by Singh and Singh (2012) in red gram and Rani *et al.* (2017) in field pea.

5.2 EFFECT OF FOLIAR APPLICATION OF NUTRIENTS ON COWPEA

Foliar application of nutrients at 40 DAS exhibited positive influence on different parameters of cowpea and effect on each parameter is discussed briefly.

5.2.1 Effect of foliar application of nutrients on growth characters

All growth attributing characters *viz.,* plant height, no. of leaves, branches and DMP were significantly influenced by foliar application of nutrients.

Maximum plant height at 60 DAS and at harvest, the highest number of branches and leaves per plant at 60 DAS were observed with foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS. Number of branches was found to be on par with f_1, f_2 and f_5. Significant increase in plant height due to foliar application of urea resulted in ready availability of amide through leaf cuticles and stomata, meeting the need of nitrogen required for vegetative growth. The increased plant height might be the impact of foliar nutrient administration, which could have increased nitrogen uptake and improved translocation. This might have increased the cell division, cell elongation and photosynthesis which eventually resulted in increased plant height, number of leaves and branches per plant. Similar findings were reported by Choudary and Yadav (2011) in cowpea, Bhowmick *et al.* (2013) in chickpea, Parimala *et al.* (2013) in chickpea and Singh *et al.* (2021) in chickpea.

Dry matter production was significantly influenced by foliar application of nutrients at 60 DAS and at harvest shown in the Fig.6. Foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS exhibited an increase in DMP of 44.44 per cent, 8.89 per cent, 12.89 per cent and 22.34 per cent respectively compared to control, f_1, f_2 and f_3. Foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS recorded significantly higher DMP at 60 DAS and at harvest which was on par with foliar application of KCl 2 per cent + DAP 2 per cent at 40 DAS. The improvement in dry matter production could be attributed to the crop's immediate uptake of nutrients provided through foliar application, which meets the crop's necessary nutrient requirement. Similar findings were reported by Singh *et al.* (2021) in chickpea and Geetha (2003) in black gram.

5.2.2 Effect of foliar application of nutrients on nodule parameters

Foliar application of nutrients had significant influence on different nodule parameters *viz.*, number of nodules, number of effective nodules and nodule fresh weight.

Number of nodules and number of effective nodules was higher in foliar application of DAP 2 per cent at 40 DAS. Number of effective nodules was found to be on par with foliar application of KCl 2 per cent at 40 DAS. The development of nodules might have associated with P, which was applied to plants as foliar spray of DAP. Similar findings were reported by Subramani and Solaimalai (2000) in black gram, Esther and Gautam (2020) in blackgram and Bhavya *et al.* (2020) in green gram.

5.2.3 Effect of foliar application of nutrients on yield parameters

Among various yield parameters, foliar application of nutrients had significant influence on number of pods per plant, pod girth, pod length, pod weight, seeds per pod, seed yield per plant, seed yield per hectare, haulm yield per plant and haulm yield per hectare.

Number of pods per plant, pod length, pod weight, seed yield per plant, seed yield per hectare were registered higher in foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS compared to control shown in the Fig.7. However, f_4 was found to be on par with f_5. Foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS produced a yield increase of 11.20 per cent, 17.01 per cent, 26.18 per cent, 7.51 per cent and 37.16 per cent respectively compared to f_1, f_2, f_3, f_5 and f_6. This increased yield might be due to additional supply of major nutrients such as N which have major role in vegetative growth and dry matter production and P which have major role in pod formation. Spray through foliage, might have caused a greater number of pods and efficient translocation of photosynthates form source to sink which might have ultimately resulted in the enhancement of growth and yield parameters as well as uptake of nutrients by crop. Obviously, the cumulative effects of these parameters might have contributed to increased grain yield potential of the crop. Similar findings were reported by Kumar and Salakinkop (2017) in groundnut and Singh *et al.* (2021) in chick pea.

Foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS registered higher haulm yield ha^{-1}. However, f_4 was found to be on par with f_5. Foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS produced an increase in haulm yield of 7.06 per cent, 11.47 per cent, 11.73 per cent and 17.48 per cent respectively compared to f_1, f_2, f_3 and f_6. The increase in yield might be due to the additional supply of macronutrients *i.e.*, N and P through foliar application. It ultimately helped in higher dry-matter accumulation which contributed to higher yield attributing characters. Similar findings were reported by Geetha and Velayutham (2016) in black gram.

Foliar application of DAP 2 per cent at 40 DAS registered higher number of seeds per pod. However, f_2 was found to be on par with f_4, f_5 and f_1. Foliage applied macronutrients at critical stages of the crop were effectively absorbed and translocated to the developing pods, producing a greater number of seeds and better filling in cowpea. Similar reports were given by Radhamani *et al.* (2003) in greengram, Kandpal *et al.* (2013) in moth bean and Thakur *et al.* (2017) in blackgram.

5.2.4 Effect of foliar application of nutrients on quality parameter

Protein content of grain was significantly influenced by foliar nutrition at 40 DAS. Maximum crude protein content of grain was recorded in foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS. This could be as a result of the extra N and P that was provided through foliar spraying. This is due to the fact that while P indirectly increased the protein content by being necessary for two processes of protein synthesis, namely the activation of amino acids and the termination of carbon in polypeptide-releasing factor m-RNA, N, an amino acid that is a component of the building block of protein, contributed directly. The key role of foliar nutrition in creating a more congenial nutritional environment might well be responsible for the improvement in seed quality. The translocation of nutrients from source to sink was improved by increased availability of N and P and regular supply of metabolites for protein synthesis, which eventually might have resulted in an increase in the protein content in seeds. This increase in protein content was in accordance with the earlier findings of Mondal *et al.* (2011) in soyabean and Sharifi *et al.* (2018) in soyabean.

5.2.5 Effect of foliar application of nutrients on physiological parameters

Leaf area index, chlorophyll, crop growth rate and relative growth rate was significantly influenced by foliar application of nutrients at 40 DAS.

Foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS was recorded significantly higher with respect to chlorophyll and leaf area index. However, chlorophyll in f_4 was found to be on par with f_1, f_2 and f_5. This could be attributed to the improved in nutrient contents of leaves which might have increased the total chlorophyll contents especially N, which is essential for chlorophyll synthesis. Similar results were concluded by Mudalagiriyappa *et al.* (2016) in chickpea, Krishna and Kaleeswari (2018) in red gram and Singh *et al.* (2021) in chickpea.

Crop growth rate and relative growth rate was recorded maximum in foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS. However, it was on par with f_5. The relative growth rate (RGR) and crop growth rate (CGR), both of which were impacted by the foliar application of macronutrients, show the extent of any crop's exponential expansion. Urea 2 per cent and DAP 2 per cent, due to their function in dry matter accumulation and ongoing photosynthesis, CGR and RGR significantly improved. Sritharan *et al.* (2005) and Sritharan *et al.* (2015) in black gram reported similar findings.

5.2.6 Effect of foliar application of nutrients on soil nutrient status

Soil OC, soil available nitrogen, phosphorous and potassium were significantly influenced by foliar application of nutrients. Maximum soil organic carbon, N and P was noticed in foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS. Maximum available K was noticed in foliar application of DAP 2 per cent + KCl 2 per cent at 40 DAS. Where basal N, bio-fertilizers, and urea spraying were used, the treatments had better soil nitrogen balance. This may be because the crop's N requirements were met through better nitrogen fixation and supply through basal dose and urea spray, and because there was relatively less soil removal compared to other treatments. This showed that if the crop is

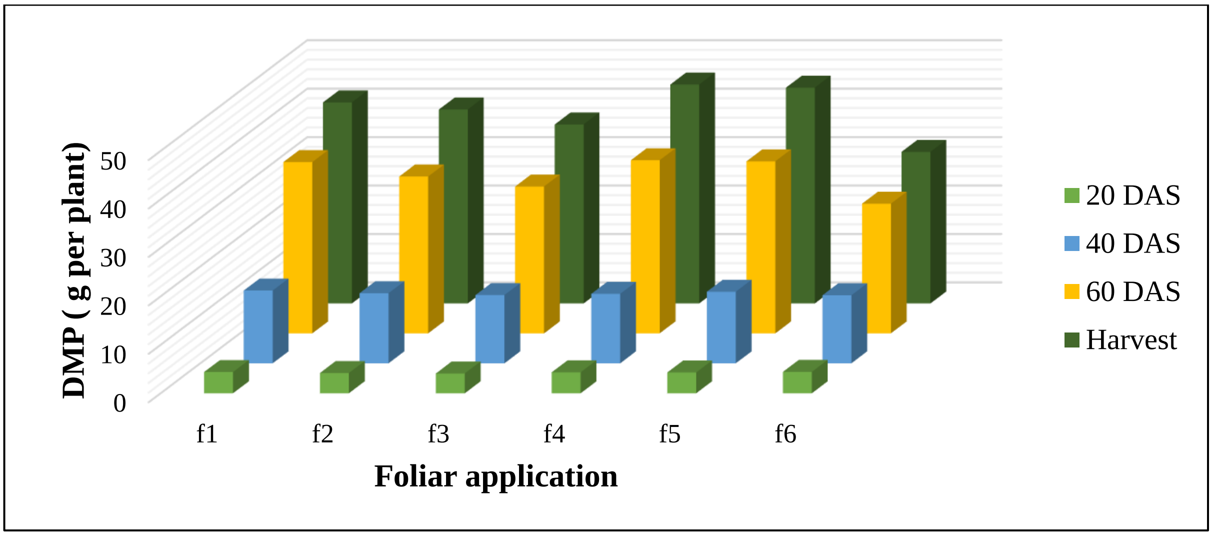

Fig 6. Effect of foliar application of nutrients on dry matter production at different growth stages of crop

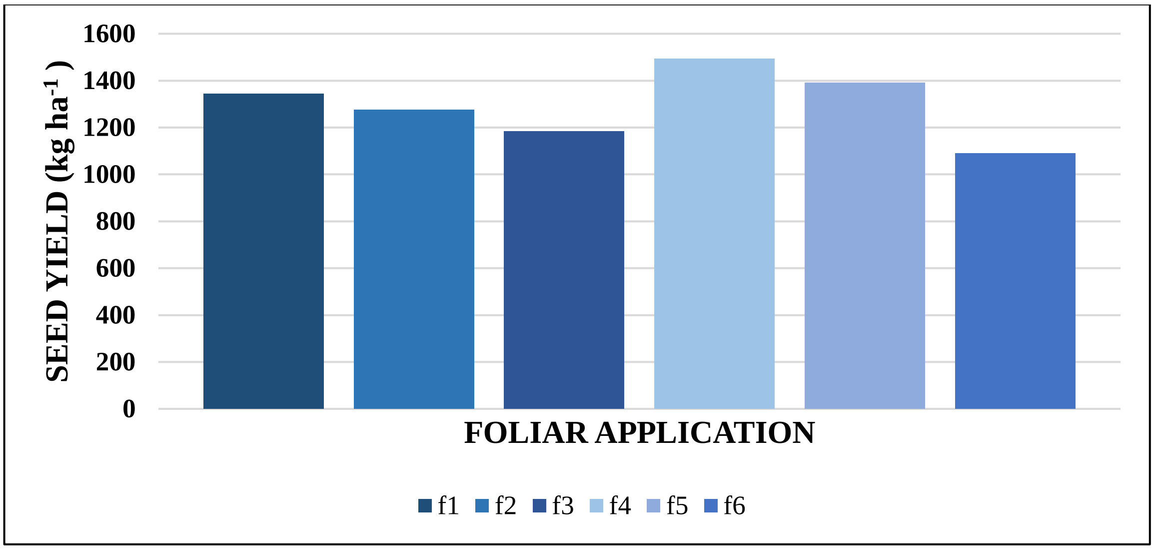

Fig 7. Effect of foliar application of nutrients on seed yield ha^{-1}

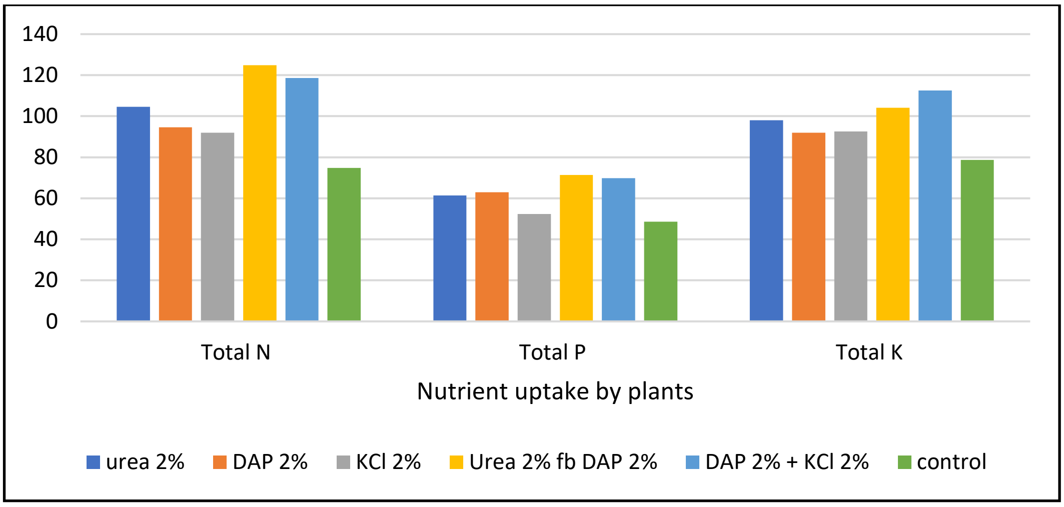

Fig 8. Effect of foliar application of nutrients on nutrient uptake in kg ha^{-1}

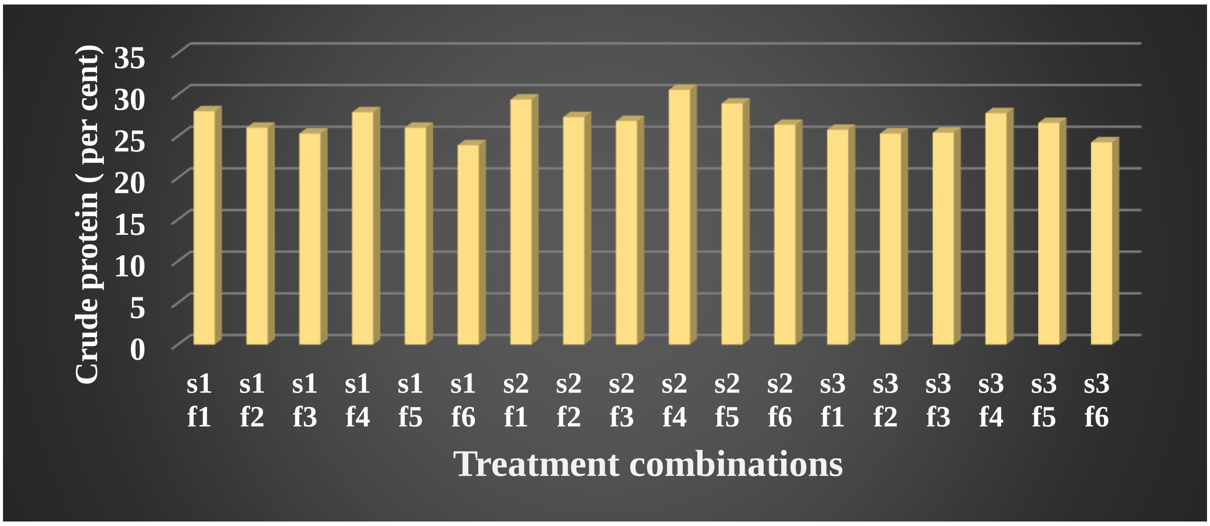

Fig 9. Effect of interaction between seed treatment and foliar application of nutrients on crude protein content in grain

given basal N and urea spray in addition to microbial inoculation, the available soil N status could also be maintained at a good level.

5.2.7 Effect of foliar application of nutrients on nutrient uptake

Nutrient treatment by foliar contact had a considerable impact on plant uptake of nitrogen, phosphorus, and potassium shown in the Fig. 8. Foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS was recorded higher in nitrogen, phosphorous and potassium uptake. Increased photosynthesis and increased nitrogen supply during cowpea's flowering and pod-filling stages might have slowed the loss of chlorophyll and nitrogen from the leaves, which in turn might have increased nitrogen uptake. Higher biomass production and increased nitrogen availability might also have contributed to these effects. The foliar spray of macronutrients and growth hormone, which may have boosted nutrient uptake from the soil and also raised metabolic activity in the plant cell, might be reason for the rise in phosphorus and potassium uptake. Increased nutrient uptake and foliar fertilisation increased the availability of nutrients in a balanced manner, and the plants' positive responses led to improved nutrient translocation to reproductive structures like pods, seeds, and other plant components. Since the N, P, and K content of seed and straw was higher after fertiliser administration through the leaves, it can be assumed that these treatments also promoted the processes for absorbing nutrients. The considerable impact of foliar feeding on nutrient uptake may be attributable to the nutrients' ease of availability and absorption through foliar spray without requiring much energy for their transportation and without experiencing any loss in transit. This increase was already documented by Dewangan *et al.* (2017) in chickpea, Jaybhay *et al.* (2018) in soyabean and Navaz *et al.* (2018) in lathyrus.

5.3 INTERACTION EFFECT OF SEED TREATMENT AND FOLIAR APPLICATION OF NUTRIENTS ON COWPEA

Interaction effect between the seed treatment and foliar application of nutrients at 40 DAS shows positive influence only on few parameters of cowpea and effect on each parameter is discussed briefly.

5.3.1 Interaction effect of seed treatment and foliar application of nutrients on growth parameters

Among various growth attributes, number of branches at 60 DAS was significantly influenced by the interaction effect between the seed treatment and foliar nutrition at 40 DAS.

Number of branches at 60 DAS were recorded significantly the highest in the treatment combination s_2f_4. However, it was found to be on par with s_2f_2 with respect to number of branches. This might be due to the application of DAP and urea, which boosted the yield components due to the expansion of photosynthetic area and the phosphorus and nitrogen applied at crucial phases of the crop, leading to better photosynthetic activity and better growth of growth components. Due to the enhanced availability of nutrients in the root zone by PGPR bacteria, combined inoculation of bio-fertilizers, urea, and DAP increased the growth properties. Similar results were reported by Perumal *et al.* (2004) in blackgram and Lavanya and Ganapathy (2011) in greengram.

5.3.2 Interaction effect of seed treatment and foliar application of nutrients on nodule parameters

The highest number of nodules and no. of effective nodules per plant at flowering were recorded in treatment combination of s_2f_2. This might be the result of enhanced PGPR bacterial activity in the rhizosphere as a result of early crop growth support for basal N, which improved root growth and consequently increased nodulation in plants. Similar findings were documented by Ghosh and Joseph (2008) in greengram and Gupta *et al.* (2011) in chickpea.

5.3.3 Effect of interaction between the seed treatment and foliar application of nutrients on quality parameter

The highest crude protein content of grain was recorded in treatment combination of s_2f_4 shown in the Fig. 9. This might be due to high nitrogen availability in seed by foliar application of nutrients and availability of nutrients by PGPR thereby increased the protein content in seed.

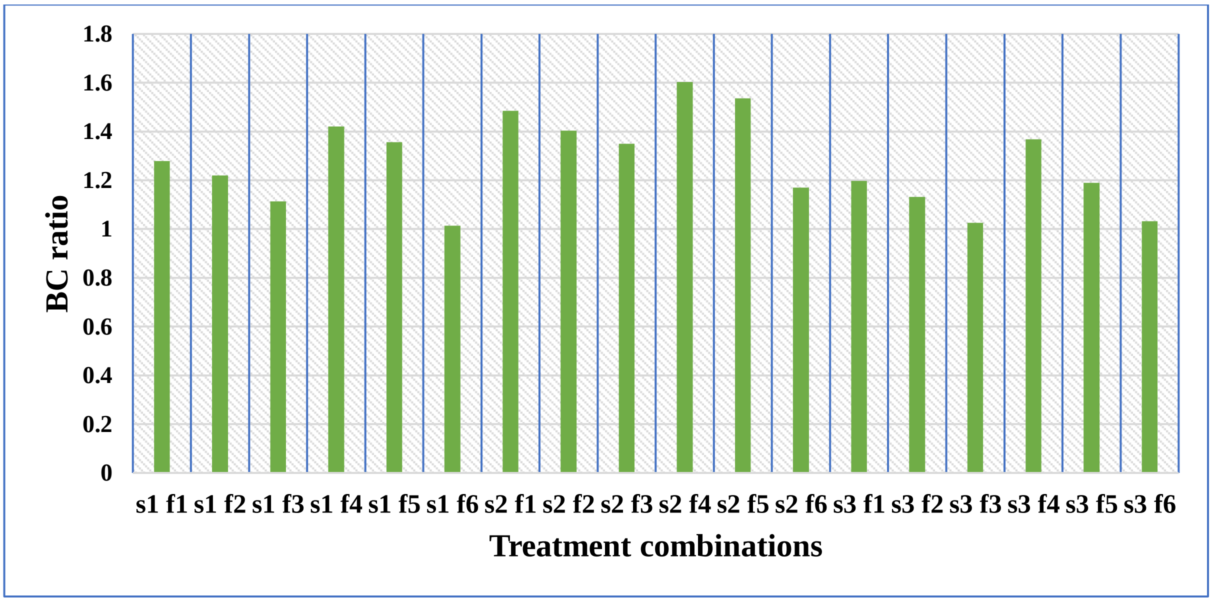

Fig 10. Effect of treatment combinations on benefit cost ratio

Based on the study, it can be concluded that in cowpea, seed treatment with PGPR mix II with 20 g kg^{-1} of seed with recommended dose of fertilisers and foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS could be recommended for cultivation as an intercrop in coconut garden, for higher yield, quality and net returns.

SUMMARY

6. SUMMARY

The present study entitled "Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut" was conducted during the period from December 2021 to April 2022, at Coconut Research Station, Balaramapuram, Kerala, India. The main objective of the study was to evaluate the effect of seed treatment with plant growth promoting rhizobacteria and foliar nutrition on the grain yield of cowpea. The treatments consisted of three seed treatments [(s_1- seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed, s_2- seed treatment with PGPR Mix II @ 20 g kg^{-1} seed, s_3- control (no seed treatment)] and six levels of foliar application of nutrients [f_1 -foliar application of urea 2% at 40 DAS, f_2 -foliar application of DAP 2% at 40 DAS, f_3 -foliar application of KCl 2 % at 40 DAS, f_4 -foliar application of urea 2% *fb* DAP 2% at 40 DAS, f_5- foliar application of KCl 2% + DAP 2 % at 40 DAS, f_6- control (POP)]. The research design employed was randomised block design with 18 treatment combinations replicated thrice. Sowing was done using seed drill. All other management practices were followed as per package of practices recommended by Kerala Agricultural University (KAU, 2016).

The results revealed that seed treatment and foliar application of nutrients showed significant effect on the growth attributes of cowpea. The highest emergence percentage was recorded in s_2 and lower emergence percentage was observed in treatment s_3 and was found to be on par with s_1. The treatment s_2 produced significantly taller plants at all stages of crop growth. At all stages of crop growth, shorter plants were recorded in s_3. However, at 40 and 60 DAS, and at harvest s_3 was found to be on par with s_1. The highest number of branches and leaves per plant were observed in s_2 at all stages. The treatment s_2 recorded significantly higher dry matter production and lower dry matter production per plant was observed in s_3 at all stages of growth.

Among foliar application of nutrients, the treatment f_4 produced significantly taller plants at 60 DAS and at harvest. Higher number of branches and leaves per plant were observed in treatment f_4. However, at 60 DAS, number of branches in f_4 was observed as higher and remained on par with f_1, f_2 and f_5. The dry matter production was recorded significantly higher in f_4 followed by f_5.

Seed treatment and foliar application of nutrients had significant influence on nodule parameters. The highest number of nodules and effective nodules per plant at flowering was recorded in s_2 and the lowest number was recorded in s_1. Among the foliar application of nutrients, the highest number of nodules per plant at flowering was recorded in f_3 which was on par with f_2 and lowest was recorded in f_6.

Significant interactions were found between the seed treatment and foliar application of nutrients. The highest number of nodules per plant was recorded in treatment combination, s_3f_3 which was on par with s_2f_2, s_2f_3 and s_3f_1 whereas lower number of nodules per plant was registered in s_1f_6. Higher number of effective nodules per plant at flowering was recorded in treatment combination, s_2f_2 and lower number of effective nodules per plant was recorded in s_1f_6.

Yield attributes exhibited significant variation in response to seed treatment and foliar application of nutrients. The treatment s_2 registered significantly the lowest number of days to 50 per cent flowering. The highest number of pods per plant (30.63), pod girth (1.88 cm), longest pods (18.22 cm), weight of pods per plant at harvest (23.37 g), number of seeds per pod (15.63) was recorded in s_2. The treatment s_3 resulted in lower number of pods per plant (25.43), pod girth (1.48 cm), weight of pods per plant at harvest (19.64 g) and pod length (16.8 cm) whereas, the lowest number of seeds per pod (12.68) was recorded in s_1 which was on par (12.98) with s_3. Higher seed yield (1451.67 kg ha^{-1}) was recorded in s_2. Lower seed yield (1178.88 kg ha^{-1}) was recorded in s_3 which was found to be on par with s_1. The highest haulm yield (3355.29 kg ha^{-1}) was recorded in s_2 and lower haulm yield (3093.70 kg ha^{-1}) was recorded in s_1 which remained on par with s_3.

Among foliar application of nutrients, maximum number of pods per plant (31.87), weight of pods per plant at harvest was registered in f_4 which was on par with f_5. Higher pod girth (1.82 cm) was observed in f_1 and was found on par with all other treatments except f_6. The longer pods (18.52 cm) were recorded in f_4 which was on par (17.87 cm) with f_1. Smaller pods (16.29 cm) were produced in f_6 which was on par with f_2 and f_3. The treatment f_2 registered higher number of seeds per pod which was on par with f_1, f_4 and f_5. Lower number of seeds per pod at harvest (12.63) was recorded in f_6 which was on par (13.22) with f_3. The highest seed yield (1631.38 kg ha^{-1}) was recorded in f_4 whereas, the lowest seed yield

(1155.40 kg ha^{-1}) was recorded in f_6. The treatment f_4 recorded higher haulm yield at harvest (3408.66 kg ha^{-1}) and was statistically comparable with f_5. However, the lowest haulm yield at harvest (2920.55 kg ha^{-1}) was recorded in f_6 which was found to be on par with f_3. Higher harvest index was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS) which was on par with all parameters except f_3 and f_6.

Interaction between the seed treatment and foliar application of nutrients had significant influence on number of seeds per pod at harvest. The treatment combination of s_2f_4 registered higher number of seeds per pod which was on par with s_2f_5 whereas lower number of seeds per pod at harvest was recorded in treatment combination s_1f_6 which was on par with s_3f_1, s_3f_3 s_3f_4 s_3f_5 s_1f_2 s_1f_3 and s_1f_4. The treatment combination, s_2f_4 was recorded significantly the highest haulm yield per plant and the lower haulm yield per plant was recorded in treatment combination of s_3f_6.

Seed treatment and foliar application of nutrients had significant influence on physiological parameters. The highest total chlorophyll content and leaf area index was recorded in s_2 at 20, 40 and 60 DAS. The treatment s_3 recorded the lowest leaf area index at 40 DAS whereas s_3 registered the lower LAI at 20 and 60 DAS. At 20-40 DAS and 40-60 DAS significantly the highest CGR was observed in s_2. The lowest crop growth rate was recorded in s_3 at both 20-40 DAS and 40-60 DAS and was found on par with s_1.

Foliar application of nutrients had significant influence on the total chlorophyll content and leaf area index only at 60 DAS. Higher total chlorophyll content was observed in f_4 and f_1 which was on par with f_2 and f_5. The treatment f_6 registered lower total chlorophyll content which was on par with f_3. The result revealed that significantly the highest leaf area index was recorded in f_4 and the lowest was recorded in f_6. At 40-60 DAS, higher CGR was observed in f_4 which was on par with f_5 and f_1. At 60 DAS-harvest higher CGR was observed in f_4 which was on par with f_5 and f_2. However, the lowest CGR was recorded in f_6 at both 40-60 DAS and at 60 DAS-harvest. Higher RGR was observed in f_4 which was on par with f_5, f_1 and f_2. Lower RGR was observed in f_6.

Seed treatment and foliar application had significant influence on the crude protein content of grain at harvest. The treatment s_2 recorded the highest crude protein content of grain (28.23%) whereas the lowest crude protein content of grain (25.86%) was recorded in s_3.

Foliar application of nutrients had significant influence on the crude protein content of grain at harvest. Higher crude protein content of grain (28.74%) was recorded in f_4 (foliar application of urea 2% *fb* DAP 2% at 40 DAS). The lowest crude protein content of grain (24.85%) was recorded in f_6 (control).

Interaction between seed treatment and foliar application of nutrients had significant influence on the crude protein content of grain at harvest. The highest crude protein content of grain (30.57%) was recorded in treatment combination of s_2f_4. Lower crude protein content of grain (23.92%) was recorded in s_1f_6 which was on par with s_3f_6 (24.26%).

Seed treatment and foliar application had significant influence on available N, P and K. The highest OC (0.56%), N content (260.64 kg ha^{-1}), P content (23.97 kg ha^{-1}) and K content (131.34 kg ha^{-1}) was recorded in s_2 while the lower OC content, N and K content was recorded in s_3. The lowest P content was recorded in s_1 which was on par with s_3.

The highest N content (255.06 kg ha^{-1}) was observed in f_4 whereas f_3 recorded the lower N content (177.01 kg ha^{-1}) which was on par with f_2 and f_6. The treatment f_4 registered the higher P content (24.77 kg ha^{-1}) which was on par with f_2 and f_5. Lower P content (20.01 kg ha^{-1}) was recorded in f_6 which was on par with f_3. Higher K content (133.77 kg ha^{-1}) was recorded in f_5 which was on par with all treatments except f_6.

Seed treatment and foliar application of nutrients had significant influence on nutrient uptake of N, P and K. The treatment s_2 recorded the highest total N uptake and N uptake by pod. The treatment s_3 recorded lower total N uptake and N uptake by pod and was comparable with s_1. The treatment s_2 recorded the highest total P uptake, P uptake by haulm and pod whereas, s_1 recorded the lower total P uptake. However, s_1 was found to be on par with s_3 with respect to P uptake by haulm. The highest total K uptake, K uptake by haulm and pod was recorded in s_2. The lowest total K uptake, K uptake by haulm and pod was recorded in s_3.

The treatment f_4 registered the highest total N uptake, N uptake by the haulm and pod. However, with respect to N uptake by pod f_4 was found to be on par with f_5. whereas, the lowest total N uptake, N uptake by haulm and pod was recorded in f_6. The highest total P uptake and P uptake by haulm was recorded in f_4 which was on par with f_5. Higher P uptake by pod was recorded in f_4 which was on par with f_5. The lowest total P uptake, P uptake by haulm and pod was recorded in f_6. However, f_6 was found to be on par with f_3 with respect to P uptake by haulm. The treatment f_5 recorded higher total K uptake, K uptake by haulm and pod. However, f_5 was found to be on par with f_4 with respect to K uptake by pod. The lowest total K uptake, K uptake by pod and haulm was recorded in f_6.

The highest value of net return (₹ 73805.97 ha^{-1}) and BCR (1.60) was registered in the treatment combination s_2f_4.

FUTURE LINE OF WORK

- The same experiment may be conducted again to confirm the trend of results obtained in the present study.
- The experiment with *Trichoderma* and PGPR both as seed and soil inoculation may be conducted.
- Seed treatment of *Trichoderma* and PGPR along with rhizobium inoculation needs to be studied.
- The possibility of yield improvement in coconut by intercropping with cowpea may also needs to be experimented.

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APPENDIX

APPENDIX I

Standard week wise meterological data during the cropping period

(December 2021 to April 2022)

Standard weeks	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity I	Relative humidity II	Evaporation (mm)	Rain (mm)
50	32.22	24.55	92.00	85.00	2.85	0
51	32.42	23.95	90.85	83.57	3.37	0
52	31.72	21.12	90.87	82.25	3.27	0
1	32.44	23.11	90.28	82.28	3.50	1.2
2	34.96	24.08	90.40	84.00	3.24	0
3	34.82	24.21	89.71	81.00	3.98	0
4	35.20	22.11	91.14	84.00	3.77	0
5	35.08	20.87	91.00	76.00	4.18	0
6	35.00	21.51	90.57	77.00	4.21	0
7	35.01	21.41	92.42	80.00	3.11	85.4
8	34.10	21.50	92.00	76.00	3.95	6
9	34.80	22.14	91.28	77.00	4.18	0
10	35.35	23.30	90.71	79.00	3.50	0
11	35.44	24.24	89.85	74.00	4.41	0
12	34.97	25.08	88.00	77.00	4.42	0
13	35.28	25.18	87.85	76.00	4.51	0
14	35.20	24.37	88.14	81.00	4.14	38.4

APPENDIX II

Average cost of inputs and market price of produce

Items	Cost (₹)
Inputs	
Cowpea seeds	1000 kg^{-1}
FYM	10 kg^{-1}
Lime	15 kg^{-1}
Urea	10 kg^{-1}
Rajphos	15 kg^{-1}
MOP	17 kg^{-1}
DAP	16 kg^{-1}
PGPR mix II	80 kg^{-1}
Trichoderma sp.	100 kg^{-1}
Labour charge	
Women	650 d^{-1}
Men	750 d^{-1}
Produce	
Grain yield	115 kg^{-1}

Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut

By

VANAM JOSHNA

(2020-11-128)

ABSTRACT

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DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE, VELLAYANI,

THIRUVANANTHAPURAM- 695 522

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ABSTRACT

The study entitled "Seed treatment and foliar nutrition on yield of cowpea (*Vigna unguiculata* L.) intercropped in coconut" was conducted during the period 2021-22, at College of Agriculture, Vellayani. The main objective of the study was to evaluate the effect of seed treatment with plant growth promoting rhizobacteria and foliar nutrition on the grain yield of cowpea.

The field experiment was conducted at Coconut Research Station, Balaramapuram, during the period from December 2021 to April 2022. The experiment was laid out in randomised block design, with 18 treatment combinations replicated thrice. The treatments consisted of three seed treatments [(s_1- seed treatment with *Trichoderma* sp. (KAU isolate) @ 20 g kg^{-1} seed, s_2- seed treatment with PGPR Mix II @ 20 g kg^{-1} seed, s_3- control (no seed treatment)] and six levels of foliar application of nutrients [f_1 -foliar application of urea 2% at 40 DAS, f_2 -foliar application of DAP 2% at 40 DAS, f_3 -foliar application of KCl 2% at 40 DAS, f_4 -foliar application of urea 2% followed by (*fb*) DAP 2% at 40 DAS, f_5- foliar application of KCl 2% + DAP 2% at 40 DAS, f_6- control (POP)]. The variety used for the study was Bhagyalakshmy. All other management practices were followed as per package of practices recommended by Kerala Agricultural University (KAU, 2016).

Seed treatment and foliar application of nutrients had significant effect on the growth and yield of cowpea. Among seed treatments, s_2 resulted in the tallest plants with greater number of branches and leaves per plant at all stages of crop growth. It also resulted in higher dry matter production per plant whereas lower value was observed in s_3. The highest number of nodules and effective nodules per plant at flowering were recorded in treatment s_2. Yield attributes *viz.*, number of pods per plant (30.63), pod girth (1.88 cm), pod length (18.22 cm), weight of pods per plant (23.37 g), number of seeds per pod (15.63), seed yield (1451.67 kg ha^{-1}) and haulm yield (3355.29 kg ha^{-1}) were reported significantly the highest in treatment s_2. Lower seed yield (1178.88 kg ha^{-1}) was recorded in s_3 which was found to be on par with s_1. Lower haulm yield (3093.70 kg ha^{-1}) was recorded in s_1 which remained on par with s_3. The highest total chlorophyll content and leaf area index were recorded in s_2 at all stages. The treatment s_2 also exhibited higher CGR at all stages except at 60 DAS – harvest. The

highest crude protein content of grain (28.23%) was registered in s_2 however, lower was recorded in s_3. The treatment s_2 also recorded the highest total N, P and K uptake.

Among foliar application of nutrients, f_4 resulted in taller plants with more number of branches and leaves per plant. However, at 60 DAS, number of branches in f_4 remained on par with f_1, f_2 and f_5. The dry matter production was also found to be higher in f_4 followed by f_5. The highest number of nodules per plant at flowering was recorded in f_3 which was on par with f_2. However, f_6 registered the lowest number of nodules per plant. Higher number of pods per plant (31.87), weight of pods per plant (24.84 g), seed yield (1631.38 kg ha^{-1}) and haulm yield (3431.23 kg ha^{-1}) were registered in f_4 followed by f_5. Longer pods (18.52 cm) were also observed in f_4 but was found on par with f_1. Higher pod girth (1.82 cm) was observed in f_1 and was found on par with all other treatments except f_6. The treatment f_2 registered higher number of seeds per pod which was on par with f_1, f_4 and f_5. Harvest index was found to be higher in treatment f_4. Higher total chlorophyll content, leaf area index, CGR and RGR were also observed in f_4. Higher crude protein content of grain (28.74%) was recorded in f_4. The treatment f_4 also registered the highest total N and P uptake while f_5 recorded higher total K uptake.

Among the S x F interactions, higher number of branches per plant was recorded in treatment combination of s_2f_4. The highest number of nodules per plant was recorded in s_3f_3 which was comparable with s_2f_2, s_2f_3 and s_3f_1. Higher number of effective nodules per plant at flowering was recorded in s_2f_2. The treatment combination of s_2f_4 recorded the highest number of seeds per pod and crude protein content of grain (30.57%), followed by s_2f_5.

The increase in grain yield was to the tune of 23.14 per cent and 15.43 per cent in s_2 compared to s_3 and s_1 respectively. The treatment f_4 resulted in a yield increase of 11.20 per cent, 17.01 per cent, 26.18 per cent, 7.51 per cent and 37.16 per cent over the treatments, f_1, f_2, f_3, f_5 and f_6 respectively. The treatment combination, s_2f_4 fetched higher net returns of ₹ 73805.97 ha^{-1} with BCR of 1.60.

Based on the study, it could be concluded that, seed treatment with PGPR mix II @ 20g kg^{-1} of seed with recommended dose of fertilizers, and foliar application of urea 2 per cent *fb* DAP 2 per cent at 40 DAS could be recommended for higher yield, quality and economics of cowpea intercropped in coconut garden.

സംഗ്രഹം

വിവിധ വിത്ത് ഉപചാരരീതികളും പത്രപോഷണവും തെങ്ങിൽ ഇടവിളയായി കൃഷി ചെയ്യുന്ന പയറിന്റെ ഉല്പാദനത്തെ എങ്ങനെ സ്വാധീനിക്കുന്നു എന്ന് കണ്ടെത്തുവാനായി ഡിസംബർ 2021 മുതൽ ഏപ്രിൽ 2022 വരെയുള്ള കാലയളവിൽ ബാലരാമപുരം നാളികേര ഗവേഷണ കേന്ദ്രത്തിൽ വെച്ച് പഠനം നടത്തുകയുണ്ടായി. റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ അവലംബിച്ചു നടത്തിയ പരീക്ഷണത്തിൽ മൂന്ന് വിത്ത് ഉപചാരരീതികളും (എസ് 1 - 1 കി. ഗ്രാം വിത്തിന് 20 ഗ്രാം എന്ന തോതിൽ ട്രൈക്കോഡെർമ ഉപയോഗിച്ചുള്ള വിത്ത് ഉപചാരം, എസ് 2 - 1 കി. ഗ്രാം വിത്തിന് 20 ഗ്രാം എന്ന തോതിൽ പി ജി പി ആർ മിക്സ് 2 ഉപയോഗിച്ചുള്ള വിത്ത് ഉപചാരം, എസ് 3 - ഉപചാരമില്ലാതെ), ആറ് പത്രപോഷണരീതികളും (എഫ് 1 - 2 % യൂറിയ ഉപയോഗിച്ചുള്ള പത്രപോഷണം, എഫ് 2 - 2 % ഡി എ പി ഉപയോഗിച്ചുള്ള പത്രപോഷണം, എഫ് 3 - 2 % കെ സി എൽ ഉപയോഗിച്ചുള്ള പത്രപോഷണം, എഫ് 4 - 2 % യൂറിയയോടൊപ്പം 2 % ഡി എ പി ഉപയോഗിച്ചുള്ള പത്രപോഷണം, എഫ് 5 - 2 % കെ സി എൽ ലിനോടൊപ്പം 2 % ഡി എ പി ഉപയോഗിച്ചുള്ള പത്രപോഷണം, എഫ് 6 - പത്രപോഷണമില്ലാതെ) പഠനവിധേയമാക്കി. കേരള കാർഷിക സർവകലാശാലയിൽ നിന്ന് പുറത്തിറക്കിയ ഭാഗ്യലക്ഷ്മി എന്ന പയറിനമാണ് പരീക്ഷണത്തിന് വേണ്ടി ഉപയോഗിച്ചത്.

പി ജി പി ആർ മിക്സ് 2 ഉപയോഗിച്ചുള്ള വിത്ത് ഉപചാരത്തിലൂടെ മെച്ചപ്പെട്ട വിളവും, വിളവ് നിർണയിക്കുന്ന ഘടകങ്ങളായ കായ്കളുടെ നീളം, തൂക്കം, എണ്ണം, കായ്കളിലെ വിത്തിന്റെ എണ്ണം എന്നിവയും മികച്ചതായി കണ്ടു.

വിവിധ പത്രപോഷണരീതികളിൽ മെച്ചപ്പെട്ട വിളവും, വിളവ് നിർണയിക്കുന്ന ഘടകങ്ങളായ കായ്കളുടെ എണ്ണം, കായ്കളുടെ തൂക്കം, വിളവെടുപ്പ് സൂചിക എന്നിവ 2 % യൂറിയയോടൊപ്പം 2 % ഡി എ പി ഉപയോഗിച്ചുള്ള പത്രപോഷണരീതിയിൽ മികച്ചതായി രേഖപ്പെടുത്തി.

പ്രസ്തുത പഠനത്തിന്റെ അടിസ്ഥാനത്തിൽ 1 കി. ഗ്രാം വിത്തിന് 20 ഗ്രാം എന്ന തോതിൽ പി ജി പി ആർ മിക്സ് 2 ഉപയോഗിച്ചുള്ള വിത്ത് ഉപചാരവും, ശുപാർശ പ്രകാരമുള്ള വളത്തിനോടൊപ്പം 2% യൂറിയ 2% ഡി എ പി എന്നിവ 40-ാം ദിവസം പത്രപോഷണത്തിലൂടെ നൽകുന്നതും തെങ്ങിൽ ഇടവിളയായി കൃഷി ചെയ്യുന്ന പയറിന്റെ വിളവിനും ഗുണനിലവാരത്തിനും അറ്റാദായത്തിനും വഴിയൊരുക്കുമെന്ന് കണ്ടെത്തി.