# PHOSPHORUS NUTRITION AND PARTIAL N SUBSTITUTION OF UPLAND RICE (*Oryza sativa* L.)

*by*

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**THESIS**

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## DECLARATION

I, hereby declare that this thesis, entitled **"PHOSPHORUS NUTRITION AND PARTIAL N SUBSTITUTION OF UPLAND RICE (*Oryza sativa* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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# CERTIFICATE

Certified that this thesis entitled **"PHOSPHORUS NUTRITION AND PARTIAL N SUBSTITUTION OF UPLAND RICE (*Oryza sativa* L.)"** is a record of research work done independently by Ms. Golmei Langangmeilu under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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G. Langangmeilu
**Golmei Langangmeilu**

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## LIST OF ABBREVATIONS AND SYMBOLS USED

| | |
|---|---|
| *et al* | And others |
| @ | At the rate of |
| BC | Benefit:Cost |
| $D_b$ | Bulk density |
| C:N | Carbon: Nitrogen |
| cm | Centimetre |
| CF | Chemical fertilizer |
| CD | Critical difference |
| $m^3$ | Cubic metre |
| DAS | Days after sowing |
| $^oC$ | Degree celsius |
| ° E | Degree East |
| EC | Emulsifiable concentrate |
| ° N | Degree North |
| DMP | Dry matter production |
| Fig. | Figure |
| FYM | Farmyard manure |
| g | Gram |
| $ha^{-1}$ | Per hectare |
| HI | Harvest index |
| INM | Integrated nutrient management |
| IPNS | Integrated plant nutrient system |
| PTB | Pattambi |
| $D_p$ | Particle density |
| % | Per cent |
| K | Potassium |
| $K_2O$ | Potash |

| | |
|---|---|
| kg | Kilogram |
| kg $ha^{-1}$ | Kilogram per hectare |
| L | Litre |
| LAI | Leaf Area Index |
| m | Metre |
| Mg $m^{-3}$ | Mega gram per cubic metre |
| $m^2$ | Square metre |
| *viz.* | Namely |
| N | Nitrogen |
| NS | Not significant |
| P | Phosphorus |
| $P_2O_5$ | Phosphate |
| RLWC | Relative leaf water content |
| SE | Standard error |
| RD | Recommended dose |
| ₹. | Rupees |
| *i.e.* | That is |
| t $ha^{-1}$ | Tonnes per hectare |
| VC | Vermicompost |
| WHC | Water holding capacity |

# Introduction

# 1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important and extensively grown crop in Asia and staple food for about 70 per cent of the world population. India is first in area under rice cultivation and second in rice production after China in the world, contributing 20 per cent (Kumari, 2015). In India, rice is grown over 43 m ha with total production of 95 m t contributing total food production of 40 per cent (Kumar *et al.,* 2017). The scope for expansion of area under sole crop of rice in lowlands is limited and available alternative is to increase cultivation of upland rice. In India, 13 per cent area under rice cultivation is grown as upland rice, contributing only 4 per cent of the rice production. A number of abiotic and biotic stresses can depress the rice yield in rainfed uplands which are mostly managed by resource poor farmers. Kerala has witnessed a reduction of 35 per cent in lowland rice area and 28 per cent in production during the last ten years. Although upland rice yield is comparatively lower to lowland rice due to its ability to tolerate stress and low cost of production it will remain dominant.

Upland rice is mainly grown on low fertile soils where they are strongly weathered with little application of lime and fertilizers. The main constraints for production is phosphorus (P) deficiency, as it is mostly associated with acidity and high P fixation (Gupta and O'Toole, 1986). Traditional upland rice cultivars are more suitable to these conditions, as they are more tolerant to low P and high acidity comparative to other cereals (Garrity *et al.,* 1990). Most of the soils contain adequate P for cropping but are not available to plants as they are not accessible to roots. Therefore, P fertilizers must be added in the long run as well as the short run if yields are to be increased appreciably. Under P deficiency plant growth is reduced by 50 per cent (Kirk *et al.,* 1998). For many years, rice has been grown under non flooded aerobic conditions in uplands but the average yields are only 1 to 2 t $ha^{-1}$ because of undesirable environmental conditions (weeds, poor soils, rainfall), low external inputs and low potential yield of upland rice cultivars (Maclean *et al.*, 2002).

Most of the arable soils are often not suited to high-input agriculture. For sustainable crop production in these soils, external nutrient inputs are essential. The external inputs may either be of organic sources such as crop residues, green manure and animal manure or inorganic sources such as chemical fertilizers (CF) and lime. The combined application of organic and inorganic sources of nutrients is a must for sustaining higher productivity in upland rice. The use of inorganic fertilizers to sustain crop production was found to increase yield only for some few years but in the long-term, it has not been effective and leads to soil degradation (Satyanarayana *et al.,* 2002). On the other hand, application of organic fertilizer alone continuously in rice field may result in low yield and low nitrogen (N) and potassium (K) content at the mid-tillering stage, implying the need of integrated nutrient management (INM) for rice production. Therefore, the combined application of organic manures and inorganic fertilizers helps in maintaining yield stability by correcting deficiencies of secondary and micronutrients and thereby enhancing nutrients efficiency and favourable soil health.

At present, the productivity status in Kerala of upland rice is less than 1 t $ha^{-1}$. While inorganic fertilizers supply their nutrients immediately to the plants, the organics, such as farmyard manure (FYM) and green manures, improves the soil physical properties by lowering bulk density, increasing water holding capacity (WHC) and enhancing infiltration rates (Tester, 1990). Green manures add organic matter and recycle nutrients into the soil. The nutrients are taken up by the green manure crops and held by the plant. The benefits of green manuring are generally interpreted as its capacity to produce or provide N as substitute for fertilizers. Green manures, especially legumes act like chemical nitrogenous fertilizers as they have relatively more N and low C:N ratio (Bhuiyan and Zaman, 1996). This helps to increase crop yields keeping the use of CF at low level. Higher availability of phosphorus from rock phosphate has been reported in rice due to green manuring (Cavigelli and Thien, 2003).

There is abundance of organic wastes; crop residues which can easily be converted to vermicompost (VC) or ordinary compost and can largely be used along with CF for increasing crop productivity with lower cost of production (Kumar *et al.*, 2012). Thus, integration of suitable proportion of organic manures with CF is important to boost up upland rice productivity. Suitable nutrient management practices must be adopted to overcome the constraints involved in low productivity of upland rice. It is necessary to use organic sources like FYM and green manuring in conjunction with CF to bring the soil well supplied with all the essential plant nutrients and also to maintain it in good health. The validity of integration of FYM, green manuring and CF is lacking for optimizing the productivity of rainfed upland rice in farmers' fields. There is a prospect of increasing upland rice production by increasing P levels and substitution of N using different organic sources. Therefore, the present study entitled "Phosphorus nutrition and partial N substitution of upland rice (*Oryza sativa* L.)" was undertaken with the following objectives

- To study the influence of different levels of P on growth and yield of upland rice
- To assess the feasibility of partial substitution of inorganic N with FYM, vermicompost and green manure cowpea
- To work out the economics of cultivation

# Review of Literature

## 2. REVIEW OF LITERATURE

Upland rice is gaining popularity in Kerala as it is direct seeded and there is no requirement of puddling or water saturation in the field. But there are constraints limiting the productivity in upland rice. The constraints include moisture stress, nutrient imbalance, weed infestation, increased environmental pollution, degradation of water resources, diminishing biodiversity and poor soil fertility. Combined nutrient management through organic and inorganic sources has a significant role in increasing productivity of crop and soil fertility. INM of fertilizers and organic manures, therefore, is one of the viable options for sustaining soil health *visa-vis* crop productivity. The literature emphasizing the effect of N, P, FYM, VC and *in situ* green manuring of cowpea on growth characters, yield attributes and yield, nutrients uptake, physiological parameters and soil properties are reviewed in this chapter.

### 2.1 INFLUENCE OF N, P and ORGANIC MANURES ON GROWTH CHARACTERS

#### 2.1.1 Nitrogen

Nitrogen is a key nutrient in determining the level of crop productivity. The efficiency of applied N is very low and varies from 20 to 25 per cent in upland rice crop due to the oxidized condition prevailing in uplands and concomitant heavy N loss through percolating water. Hence, fractional application of N in right amount and proportion, and when it is needed the most seems to be a practical proposition. Plant height was found to increase with increased level of N (Kumari *et al.*, 2000). Thomas (2000) obtained taller plants in upland rice at higher N levels. Mini (2005) observed significant increased in plant height with increasing level of N upto 100 kg $ha^{-1}$. Sharma *et al.* (2007) observed significant increased in growth characters with higher levels of N compared to lower levels in direct seeded upland rice. Rao *et al.* (2014)

reported that plant height increased progressively with higher levels of N for rice varieties RGL 2537 in high altitude area of Andhra Pradesh. Gangmei and George (2017) observed the tallest plant with application of 75 kg N $ha^{-1}$ of black rice.

Anu (2001), in studies on upland rice, obtained higher tiller number with 80 kg N $ha^{-1}$. The maximum tillers in upland rice was recorded with 90 kg N $ha^{-1}$ (Ranjini, 2002). Jahan *et al.* (2014) observed that the tiller number $m^{-2}$ was the highest with the treatment having 120 kg N $ha^{-1}$. Rao *et al.* (2014) recorded maximum tiller number $m^{-2}$ @ 120 kg N $ha^{-1}$. Kumar (2016) opined that application of 120 kg N $ha^{-1}$ (60 kg as CF and 60 kg as FYM) produced maximum tiller number in upland rice.

Kumar *et al.* (2014) found maximum LAI in rice @ 200 kg N $ha^{-1}$. The maximum LAI at 60 DAS (4.98) in upland rice was recorded @ 120 kg N $ha^{-1}$ with 60 kg as CF and 60 kg as FYM in upland rice (Kumar, 2016).

### 2.1.2 Phosphorus

Phosphorus is the second major element for plant growth. The ideal pH for maximum availability of P ranges from 6.5 to 7.5. P is essential for plants for their vigor and general health. It stimulates the development of roots, increases stalk and stem strength and improves the formation of flower and seed production. Fageria *et al.* (1982) reported higher tiller numbers per unit area and LAI with increase in the levels of P. Choudhary and Suri (2014) obtained higher plant height and LAI at 45 kg $P_2O_5$ $ha^{-1}$. Rice responded well to application of P upto 30 kg $P_2O_5$ $ha^{-1}$ (KAU, 2016).

### 2.1.3 FYM

Farmyard manure supplies all major nutrients (N, P, K, Ca, Mg, S) as well as micronutrients necessary for the pant growths. It improves the soil physical, chemical and biological properties. Application of FYM improved the soil structure and soil WHC which is good for root development.

Dass *et al.* (2009) opined that application of FYM @ 5 t $ha^{-1}$ along with farmers' practice (FYM @ 2 t $ha^{-1}$ + Urea @ 25 kg $ha^{-1}$ + DAP @ 25 kg $ha^{-1}$) produced the tallest plant and LAI. Shekara *et al.* (2010) obtained the tallest plant in rice with FYM applied @ 20 t $ha^{-1}$ . Panigrahi *et al.* (2014) recorded taller plant with more tillers and higher LAI with FYM applied @ 15 t $ha^{-1}$. FYM applied @ 5 t $ha^{-1}$ significantly resulted in higher plant height and tiller number (Choudhary and Suri, 2014). Application of FYM @ 5 t $ha^{-1}$ favourably influenced the growth characters of rice (KAU, 2016). Gangmei and George (2017) reported higher number of tillers per hill with FYM @ 10 t $ha^{-1}$ in black rice. Apon *et al.* (2018) registered the tallest plant due to application of 5 t $ha^{-1}$ of FYM gave.

**2.1.4 Vermicompost**

Composts work as a 'slow-release fertilizer' compared to CF. Application of VC release the organic N much faster and overall efficiency of N is considerably greater than that of chemical fertilizers.

Banik and Bejbaruah (2004) reported higher number of productive tillers with 15 kg N $ha^{-1}$ applied through VC. Mishra *et al.* (2005) observed significant increase in growth characters *viz.,* shoot length, number of leaf, leaf area, tiller number and dry weight of rice plants in VC treated soils. Guerrero *et al.* (2008) reported that VC applied @ 5 to 10 t $ha^{-1}$ profoundly influenced the growth characters of upland rice. Thirunavukkarasu and Vinoth (2013) revealed that growth and growth attributes of rice were higher with the application of vermicompost.

### 2.1.5 Green manuring

Green manures are one of the good organic sources of N for rice. Green manures crops during decomposition release nutrients and involve in recycling the N, P and K in integrated plant nutrients system (IPNS). Cowpea (*Vigna unguiculata* L.) can be grown in upland acid soil for seed, green manure and fodder production.

Hemalatha *et al.* (2000) opined that green manuring produced taller plants and higher numbers of tillers in rice. Srinivasan (2002) found taller plants of upland rice intercropped with cowpea (3:1) compared to sole crop. Kayeke *et al.* (2007) found that green manuring significantly taller plant and higher number of tillers in upland rice. Jat *et al.* (2011) opined that incorporation of cowpea resulted in taller plants with higher number of tiller $m^{-2}$ of rice compared to no residue incorporation. Aparna (2018) reported that live mulching with green manure cowpea and subsequent incorporation increased the plant height of upland rice at harvest.

### 2.1.6 Combined Effects of N and P

Anu (2001) reported higher values for growth characters of upland rice at NP applied @ 80:30 kg $ha^{-1}$. Mini (2005) found that upland rice fertilized with 100:30 kg NP $ha^{-1}$ favourably influenced the growth characters. Saito *et al.* (2006) obtained higher growth characters of upland rice with 90:50 kg NP $ha^{-1}$. Kumar (2016) reported that NP applied @ 120 kg N and 30 kg $P_2O_5$ $ha^{-1}$ favourably influenced the growth characters of upland rice.

### 2.1.7 Combined Effects of N, P and FYM

Imade *et al.* (2017) obtained the tallest plant in rice with application at 100 kg N and 30 kg $P_2O_5$ $ha^{-1}$ + 10 t $ha^{-1}$ of FYM. Apon *et al.* (2018) recorded the tallest plant at 60 DAS with 75 per cent of 60:30 kg NP $ha^{-1}$ + 5 t $ha^{-1}$ of FYM. The maximum tiller number was recorded with 50 % of recommended dose (RD) of N and P + 50 % N as FYM at all the growth stages of upland rice (Singh *et al.*, 2018).

### 2.1.8 Combined Effects of N, P and VC

Thirunavukkarasu and Vinoth (2013) obtained higher growth and growth characters in rice with application of VC @ 2.5 t $ha^{-1}$ along with addition of N based on leaf colour chart critical value less than four. Yadav and Meena (2014) observed taller plant with 90: 40 kg NP $ha^{-1}$ along with 75 % RD of N as CF + 25 % RD of N as VC + BGA as compared to other treatments in aromatic rice. Paramesh *et al.* (2014) observed significantly higher growth with combined application of 50 % RD of N through CF and 50 % RD of N through VC in aerobic rice. Imade *et al.* (2017) registered higher values of plant height and tiller number per hill when 100 kg N (75% N through CF and 25% through VC) and 30 kg $P_2O_5$ $ha^{-1}$ was applied in rice.

### 2.1.9 Combined Effects of N, P and green manuring

Srinivasan (2002) reported higher LAI when upland rice was intercropped with cowpea along with 60:30 kg NP $ha^{-1}$ in upland rice. Singh (2005) opined that line sowing of upland rice + green manure of cowpea in 2:1 ratio + 50 % of N and P resulted in significantly taller plant of 97.1 cm over other treatments at all growth stage. Aparna (2018) obtained higher growth characters in upland rice with the application 60:30 kg NP $ha^{-1}$ along with live mulching of green manure cowpea.

### 2.1.10 Combined Effects of N, P, FYM, VC and green manuring

Borah *et al.* (2016) revealed application of 75% RD of N through the application of FYM or VC and 25 % RD through CF improved the growth characters in upland rice. Yadav *et al.* (2017) observed higher values of plant height (122.1cm) and tillers per row (57.01) at maturity stage with the application of 70 % RD of nutrients as CF +15 % N as VC+ 15 % N as poultry manure in rice. Aparna (2018) obtained higher growth characters of upland rice at 60:30 kg NP $ha^{-1}$ along with 5 t $ha^{-1}$ of FYM and live mulching of green manure cowpea.

## 2.2 INFLUENCE OF N, P AND ORGANIC MANURES ON YIELD ATTRIBUTES AND YIELD

### 2.2.1 Nitrogen

Application of higher dose of N gave the highest grain yield of rice (Sudhakar *et al.*, 2003). Kumar and Shivay (2009) observed maximum grain yield of rice at N level of 100 kg $ha^{-1}$. Application of 120 kg N $ha^{-1}$ gave the highest grain yield in upland rice (Onaga *et al.*, 2012). Rao *et al.* (2014) obtained the highest grain yield in direct seeded upland rice with the application of 120 kg N $ha^{-1}$. Kumar (2016) obtained the highest grain yield of upland rice @ 120 kg N $ha^{-1}$.

Sharma *et al.* (2007) opined that application of 120 kg N $ha^{-1}$ recorded higher straw yield. Higher straw yield at 160 kg N $ha^{-1}$ in rice was reported by Sharma *et al.* (2014). Kumar (2016) reported the highest straw yield @ 120 kg N $ha^{-1}$ as compared to lower levels of N in upland rice.

Onaga *et al.* (2012) observed the highest number of spikelets $m^{-2}$ and test weight with 120 kg N $ha^{-1}$. Pramanik and Bera (2013) reported higher effective tillers per hill with 150 kg N $ha^{-1}$. Ali *et al.* (2014) opined progressive increase in number of productive tillers with the increase in N level upto 120 kg N $ha^{-1}$.

Ranjini (2002) obtained maximum harvest index (HI) in upland rice @ 90 kg N $ha^{-1}$. Kumar and Shivay (2009) observed higher HI with 100 kg N $ha^{-1}$ in rice. Pramanik and Bera (2013) registered higher HI at 150 kg N $ha^{-1}$ in scented rice. Kumar (2016) obtained maximum HI of 0.45 with higher levels of N in upland rice.

**2.2.2 Phosphorus**

Shen *et al.* (2004) revealed that long term application of P fertilizer increased the grain yield in rice. Gebrekidan and Seyoum (2006) observed increase in average grain yield and total biomass by 20 per cent and 27 per cent respectively with P applied @ 50 kg N $ha^{-1}$ in rice. Kishor *et al.* (2008) registered higher grain yield with the application of P @ 60 kg $ha^{-1}$ in upland rice. Hasanuzzaman *et al.* (2012) observed higher straw yield with the application of P @ 30 kg $ha^{-1}$ in rice.

Annadurai and Palaniappan (1994) recorded significant increase in yield attributes and the yield of IR-20 with application of graded level of P upto 38 kg $P_2O_5$ $ha^{-1}$. Higher tillers $m^{-2}$ was obtained with 45 kg N $ha^{-1}$ in direct seeded upland rice (Choudhary and Suri, 2014)

**2.2.3 FYM**

Shekara *et al.* (2010) obtained higher grain yield in rice with FYM applied @ 20 t $ha^{-1}$. Panigrahi *et al.* (2014) obtained the highest yields in rice with FYM applied @ 15 t $ha^{-1}$. Gangmei and George (2017) obtained maximum yield in black rice with application of 10 t $ha^{-1}$ FYM. Application of 5 t $ha^{-1}$ of FYM registered higher grain yield of rice (KAU, 2016).

Shekara *et al.* (2010) recorded higher productive tillers per hill, filled spikelets and 1000 grain weight in rice with FYM applied @ 20 t $ha^{-1}$ compared to no FYM application in rice. Gangmei and George (2017) reported higher yield attributes of black rice such as number of effective tillers per hill, number of spikelets, number of filled spikelets per panicle and test weight due to application of FYM @ 10 t $ha^{-1}$.

### 2.2.4 Vermicompost

Murali and Setty (2004) observed significantly higher grain and straw yields with VC applied @ 5 t ha$^{-1}$ in scented rice. Mishra *et al.* (2005) obtained higher yield attributes and yield with vermicomposted municipal solid waste in rice. Kumar *et al.* (2014) reported higher yield attributes with VC application of 5 t ha$^{-1}$. Mahmud *et al.* (2016) observed higher straw yield, biological yield and yield attributes like plant height, effective tillers per hill, panicle length, filled grains per panicle and 1000 grain weight with the application of VC @ 4 t ha$^{-1}$.

### 2.2.5 Green manuring

It is well recognized that legumes grown in multiple cropping systems, either in rotation or as intercrops, will increase growth and yields of main crops.

John (1987) reported increased yield of dry seeded upland rice with incorporated cowpea residue compared to fallowing. Paikaray *et al.* (2001) registered higher grain yields of rice with 120 kg N ha$^{-1}$ given as green manure cowpea. Srinivasan (2002) observed higher yield and yield attributes in upland rice with intercropping of rice with cowpea (3:1). Singh (2005) reported significantly higher grain number, filled grains, test weight and grain yield from line sowing of rice at 60 kg seed ha$^{-1}$ intercropped with green manure cowpea (2:1). Oroka and Omoregie (2007) reported higher yield from intercropping rice with cowpea. Growing cowpea as an intercrop in semi dry rice and its subsequent incorporation significantly improved the overall productivity (KAU, 2016).

### 2.2.6 Combined Effects of N and P

Application of 90: 50 kg NP ha$^{-1}$ recorded higher grain yield in upland rice (Saito *et al.,* 2006). Rajawat (2009) observed significantly higher grain and straw yields, number of grains per panicle, length of panicle and panicle weight with 40 kg

N and 40 kg $P_2O_5$ $ha^{-1}$. Aruna *et al.* (2015) reported the highest grain and straw yields of aerobic rice at 140 kg N and 40 kg $P_2O_5$ $ha^{-1}$. Application of 60 kg N and 30 kg $P_2O_5$ $ha^{-1}$ is recommended for upland rice cultivation in Kerala (KAU, 2016).

### 2.2.7 Combined Effects of N, P and FYM

Raikar *et al.* (2010) reported higher yield attributes and yield with the integration of FYM incorporation equivalent to 50 % RD of N + 50 kg N + 50 kg $P_2O_5$ $ha^{-1}$ in scented rice. Application of 5 t $ha^{-1}$ of FYM along with 60 kg N and 30 kg $P_2O_5$ $ha^{-1}$ is recommended for upland rice in Kerala (KAU, 2016). Higher number of productive tillers and grain yield was recorded with 60 kg N and 60 kg $P_2O_5$ $ha^{-1}$ along with FYM @ 10 t $ha^{-1}$ in upland rice (Rizongba *et al.*, 2016). Imade *et al.* (2017) recorded higher panicle $m^{-2}$, length of panicle, grain yield and straw yield in rice with application of 100 kg N and 30 kg $P_2O_5$ $ha^{-1}$ along with FYM @ 10 t $ha^{-1}$.

### 2.2.8 Combined Effects of N, P and VC

Banik and Bejbaruah (2004) reported higher grain yield in rice with the application of 15 kg N as VC in combination with 45: 13 kg NP $ha^{-1}$ as CF. Barik *et al.* (2008) observed the highest grain yield in rice with application of 60 % RD of N from urea and 40 % RD of N from VC. Kumar *et al.* (2014) recorded higher yield attributes and yield in rice with the application of 125 % RD (120:60:40 kg NPK $ha^{-1}$) + 5 t $ha^{-1}$ of VC. Paramesh *et al.* (2014) obtained higher yield with combined application of 50 % RD of N through CF + 50 % RD of N through VC in aerobic rice. Mahmud *et al.* (2016) recorded higher grain and straw yields of rice from the combined application of 4 t $ha^{-1}$ of VC along with 100:16 kg NP $ha^{-1}$ through fertilizers.

### 2.2.9 Combined Effects of N, P and green manuring

Srinivasan (2002) reported higher yield attributes and yield in upland rice intercropped with cowpea with 60 kg N and 30 kg $P_2O_5$ $ha^{-1}$. Yadav (2004) reported the highest grain yield of rice with application of 75 % NPK as CF + 25 % N through green manuring. Babar (2008) registered higher grain yield in rice with application of 150: 50 kg NP $ha^{-1}$ where 50 % dose of N was applied through CF and 50 % dose of N through green manuring. Kumar *et al.* (2014) obtained higher yield and yield attributes in upland rice when intercropped with cowpea along with application of 60:30 kg NP $ha^{-1}$. Aparna (2018) reported that application of 60:30 kg NP $ha^{-1}$ along with live mulching and its subsequent incorporation of cowpea in upland rice increased grain and straw yields and harvest index.

### 2.2.10 Combined Effects of N, P, FYM, VC and green manuring

Katyal and Gangwar (2000) reported higher yield and yield attributes in rice-rice cropping system with 50 % as CF and FYM or green manure (50 %) compared to 100 % of recommended inorganic N. Application of 5 t $ha^{-1}$ of FYM with live mulching of green manure cowpea (12.5 kg $ha^{-1}$) and 60 kg N, 30 kg $P_2O_5$ and 30 kg $K_2O$ $ha^{-1}$ is recommended for upland rice in Kerala (KAU, 2016). Tiwari *et al.* (2017) obtained higher yield attributes and yield in rice with application of 50 % RD (120:60:60 kg NPK $ha^{-1}$) and 50 % as FYM and was on par with 50 % RD as CF + 50 % through green manuring (sesbania). Yadav *et al.* (2017) registered the highest grain and straw yields with the application of 70% RD of N through CF + 15% N as VC+15% N as poultry manure in rice.

2.3 INFLUENCE OF N, P AND ORGANIC MANURES ON PHYSIOLOGICAL AND CHEMICAL ESTIMATION

**2.3.1 Nitrogen**

Thomas (2000) reported the highest relative leaf water content (RLWC) and protein content of grain in upland rice with 90 kg N $ha^{-1}$. Mini (2005) recorded higher RLWC and N uptake with application of 100 kg N $ha^{-1}$. Sharma *et al.* (2007) observed significant increase in NPK uptake by grain and straw in upland rice with increasing levels of N upto 120 kg $ha^{-1}$. Kumar (2016) obtained maximum dry matter production (DMP), RLWC, protein content of grain and nutrient uptake with 120 kg N $ha^{-1}$ in upland rice.

**2.3.2 Phosphorus**

George *et al.* (2001) recorded increase in grain P by 36 per cent and total P uptake by 53 per cent with increasing level of P application in upland rice. Gebrekidan and Seyoum (2006) observed increase in DMP and P uptake by 53 per cent in rice with application of 50 kg $P_2O_5$ $ha^{-1}$. Islam *et al.* (2008) reported that P content of rice increased progressively with increased P levels. Laxminarayana (2011) obtained higher P uptake in rice with application of 40 kg $P_2O_5$ $ha^{-1}$ compared to lower levels of P.

**2.3.3 FYM**

Higher protein content of rice with application of FYM @ 10 t $ha^{-1}$ was reported by Dixit and Gupta (2000). Dass *et al.* (2009) opined higher DMP and organic carbon content in upland rice with the application of 5 t $ha^{-1}$ of FYM. Shekara (2010) obtained maximum DMP and higher nutrient uptake in rice with FYM applied @ 20 t $ha^{-1}$. Gangmei and George (2017) observed maximum protein content in black rice with the application of FYM @ 10 t $ha^{-1}$. Krishnaprabu *et al.*

(2017) reported significantly higher-protein content in red rice with FYM @ 12.5 t $ha^{-1}$.

### 2.3.4 Vermicompost

Bejbaruah *et al.* (2013) obtained the highest N uptake with 69 kg N $ha^{-1}$ through VC. Thirunavukkarasu and Vinoth (2013) reported higher NPK uptake in rice with VC @ 2.5 t $ha^{-1}$. Kumar (2014) obtained higher nutrient uptake and protein content with application of 5 t $ha^{-1}$ VC. Taheri *et al.* (2018) registered increase in grain protein content in rice due to application vermicompost.

### 2.3.5 Green manuring

Srinivasan (2002) recorded higher N uptake in upland rice intercropped with cowpea in 3:1 ratio compared to 2:1 ratio. Aparna (2018) reported that live mulching with green manure cowpea and subsequent incorporation increased the DMP and NPK uptake of upland rice at harvest.

### 2.3.6 Combined Effects of N and P

Aruna *et al.* (2015) recorded the highest NPK uptake with 140 kg N and 40 kg $P_2O_5$ $ha^{-1}$ in aerobic rice. Tiwari *et al.* (2017) recorded significant increase in NPK uptake by rice with application of 120:60 kg NP $ha^{-1}$. Apon *et al.* (2018) observed significantly higher nutrient uptake with 60:30 kg NP $ha^{-1}$ in rainfed upland rice.

### 2.3.7 Combined Effects of N, P and FYM

Kumar *et al.* (2014) obtained maximum N, P and K content with the application of 75 % RD (150: 60: 60 kg NPK $ha^{-1}$) + 25 % FYM in hybrid rice. Gangmei and George (2017) obtained maximum protein content in grain due to application of 75 : 40 kg NP $ha^{-1}$ along with FYM @ 10 t $ha^{-1}$ in rice. Imade *et al.* (2017) registered higher protein content due to application of RD of nutrients as CF +

FYM @ 10 t $ha^{-1}$. Tiwari *et al.* (2017) recorded the highest NPK uptake by grain and straw due to 120:60 kg NP $ha^{-1}$ (50 % N as CF + 50 % as FYM) in aerobic rice.

**2.3.8 Combined Effects of N, P and VC**

Banik and Bejbaruah (2003) obtained significantly higher uptake of N, P and K with application of 15 kg N $ha^{-1}$ through VC along with NP at 45 kg N and 13 kg $P_2O_5$ $ha^{-1}$. Yadav and Meena (2014) observed higher DMP and increase in NPK uptake due to 90 kg N (75% through CF + 25% as VC) and 40 kg $P_2O_5$ $ha^{-1}$ in aromatic rice. Venkatesha *et al.* (2015) recorded higher DMP and NPK uptake with application of 50 % N through inorganic fertilizer + 50 % N through VC compared to other combinations in aerobic rice.

**2.3.9 Combined Effects of N, P and green manuring**

Yadav (2004) observed higher NPK uptake in rice with application of 50:50 kg NP $ha^{-1}$ along with green manuring. Babar (2008) recorded maximum DMP and total nutrient uptake with application of 150:50 kg NP $ha^{-1}$ along with green leaf manuring with glyricidia in rice. Kumar *et al.* (2017) reported the highest NPK uptake due to green manuring with dhaincha. Aparna (2018) recorded the highest NPK uptake in upland rice with live mulching with green manure cowpea + 60 : 30 kg NP $ha^{-1}$.

**2.3.10 Combined Effects of N, P, FYM, VC and green manuring**

Rekhi *et al.* (2000) registered maximum available P in rice-wheat cropping system due to the application of fertilizers and organic manure. The highest nutrient uptake was recorded due to soil test based application of 80:26 kg NP $ha^{-1}$ along with FYM @ 5 t $ha^{-1}$ and green manuring with green gram in rainfed upland rice compared to RD of nutrients as CF and farmers' practice (Singh *et al.*, 2006). Tiwari *et al.* (2017) observed significant increase in nutrient uptake with inorganic and organic sources *viz.*, FYM, VC and poultry manure applied as 30% N basis in rice.

## 2.4 INFLUENCE OF N, P AND ORGANIC MANURES ON SOIL PROPERTIES

Prasad and Misra (2001) obtained significantly higher soil organic carbon after the harvest of rice with green manure incorporation of cowpea or sesbania. Tripathy and Singh (2002) reported that 150 kg N ha$^{-1}$ with 50% N substituted as FYM in rice increased the porosity and WHC of soil and lowered bulk density. Yadav (2004) obtained higher available NPK and organic carbon content in soil with sesbania intercrop in upland rice. Bajpai *et al.* (2006) reported combined application of 50 % N through NPK fertilizer + 50% N through green manure in rice decreased the bulk density in soil. Application of 100:50 kg NP ha$^{-1}$ increased the soil organic carbon by 15.9 per cent while integrated fertilization or organics increased soil organic carbon by 27.6 per cent compared to control (Banger *et al.*, 2009). Alom *et al.* (2010) reported improvement in organic matter and the soil physical property with cereal-legume intercropping. Sepehya *et al.* (2012) recorded increased in porosity and WHC when 90 kg N ha$^{-1}$ was applied with 50 % substituted as FYM. Tadesse *et al.* (2013) recorded significant increase in available nutrients, soil organic matter and WHC with application FYM of 15 t ha$^{-1}$ while soil bulk density decreased.

## 2.5 INFLUENCE OF N, P AND ORGANIC MANURES ECONOMICS OF CULTIVATION

Borah *et al.* (2016) obtained the highest gross and net income with 75% RD of N through VC + 25 % as CF in upland rice. Kumar (2016) recorded maximum net income with the application of 120 kg N ha$^{-1}$ applied as 90 kg as CF, 30 kg through FYM along with 30 kg $P_2O_5$ ha$^{-1}$ while the highest BC ratio was recorded with the application of 120 kg N $ha^{-1}$ applied as 90 kg through CF, 30 kg through FYM along with 30 kg $P_2O_5$ $ha^{-1}$ in upland rice.

# Materials and Methods

# 3. MATERIALS AND METHODS

A field experiment on 'Phosphorus nutrition and partial N substitution of upland rice (*Oryza sativa* L.)' was conducted at the Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuram during *Kharif,* 2018. The objectives were to study the influence of different levels of P, to assess the feasibility of partial substitution of inorganic N with FYM, vermicompost and *in situ* green manure cowpea and to work out the economics of cultivation. The materials used and methods followed are briefly described here under.

## 3.1 MATERIALS

### 3.1.1 Experimental Site

The field experiment was laid out at the Instructional farm, College of Agriculture Vellayani, Thiruvananthapuram. The farm is located at 8.5° N latitude and 76.9° E longitude and at an altitude of 29 m above mean sea level.

### 3.1.2 Soil

The soil of the experimental field is red sandy clay loam and belongs to the order oxisols of Vellayani series. The composite soil samples were drawn from 0-15 cm depth before conducting the experiment. The physico-chemical properties of the soil are given in the Table 1. The soil was strongly acidic with medium organic carbon and available K, low available N and high available P status.

### 3.1.3 Climate

The weather parameters during the cropping period are given in Appendix 1 and Fig.1.

The weather parameters were recorded for the standard weeks pertaining to the cropping period. The maximum temperature and minimum temperature ranged

Table 1. Physico-chemical parameters of soil

| Particulars | Value | Method used |
|---|---|---|
| **A. Particle size composition** | | |
| Coarse sand (%) | 16.92 | International pipette method (Piper, 1967) |
| Fine sand (%) | 30.52 | |
| Silt (%) | 23.85 | |
| Clay (%) | 27.81 | |
| Texture | Sandy clay loam | |
| **B. Physical properties** | | |
| Bulk density (Mg $m^{-3}$) | 1.59 | Core method (Gupta and Dakshinamoorthy, 1980) |
| Porosity (%) | 41.05 | |
| Water holding capacity (%) | 19.03 | |
| **C. Chemical composition** | | |
| pH | 4.6 (strongly acidic) | pH meter with glass electrode (Jackson, 1973) |
| Organic carbon (%) | 0.64 (Medium) | Chromic acid wet digestion method (Walkley and Black, 1934) |
| Available N (kg $ha^{-1}$) | 188.16 (Low) | Alkaline permanganate method (Subbiah and Asija, 1956) |
| Available P (kg $ha^{-1}$) | 36.53 (High) | Bray extraction and photoelectric colorimetry (Jackson, 1973) |
| Available K (kg $ha^{-1}$) | 250.14 (Medium) | Neutral normal ammonium acetate extract using flame photometry (Jackson, 1973) |

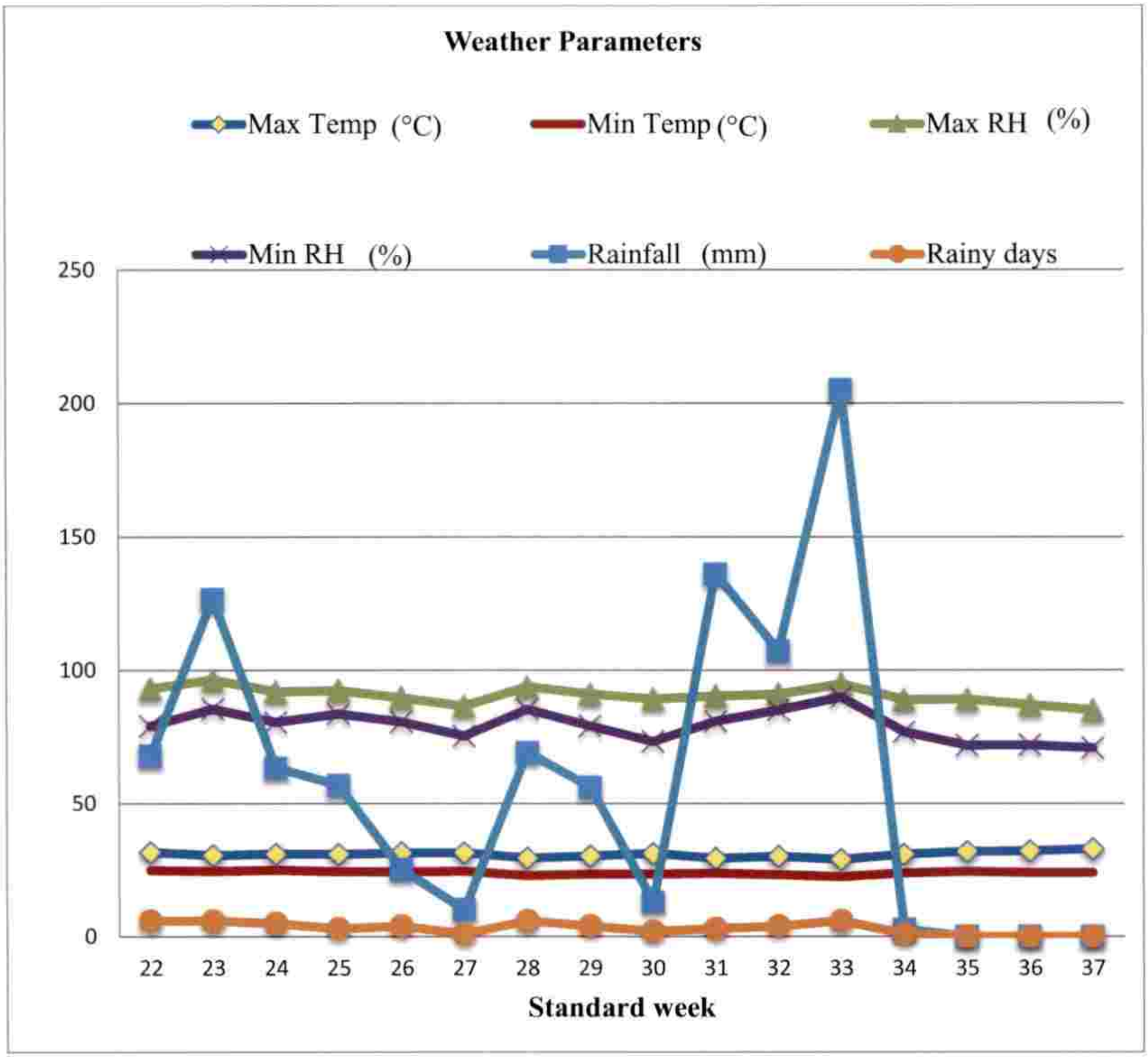


Fig.1. Weather data during the cropping period (May 29 to September 15, 2018)

from 29.1°C to 33°C and 23.3°C to 25.06°C respectively. A total rainfall of 940.7 mm was received in 51 rainy days. Relative humidity varied from 96.43 to 70.90 per cent.

### 3.1.4 Season

The experiment was conducted during the first crop season (*Kharif*), 2018. The crop was sown on 29th May, 2018 and harvested on 15th September, 2018.

### 3.1.5 Crop Variety

Aiswarya (PTB 52), released from Regional Agricultural Research Station, Pattambi was used for conducting the experiment. It is a medium duration variety (120-125 days). The grains are red in colour, bold and long. It is resistant to pest and disease such as brown plant hopper, blast and blight and suitable for upland cultivation and can be grown in first and second crop seasons.

### 3.1.6 Source of Seed Material

Seeds of Aiswarya variety were procured from Regional Agricultural Research Station, Pattambi and green manure cowpea variety Anaswara from Integrated Farming Systems Research Station, Karamana, Thiruvananthapuram.

### 3.1.7 Manures and Fertilizers

Well decomposed and dried FYM containing 0.5 per cent N, 0.3 per cent $P_2O_5$ and 0.4 per cent $K_2O$ and VC with 1.23 per cent N, 0.5 per cent $P_2O_5$ and 1.54 per cent $K_2O$ were used for the experiment. Green manure cowpea variety Anaswara was sown in between two rows of rice and incorporated after 45 days. The green manure cowpea contained 2.7 per cent N. The fertilizers used for the experiment were urea (46 % N), Rajphos (20 % $P_2O_5$) and muriate of potash (60 % $K_2O$).

3.2 DESIGN AND LAYOUT

| | |
|---|---|
| Design | : RBD |
| Season | : *Kharif*, 2018 |
| Treatments | : 11 |
| Number of replication | : 3 |
| Plot size | : 5 m x 4 m |
| Spacing | : 20cm x 10 cm |

Border rows were left to prevent border effect on all the sides in each plot and five plants were selected randomly from the net plot area for observations. The layout of the experiment is given in Fig.2.

### 3.2.1 Treatments

$T_1$ : 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (100 % N as CF)

$T_2$ : 45 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (100% N as CF)

$T_3$ : 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF + 50% N as FYM)

$T_4$ : 45 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF + 50% N as FYM)

$T_5$ : 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea)

$T_6$ : 45 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea)

$T_7$ : 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF + 50% N as VC)

$T_8$ : 45 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF + 50% N as VC )

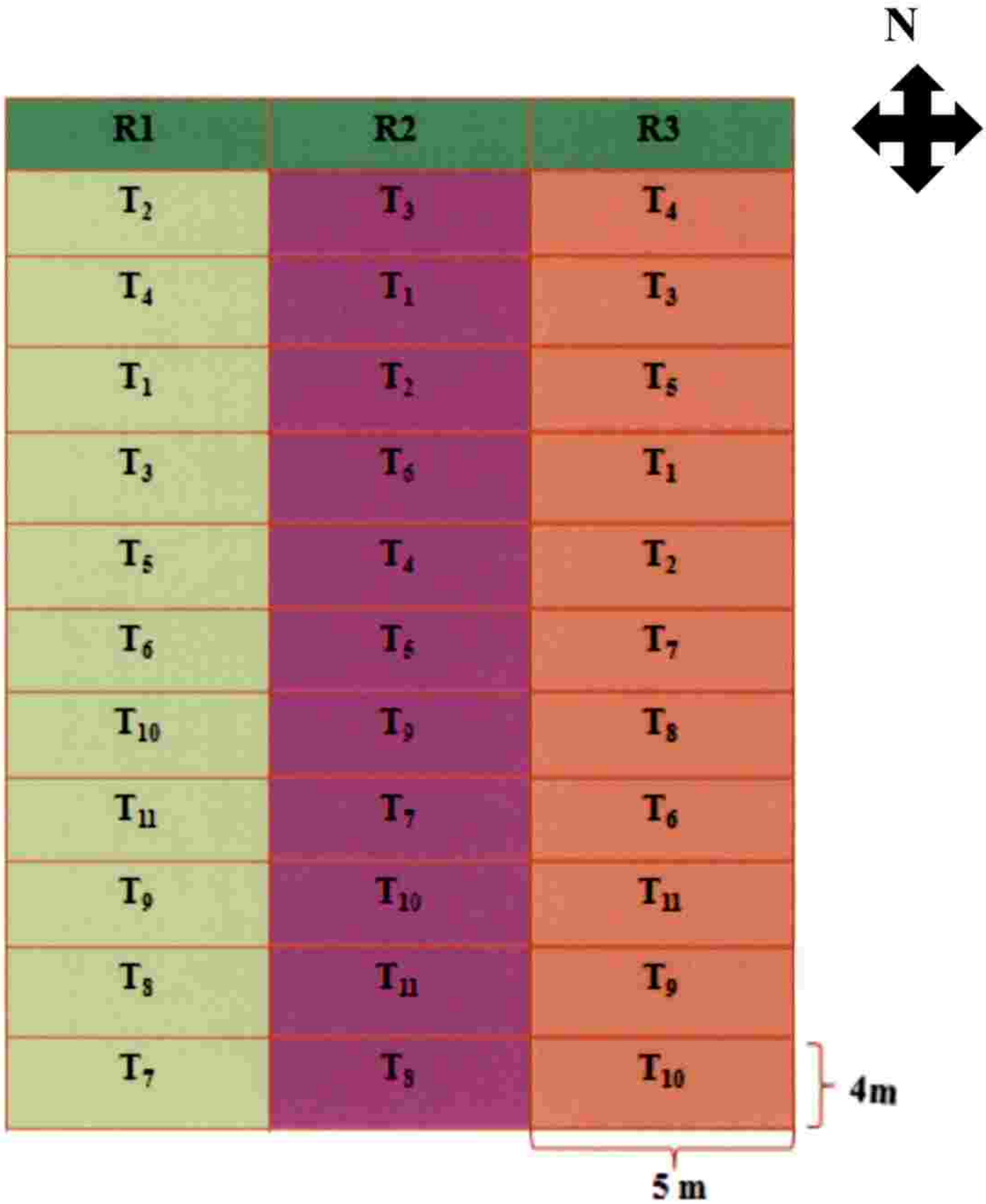


Fig. 2. Layout of the experimental field

Plate 1. General view of the experimental field

Plate 2.1. Seedling stage

Plate 2.2. Tillering stage

Plate 2.3. Maturity stage

Plate 2.4. Harvesting stage

Plate 2. Different growth stages of upland rice

$T_9$ : 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ ( 50% N as CF, 25% N as VC and *in situ* green manure cowpea)

$T_{10}$ : 45 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ ( 50% N as CF, 25% N as VC and *in situ* green manure cowpea)

$T_{11}$: 30 kg $P_2O_5$ $ha^{-1}$ and 60 kg N $ha^{-1}$ 100% N as CF (control)

Uniform dose of 60 kg $K_2O$ $ha^{-1}$ was applied to all treatments except control where it was 30 kg $K_2O$ $ha^{-1}$.

3.3 CULTIVATION PRACTICES

### 3.3.1 Land Preparation

The experimental area was uniformly ploughed, levelled and laid out as per the experimental design. Soil samples were collected from the field for analysis before starting the experiment. Individual plots were levelled uniformly before sowing.

### 3.3.2 Manures

Farmyard manure @ 5 t $ha^{-1}$ was added to all the plots uniformly and additionally calculated amount of FYM and VC as per the treatments were applied and mixed with the top soil. Green manure cowpea was sown along with rice and incorporated into the soil after 45 days as per the treatments. N was applied at three splits according to the treatments and full dose of P as basal at the time of levelling. K was applied in two splits.

### 3.3.3 Sowing

Aiswarya seeds @ 85 kg $ha^{-1}$ were dibbled at a spacing of 20 cm x 10 cm on May 29, 2018. One row of cowpea variety Anaswara was sown between two rows of rice in the respective treatments at a spacing of 20 cm within the row.

### 3.3.4 After Cultivation

Thinning and gap filling were done at 15 DAS for maintaining uniform plant population. Three hand weeding were carried out one at 15 DAS, 30 DAS and 45 DAS.

### 3.3.5 Irrigation

According to the requirement of crop during the cropping period, the irrigation was scheduled and seven irrigations were given.

### 3.3.6 Plant Protection

Insecticides Flubendiamide 39.35 % EC and Lambda cyhalothrin 5% EC were sprayed against stem borer and leaf roller @ 3g $L^{-1}$. Fungicides Trifloxystrobin 25% +Tebuconazole 50% @ 0.5g $L^{-1}$ were applied against rice blast.

### 3.3.7 Harvest

At full maturity the crop was harvested. The crops from the net plot area and border plants were harvested separately from each plot. The grain and straw yields were separately weighed and recorded the data.

## 3.4 OBSERVATIONS

Randomly five sample plants were selected from net plot area for recording observations.

### 3.4.1 Growth Characters

#### *3.4.1.1 Plant Height*

Height was taken from the base to the tip of the top most leaf of five observational plants at different growth stages and mean values were expressed in cm.

*3.4.1.2 Tiller Number $m^{-2}$*

The tiller number $m^{-2}$ at different growth stages were recorded from the observational plants and the mean values were noted.

*3.4.1.3 LAI at 60 DAS*

From the top of the third leaf of tagged plants, the measurements of maximum length and breadth were taken at 60 DAS. The average value was multiplied with total number of leaves as per the standard procedure (Yoshida *et al.,* 1976).

$$LAI = \frac{K\,(\text{Length} \times \text{Width}) \times \text{Number of leaves per hill}}{\text{Land area}}$$

Where, K - Constant factor (0.75)

**3.4.2 Yield Attributes and Yield**

*3.4.2.1 Productive Tiller $m^{-2}$*

The observation was recorded and average values were calculated.

*3.4.2.2 Length of Panicle*

Length of panicle was taken from the scar to the apex of the panicle. The mean was calculated and expressed in cm.

*3.4.2.3 Grain Weight per Panicle*

Separated grains from each panicle were weighed using an electronic balance. The mean value was calculated in g.

*3.4.2.4 Number of Spikelets per Panicle*

The spikelets from each panicle of the sample plants were separated, counted and the mean value was worked out.

*3.4.2.5 Number of Filled Grains per Panicle*

The observation was recorded from the sample plants and the mean value worked out.

*3.4.2.6 1000 Grain Weight*

From five sample plants, 1000 grains were separated and the mean weight expressed in g.

*3.4.2.7 Grain Yield*

The harvested grains from the net plot area was sun dried and mentioned in standard unit.

*3.4.2.8 Straw Yield*

The harvested crop residue from the net plot was sun dried and mentioned in standard unit.

*3.4.2.9 Harvest Index*

The data was worked out as per the standard procedure (Donald and Hamblin, 1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

**3.4.3 Physiological and Chemical Estimation**

*3.4.3.1 Proline Content at Panicle Initiation*

Proline content of leaves at panicle initiation stage was worked out and expressed as $\mu$ mol $g^{-1}$ of fresh weight (Bates *et al.*, 1973).

#### *3.4.3.2 Relative Leaf Water Content*

RLWC at panicle initiation and flowering stages was estimated using the formula as follows (Slatyer and Baars, 1965).

$$RLWC = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

#### *3.4.3.3 Protein Content of Grain*

The grain protein content was estimated by multiplying the N content of grain with 6.25 as per the procedure laid down by Simpson *et al.* (1965).

#### *3.4.3.4 Total Dry Matter Production at Harvest*

The tagged plants were uprooted, washed and then the grains and straw were separated. They were sun dried and subsequently oven dried at 70±5 °C. The value was calculated in standard units.

#### *3.4.3.5 NPK Uptake*

Uptake of N, P and K were estimated by the standard procedure as given below.

$$\text{N/P/K uptake} = \frac{\text{Percentage of N/P/K x dry matter production (kg ha}^{-1})}{100}$$

### 3.4.4 Soil Properties

Before sowing, composite samples of soil were drawn 20 cm deep. Similarly, soil samples after harvest were collected plot-wise from a depth of 20 cm. Physical properties such as bulk density, porosity and WHC were analysed before and after the experiment. (Gupta and Dakshinamoorthy, 1980)

$$\text{Bulk density } (Mg\ m^{-3}) = \frac{\text{Weight of soil solid (Mg)}}{\text{Total soil volume } (m^3)}$$

$$\text{WHC } (\%) = \frac{\text{Wet weight of soil}}{\text{Dry weight of soil}} \times D_b \times 100$$

$$\text{Porosity } (\%) = (1 - D_b / D_p) \text{ X } 100$$

Where, $D_b$ is soil bulk density and

$D_p$ is soil particle density

Available N, P and K and organic carbon content of soil were analyzed before and after the experiment and were expressed in standard units. Methods adopted for analysis of the soil samples are indicated in Table 1.

### 3.4.5 Major Weeds of Upland Rice

Weed composition and weed dry weight were recorded.

### 3.4.6 Pest and Disease Incidence

Observations on the incidence of major pest and disease were made.

### 3.4.7 Economic Analysis

Cost of cultivation was calculated and gross income was found out based on market price of grain and straw. From the data on gross income and cost of cultivation, net income was calculated and BC ratio was worked out as follows.

$$\text{BC ratio} = \frac{\text{Gross income } (₹\ ha^{-1})}{\text{Cost of cultivation } (₹\ ha^{-1})}$$

## 3.5 STATISTICAL ANALYSIS

The data recorded during the experiment were subjected to analysis of variance (F-test) as per the procedure laid down by Panse and Sukhatme (1985). Wherever statistical significance was observed, critical difference (CD) at 0.05 level of probability was worked out for comparison. The effects which were not significant were indicated as NS.

# Results

# 4. RESULTS

The observations on different parameters were tabulated, statistically analysed and the results presented here under.

## 4.1 GROWTH CHARACTERS

### 4.1.1 Plant Height

The mean data at 30 DAS, 60 DAS and at harvest are shown in Table 2.

At early stages, the treatments showed no pronouced difference. Though not significant, the treatment $T_1$ produced the tallest plants at 30 and 60 DAS respectively. The treatment $T_{11}$ produced the shortest plant at 30 and 60 DAS.

At harvest, the treatment $T_6$ produced the tallest plants of 110.74 cm and was on par with $T_5$, $T_4$, $T_9$ and $T_8$ and superior to rest of the treatments. The shortest plants of 92.72 cm were produced by $T_{11}$.

### 4.1.2 Tiller Number $m^{-2}$

The mean data on tiller number $m^{-2}$ at different growth stage *viz.*, 30 DAS, 60 DAS and at harvest are presented in Table 3.

At 30 DAS, the treatment did not significantly influence tiller number $m^{-2}$. However, the treatment $T_5$ recorded maximum tiller number $m^{-2}$ of 128 and $T_{11}$ recorded the lowest number of 122.67.

At 60 DAS, the treatments differed significantly and $T_5$ produced maximum tiller number $m^{-2}$ of 370.67 and was on par with $T_6$. The lowest tiller number $m^{-2}$ of 302.67 was produced by $T_{11}$.

Table 2. Effect of P levels and N sources on plant height at different growth stages, cm

| Treatments | 30 DAS | 60 DAS | Harvest |
|---|---|---|---|
| $T_1$ | 67.10 | 88.42 | 102.49 |
| $T_2$ | 66.10 | 88.22 | 101.51 |
| $T_3$ | 61.92 | 87.99 | 99.73 |
| $T_4$ | 64.09 | 93.73 | 105.30 |
| $T_5$ | 60.11 | 94.93 | 107.73 |
| $T_6$ | 64.13 | 96.02 | 110.74 |
| $T_7$ | 59.15 | 84.26 | 96.85 |
| $T_8$ | 62.93 | 88.34 | 102.90 |
| $T_9$ | 60.26 | 91.95 | 104.19 |
| $T_{10}$ | 58.34 | 85.93 | 97.18 |
| $T_{11}$ | 55.92 | 81.41 | 92.72 |
| SEm (±) | 3.65 | 4.37 | 3.32 |
| CD(0.05) | NS | NS | 9.642 |

At harvest, the treatments showed significant difference and $T_5$ produced maximum tiller number$^{-2}$ of 358.67 and was on par with $T_6$. The lowest tiller number$^{-2}$ of 276 was produced by $T_{11}$.

**4.1.3 LAI at 60 DAS**

The mean data on LAI at 60 DAS are presented in Table 3.

The treatment $T_5$ (30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ with 50 % N as CF, 25% N as FYM and *in situ* green manure cowpea) produced maximum LAI of 4.97 and was on par with $T_9$, $T_6$, $T_{10}$ and $T_4$ and superior to rest of the treatments. The lowest LAI of 4.16 was produced by $T_{11}$.

4.2 YIELD ATTRIBUTES AND YIELD

**4.2.1 Productive Tiller m$^{-2}$**

The data on productive tiller m$^{-2}$ are presented in Table 4.

The treatments differed significantly and $T_5$ produced the highest productive tiller m$^{-2}$ (334.67) and was on par with $T_6$. The lowest productive tiller m$^{-2}$ (252.00) was produced by $T_{11}$.

**4.2.2 Length of Panicle**

The mean data on length of panicle at harvest as influenced by the treatments are presented in Table 4.

There was no significant difference between the treatments. Though not significant, the treatment $T_5$ produced maximum length of panicle 25.23 cm and the lowest length of panicle (22.45 cm) was recorded by $T_{11}$.

Table 3 . Effect of P levels and N sources on tiller number $m^{-2}$ and leaf area index at 60 DAS

| Treatments | Tiller number $m^{-2}$ | | | Leaf area index at 60 DAS |
|---|---|---|---|---|
| | 30 DAS | 60 DAS | Harvest | |
| $T_1$ | 124.00 | 337.33 | 309.33 | 4.27 |
| $T_2$ | 125.33 | 340.00 | 326.67 | 4.38 |
| $T_3$ | 125.33 | 340.67 | 329.33 | 4.39 |
| $T_4$ | 125.33 | 348.00 | 332.67 | 4.66 |
| $T_5$ | 128.00 | 370.67 | 358.67 | 4.97 |
| $T_6$ | 124.00 | 365.33 | 345.33 | 4.84 |
| $T_7$ | 124.00 | 331.33 | 315.33 | 4.32 |
| $T_8$ | 126.67 | 340.67 | 321.33 | 4.23 |
| $T_9$ | 124.00 | 348.00 | 333.33 | 4.85 |
| $T_{10}$ | 124.00 | 346.67 | 330.00 | 4.72 |
| $T_{11}$ | 122.67 | 302.67 | 276.00 | 4.16 |
| SEm (±) | 3.00 | 3.28 | 4.96 | 0.11 |
| CD(0.05) | NS | 9.736 | 14.740 | 0.312 |

Table 4. Effect of P levels and N sources on productive tillers $m^{-2}$, length of panicle and grain weight per panicle

| Treatments | Productive tillers $m^{-2}$ | Length of panicle (cm) | Grain weight per panicle (g) |
|---|---|---|---|
| $T_1$ | 297.33 | 22.62 | 3.22 |
| $T_2$ | 302.67 | 23.50 | 3.23 |
| $T_3$ | 308.00 | 23.73 | 3.25 |
| $T_4$ | 312.00 | 24.92 | 3.35 |
| $T_5$ | 334.67 | 25.23 | 3.47 |
| $T_6$ | 318.67 | 24.74 | 3.32 |
| $T_7$ | 295.33 | 23.09 | 3.08 |
| $T_8$ | 296.67 | 23.20 | 3.27 |
| $T_9$ | 310.00 | 23.71 | 3.28 |
| $T_{10}$ | 306.00 | 23.92 | 3.25 |
| $T_{11}$ | 252.00 | 22.45 | 2.95 |
| SEm (±) | 5.22 | 0.07 | 0.06 |
| CD(0.05) | 15.520 | NS | 0.184 |

### 4.2.3 Grain Weight per Panicle

The mean data on grain weight per panicle as influenced by the treatments are presented in Table 4.

The treatment showed significant difference and the treatment $T_5$ recorded maximum grain weight per panicle of 3.47 g and was on par with $T_4$, $T_6$ and $T_2$. The lowest grain weight per panicle of 2.95 g was produced by $T_{11}$.

### 4.2.4 Number of Spikelets per Panicle

The mean data on number of spikelets per panicle as influenced by treatments are presented in Table 5.

The treatments showed a significant difference and $T_6$ produced the highest number of spikelets per panicle (134.87). The treatment $T_6$ was on par with all treatments excluding $T_1$, $T_7$ and $T_{11}$. The lowest number of spikelets per panicle (117.50) was produced by $T_7$.

### 4.2.5 Number of Filled Grains per Panicle

The mean data on number of filled grains per panicle as influenced by the treatments are presented in Table 5.

There was significant difference between the treatments and $T_5$ recorded maximum number of filled grains per panicle (128.53). The treatment $T_5$ was on par with $T_6$, $T_9$ and $T_8$. The lowest number of filled grains per panicle (103.30) was produced by $T_{11}$.

### 4.2.6 1000 Grain Weight

The mean data on 1000 grain weight as influenced by the treatments are presented in Table 5.

Table 5. Effect of P levels and N sources on number of spikelets per panicle, number of filled grains per panicle and 1000 grain weight

| Treatments | Number of spikelets per panicle | Number of filled grains per panicle | 1000 grain weight (g) |
|---|---|---|---|
| $T_1$ | 127.07 | 111.63 | 26.40 |
| $T_2$ | 131.63 | 113.30 | 26.17 |
| $T_3$ | 129.53 | 115.97 | 26.80 |
| $T_4$ | 132.63 | 114.63 | 26.17 |
| $T_5$ | 134.20 | 128.53 | 26.83 |
| $T_6$ | 134.87 | 125.73 | 26.50 |
| $T_7$ | 122.63 | 113.87 | 26.63 |
| $T_8$ | 129.87 | 120.57 | 25.93 |
| $T_9$ | 131.07 | 122.97 | 26.30 |
| $T_{10}$ | 128.83 | 116.73 | 25.67 |
| $T_{11}$ | 117.50 | 103.30 | 25.43 |
| SEm (±) | 2.50 | 4.10 | 0.88 |
| CD(0.05) | 7.421 | 12.168 | NS |

There was no significant difference between the treatments. Though not significant, the treatment $T_5$ produced the highest 1000 grain weight (26.83 g). The lowest 1000 grain weight (25.43g) was recorded by $T_{11}$.

### 4.2.7 Grain Yield ha$^{-1}$

The mean data on grain yield as influenced by the treatments are presented in Table 6.

The grain yield was profoundly influenced by the treatments. The treatment $T_5$ registered the highest grain yield of 3357 kg ha$^{-1}$ and was on par with $T_6$ and superior to rest of the treatments. The lowest grain yield of 1745 kg ha$^{-1}$ was produced by $T_{11}$.

### 4.2.8 Straw Yield ha$^{-1}$

The mean data on straw yield as influenced by the treatments are presented in Table 6.

The treatments differed significantly and $T_5$ produced the highest straw yield of 4133 kg ha$^{-1}$ and was on par with $T_6$. The lowest grain yield of 2477 kg ha$^{-1}$ was produced by $T_{11}$.

### 4.2.9 Harvest Index

The mean data on HI as influenced by the treatments are presented in Table 6.

The treatments differed significantly and $T_5$ and $T_6$ recorded the highest HI of 0.45. The lowest HI of 0.41 was produced by $T_{11}$.

Table 6. Effect of P levels and N sources grain yield, straw yield and harvest index

| Treatments | Grain yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Harvest index |
|---|---|---|---|
| $T_1$ | 2577 | 3615 | 0.42 |
| $T_2$ | 2677 | 3700 | 0.42 |
| $T_3$ | 2951 | 3980 | 0.43 |
| $T_4$ | 3057 | 4002 | 0.43 |
| $T_5$ | 3357 | 4133 | 0.45 |
| $T_6$ | 3240 | 4033 | 0.45 |
| $T_7$ | 2965 | 3974 | 0.43 |
| $T_8$ | 3064 | 3984 | 0.43 |
| $T_9$ | 3106 | 4000 | 0.44 |
| $T_{10}$ | 3057 | 3996 | 0.43 |
| $T_{11}$ | 1745 | 2477 | 0.41 |
| SEm (±) | 38 | 42 | 0.002 |
| CD(0.05) | 111.5 | 125.0 | 0.007 |

4.3 PHYSIOLOGICAL AND CHEMICAL ESTIMATIONS

### 4.3.1 Proline Content at Panicle Initiation

The mean data on proline content at panicle initiation as influenced by the treatments are presented in Table 7.

The treatments showed no pronouced difference. Though not significant, $T_{11}$ recorded the highest proline content of 0.80 μ mol $g^{-1}$ FW. The lowest proline content of 0.52μ mol $g^{-1}$ FW was produced by $T_5$.

### 4.3.2 Relative Leaf Water Content

The mean data on RLWC as influenced by the treatments are presented in Table 7.

There was no significant difference between the treatments at panicle initiation. Though not significant, $T_6$ recorded maximum RLWC of 75.69 per cent and the lowest 63.57 per cent was produced by $T_3$.

The treatments showed no pronouced difference at flowering stage and $T_6$ produced maximum RLWC of 76.10 per cent and was on par with $T_5$, $T_4$, $T_9$ and $T_8$. The lowest RLWC of 70.08 per cent was produced by $T_{11}$.

### 4.3.3 Protein Content of Grain

The mean data on protein content of grain as influenced by the treatments are presented in Table 7.

The treatments differed significantly and $T_4$ produced the highest protein content of 4.92 per cent and was on par with the rest except $T_1$, $T_2$, $T_3$, $T_9$ and $T_{11}$. The lowest protein content of 3.87 per cent was produced by.

Table 7. Effect of P levels and N sources on physiological parameters

| Treatments | Proline content at panicle initiation (μ mol $g^{-1}$ FW) | Relative leaf water content (%) | | Protein content of grain (%) |
|---|---|---|---|---|
| | | Panicle initiation | Flowering | |
| $T_1$ | 0.70 | 70.32 | 71.85 | 4.35 |
| $T_2$ | 0.68 | 67.93 | 71.62 | 4.35 |
| $T_3$ | 0.67 | 63.57 | 72.30 | 4.25 |
| $T_4$ | 0.68 | 66.88 | 73.67 | 4.92 |
| $T_5$ | 0.52 | 66.02 | 75.52 | 4.77 |
| $T_6$ | 0.56 | 75.69 | 76.10 | 4.80 |
| $T_7$ | 0.71 | 67.22 | 70.95 | 4.55 |
| $T_8$ | 0.67 | 73.32 | 73.37 | 4.65 |
| $T_9$ | 0.63 | 70.50 | 73.54 | 4.32 |
| $T_{10}$ | 0.61 | 67.13 | 72.37 | 4.78 |
| $T_{11}$ | 0.80 | 70.98 | 70.08 | 3.87 |
| SEm (±) | 0.05 | 3.37 | 1.14 | 0.16 |
| CD(0.05) | NS | NS | 3.383 | 0.469 |

#### 4.3.4 Total Dry Matter Production

The mean data on total DMP as influenced by the treatments are presented in Table 8.

The treatments differed significantly and $T_5$ produced the highest total DMP of 7490 kg $ha^{-1}$ and was on par with $T_6$. The lowest total DMP of 4222 kg $ha^{-1}$ was produced by $T_{11}$.

#### 4.3.5 Nitrogen Uptake

The mean data on N uptake as influenced by the treatments are presented in Table 8.

The treatments differed significantly and $T_5$ produced the highest N uptake of 92.15 kg $ha^{-1}$ and was on par with $T_4$ and $T_6$. The lowest N uptake of 41.12 kg $ha^{-1}$ was produced by $T_{11}$.

#### 4.3.6 Phosphorus Uptake

The mean data on P uptake as influenced by the treatments are presented in Table 8.

The treatments differed significantly and $T_5$ registered the highest P uptake of 16.75 kg $ha^{-1}$ and was on par with $T_4$, $T_6$ and $T_9$. The lowest P uptake (7.60 kg $ha^{-1}$) was produced by $T_{11}$.

#### 4.3.7 Potassium Uptake

The mean data on K uptake as influenced by the treatments are presented in Table 8.

Table 8. Effect of P levels and N sources on total dry matter production and uptake of N, P and K at harvest (kg ha$^{-1}$)

| Treatments | Total dry matter production | N Uptake | P Uptake | K Uptake |
|---|---|---|---|---|
| $T_1$ | 6192 | 66.23 | 10.94 | 36.54 |
| $T_2$ | 6344 | 67.86 | 11.61 | 37.82 |
| $T_3$ | 6931 | 75.89 | 13.00 | 40.43 |
| $T_4$ | 7059 | 89.93 | 15.10 | 41.00 |
| $T_5$ | 7490 | 92.15 | 16.75 | 45.98 |
| $T_6$ | 7286 | 85.89 | 14.88 | 45.19 |
| $T_7$ | 6939 | 80.28 | 12.47 | 39.76 |
| $T_8$ | 7048 | 82.71 | 13.67 | 40.68 |
| $T_9$ | 7113 | 78.36 | 14.95 | 43.65 |
| $T_{10}$ | 7062 | 80.25 | 13.92 | 40.96 |
| $T_{11}$ | 4222 | 41.12 | 7.60 | 20.13 |
| SEm (±) | 73 | 3.16 | 0.75 | 1.58 |
| CD(0.05) | 215.5 | 9.394 | 2.225 | 4.689 |

The treatments differed significantly and $T_5$ produced the highest K uptake of 45.98 kg $ha^{-1}$ and was on parvwith $T_6$ and $T_9$. The lowest K uptake of 20.13 kg $ha^{-1}$ was produced by $T_{11}$.

## 4.4. SOIL PROPERTIES

### 4.4.1 Bulk Density

The mean data on bulk density as influenced by the treatments are presented in Table 9.

The treatments showed no pronouced difference. Though not significant, the treatment $T_5$ produced the lowest bulk density of 1.42 Mg $m^{-3}$ and $T_{11}$ recorded the highest bulk density 1.53 Mg $m^{-3}$.

### 4.4.2 Porosity

The mean data on porosity as influenced by the treatments are presented in Table 9.

The treatments showed no pronouced difference. Though not significant, $T_5$ produced the highest porosity of 43.87 per cent and $T_{11}$ recorded the lowest porosity 41.60 per cent.

### 4.4.3 Water Holding Capacity

The mean data on WHC as influenced by the treatments are presented in Table 9.

The treatments showed no pronouced difference. Though not significant, $T_5$ recorded the highest WHC of 23.45 per cent and $T_{11}$ recorded the lowest WHC of 19.23 per cent.

Table 9. Effect of P levels and N sources on bulk density, porosity and water holding capacity

| Treatments | Bulk density ($Mg\ m^{-3}$) | Porosity (%) | Water holding capacity (%) |
|---|---|---|---|
| $T_1$ | 1.50 | 42.73 | 19.70 |
| $T_2$ | 1.52 | 42.80 | 19.94 |
| $T_3$ | 1.51 | 43.27 | 20.28 |
| $T_4$ | 1.51 | 43.53 | 20.46 |
| $T_5$ | 1.42 | 43.87 | 23.45 |
| $T_6$ | 1.44 | 43.57 | 22.64 |
| $T_7$ | 1.51 | 42.57 | 19.51 |
| $T_8$ | 1.49 | 43.00 | 20.64 |
| $T_9$ | 1.48 | 43.47 | 21.75 |
| $T_{10}$ | 1.49 | 42.90 | 21.34 |
| $T_{11}$ | 1.53 | 41.60 | 19.23 |
| SEm (±) | 0.03 | 0.51 | 1.03 |
| CD(0.05) | NS | NS | NS |

#### 4.4.4 Available Nitrogen

The mean data on available N as influenced by the treatments are presented in Table 10.

The treatments differed significantly and $T_5$ produced the highest 212.39 kg $ha^{-1}$ and was on par with $T_6$ and $T_9$. The lowest available N of 189.25 kg $ha^{-1}$ was produced by $T_{11}$.

#### 4.4.5 Available Phosphorus

The mean data on available P as influenced by the treatments are presented in Table 10.

The treatments differed significantly and $T_9$ produced the highest available P of 44.22 kg $ha^{-1}$ and was on par with $T_{10}$, $T_5$ and $T_6$. The lowest available P of 37.02 kg $ha^{-1}$ was produced by $T_{11}$.

#### 4.4.6 Available Potassium

The mean data on available K as influenced by the treatments are presented in Table 10.

The treatments differed significantly and $T_5$ produced the highest available K of 300.49 kg $ha^{-1}$ and was on par with $T_9$, $T_{10}$, $T_6$ and $T_4$. The lowest available K of 254.82 kg $ha^{-1}$ was produced by $T_{11}$.

#### 4.4.7 Soil Organic Carbon

The mean data on soil organic carbon as influenced by the treatments are presented in Table 10.

The treatments showed no pronouced difference. Though not significant, $T_5$ produced the highest organic carbon of 0.85 per cent. The lowest organic carbon of 0.63 per cent was produced by $T_{11}$.

Table 10. Effect of P levels and N sources on available N, P, K and organic carbon

| Treatments | Available N (kg ha$^{-1}$) | Available P (kg ha$^{-1}$) | Available K (kg ha$^{-1}$) | Organic carbon (%) |
|---|---|---|---|---|
| $T_1$ | 190.65 | 37.29 | 272.50 | 0.66 |
| $T_2$ | 192.16 | 38.79 | 271.50 | 0.69 |
| $T_3$ | 195.13 | 39.06 | 277.76 | 0.76 |
| $T_4$ | 199.89 | 40.17 | 292.98 | 0.81 |
| $T_5$ | 212.39 | 41.94 | 300.49 | 0.85 |
| $T_6$ | 204.10 | 41.40 | 293.06 | 0.82 |
| $T_7$ | 192.19 | 38.37 | 272.69 | 0.76 |
| $T_8$ | 194.80 | 39.53 | 284.14 | 0.78 |
| $T_9$ | 202.60 | 44.22 | 299.36 | 0.82 |
| $T_{10}$ | 200.19 | 42.09 | 296.70 | 0.84 |
| $T_{11}$ | 189.25 | 37.02 | 254.82 | 0.63 |
| SEm (±) | 3.76 | 1.18 | 5.18 | NS |
| CD(0.05) | 11.166 | 3.514 | 15.397 | 0.06 |



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4.5 OBSERVATIONS ON MAJOR WEEDS OF UPLAND RICE

**4.5.1 Weed Composition**

The important weeds observed were *Cynodon dactylon, Echinocloa colona* among grasses, *Cyperus rotundus* among sedges and *Phyllanthus niruri, Alternanthera sessilis* and *Mimosa pudica* among broad leaved weeds.

**4.5.2 Weed Dry Weight**

The mean data on weed dry weight as influenced by the treatments are presented in Table 11.

There was no significant difference between the treatments at 15 DAS and 30 DAS. Though not significant, $T_1$ produced maximum weed dry weight 10.47 g $m^{-2}$ and the lowest 4.27 g $m^{-2}$ by $T_5$ at 15 DAS. The treatment $T_3$ produced maximum weed dry weight of 28.29 g $m^{-2}$ and the lowest 25.29 g $m^{-2}$ by $T_9$ at 30 DAS.

At 45 DAS, the treatments differed significantly and $T_3$ produced maximum weed dry weight 29.29 g $m^{-2}$ and was on par with $T_1$ and $T_2$. The lowest weed dry weight of 21.67 g $m^{-2}$ was produced by $T_5$.

4.6. PEST AND DISEASE INCIDENCE

Pests observed in experimental field were leaf roller, gundhi bug and stem borer and the pest population did not exceed the economic threshold level. Blast incidence was noticed and control measures were taken.

4.7 ECONOMIC ANALYSIS

The mean data on economics of cultivation is given in Table 12.

Table 11. Effect of P levels and N sources on weed dry weight

| Treatments | Weed dry weight (g $m^{-2}$) | | |
|---|---|---|---|
| | 15 DAS | 30 DAS | 45 DAS |
| $T_1$ | 10.47 | 27.69 | 28.69 |
| $T_2$ | 8.53 | 27.11 | 28.09 |
| $T_3$ | 4.53 | 28.29 | 29.29 |
| $T_4$ | 8.03 | 26.61 | 26.05 |
| $T_5$ | 4.27 | 25.33 | 21.67 |
| $T_6$ | 6.79 | 25.85 | 22.13 |
| $T_7$ | 8.20 | 27.87 | 26.00 |
| $T_8$ | 5.33 | 26.33 | 25.33 |
| $T_9$ | 5.16 | 25.35 | 22.81 |
| $T_{10}$ | 8.47 | 25.29 | 23.29 |
| $T_{11}$ | 10.33 | 27.16 | 26.56 |
| SEm (±) | 2.94 | 3.20 | 0.89 |
| CD(0.05) | NS | NS | 2.642 |

Table 12. Effect of P levels and N sources on gross income, net income and benefit cost ratio

| Treatments | Gross income (₹ $ha^{-1}$) | Net income (₹ $ha^{-1}$) | BC ratio |
|---|---|---|---|
| $T_1$ | 95396 | 33480 | 1.55 |
| $T_2$ | 97816 | 34374 | 1.54 |
| $T_3$ | 108443 | 24820 | 1.30 |
| $T_4$ | 111720 | 26972 | 1.32 |
| $T_5$ | 121366 | 47068 | 1.63 |
| $T_6$ | 117367 | 42314 | 1.56 |
| $T_7$ | 108815 | 7347 | 1.07 |
| T8 | 111830 | 10897 | 1.11 |
| $T_9$ | 113220 | 27247 | 1.32 |
| $T_{10}$ | 111734 | 25572 | 1.30 |
| $T_{11}$ | 64743 | 4465 | 1.07 |
| SEm (±) | | 1275 | 0.02 |
| CD(0.05) | | 3787.9 | 0.046 |

The treatments differed significantly and $T_5$ produced the highest net income of ₹ 47068 $ha^{-1}$ and superior to rest of the treatments. The next best treatment was $T_6$. The lowest net income of ₹ 4465 $ha^{-1}$ was produced by $T_{11}$.

With regard to BC ratio, $T_5$ recorded the highest value of 1.63 and was superior to rest of the treatments. The treatment $T_6$ recorded the next highest value of 1.59. The lowest BC ratio 1.07 was recorded by $T_{11}$ and $T_7$.

# Discussion

# 5. DISCUSSION

The results of the experiment on 'Phosphorus nutrition and partial N substitution of upland rice (*Oryza sativa* L.)' as detailed in previous chapter are briefly discussed here under.

## 5.1 GROWTH CHARACTERS

Levels of P and partial substitution of N with FYM, VC and *in situ* green manure cowpea significantly influenced the growth characters of upland rice.

The results in Table 2 revealed the pronounced influence of treatments at harvest and there was no significant difference during early stages *viz.*, 30 and 60 DAS. At harvest, the treatment $T_6$ produced the tallest plants. There was progressive increase in plant height with advancement in growth phase. Application of adequate N in general increased the vegetative growth and photosynthetic activity. This is in conformity with the findings of Ranjini (2002), Mini (2005), Choudhary and Suri (2014) and Kumar (2016) in upland rice. Application of P @ 45 kg $P_2O_5$ $ha^{-1}$ greatly influenced plant height at harvest. P has prominent influence in metabolism, transfer and storage of energy from photosynthesis. This is in conformity with the reports of Fageria *et al.* (1982) and Choudhary and Suri (2014). Application of FYM and green manure favourably influenced plant height. FYM is an important organic manure supplying nutrients for plant growth in addition to its effect on soil properties. This corroborates with the findings of Dass *et al.* (2009), Shekara *et al.* (2010) and Choudhary and Suri (2014). Application of green manure (cowpea, dhaincha and black gram) with CF improved the soil health and rice growth. Combined use of organic manures like FYM and green manuring along with fertilizers improved the soil health by supplying all essential plant nutrients (Singh *et al.*, 2006). Green manure is one of the good organic nitrogen sources for rice. The positive influence of green manure on rice was reported by Kayeke *et al.* (2007), Jha *et al.* (2013) and

Aparna (2018). The beneficial effect of combined application of organic and inorganic nutrient sources might be due to comparatively low nutrient loss, its higher availability and high nutrient use efficiency (Bellakki *et al.,* 1998). Integrated application of N, P, FYM and incorporation of green manure cowpea favourably influenced plant height as reported by Borah *et al.* (2016), Kumar (2016) and Aparna (2018).

Tiller production was profoundly favoured by the0treatments at 60 DAS and at harvest as evident from Table 3. At 60 DAS and harvest, the treatment $T_5$ produced maximum tiller number$^{-2}$ and the lowest by $T_{11}$. Maximum tillering at $T_5$ could be attributed to more nutrient availability by INM practices through FYM and green manure cowpea. FYM improved tillering through its effect on improving soil properties, microbial activity, WHC and porosity. More availability of N and P due to treatment $T_5$ might have promoted tiller production. Lowering of tillers after 60 DAS was mainly attributed to ageing and death of subsequent tillers. Tillering is the expression of proper development of buds which is a function of proper nutrition of the mother culm (Tisdale *et al.*, 1975). Favourable effect of integrated nutrient management through CF, FYM and green manure cowpea on tillering in upland rice was reported by Ranjini (2002), Kumar (2016) and Aparna (2018).

The treatments had significant influence on Leaf area index at 60 DAS (Table 3). The treatment $T_5$ produced maximum LAI (4.97). The combined effect of inorganic and organic nutrient management through CF, FYM and green manure cowpea produced the highest LAI. Higher plant height and more tiller number resulted in more leaf production which might have contributed to higher LAI. Kumar (2016) obtained higher LAI of 4.98 due to combined application of CF and FYM. The favourable effect of FYM on LAI might be attributable to improvement of soil health besides supplying NPK and micronutrients (Motsara, 2000). Physico-chemical and microbiological properties enhancement of soil due to FYM and green manure cowpea application might have favoured growth and higher LAI of rice in INM treatment (Choudhary *et al.*, 2006).

5.2 YIELD ATTRIBUTES AND YIELD

The results of the study revealed that yield attributes (Tables 4, 5 and 6 and Fig. 3, 4 and 5) were favourably influenced by the treatments except length of panicle and 1000 grain weight.

All the yield attributes except number of spikelets per panicle were higher with the treatment $T_5$, while the treatment $T_6$ registered maximum number of spikelets per panicle. Combined use of FYM and inorganic fertilizers produced the highest value for the yield attributes and this might be due to adequate nutrients availability (Data, 1981; Nachimuthu *et al.*, 2007). The number of productive tillers depends on nutrient content during tiller bud initiation and subsequent developmental stages (Power and Alessi, 1978). Supplying adequate nutrients in readily available form through INM promoted productive tillers. Number of spikelets is an important yield contributing attribute of rice. Number of spikelets per panicle is correlated positively with grain yield. FYM in conjunction with green manure and CF supplied macro and micronutrients and its continued use could help in avoiding their deficiencies by improving soil health, physical properties, biological activities and increased availability of nutrient in soil. Effective translocation of photosynthates might have promoted grain filling and more filled grains per panicle. Increased availability of nutrients in treatment $T_5$ resulted in more productive tillers, spikelets and filled grains. This is in conformity with the findings of Ranjini (2002) and Kumar (2016) in upland rice.

The results revealed the significant influence of the treatments on yields (Table 6, Fig.5). The treatment $T_5$ produced maximum grain and straw yields of 3357 and 4133 kg $ha^{-1}$ respectively. Crop yield is the integrated result of events occurring throughout life cycle of the crop and is determined by various factors

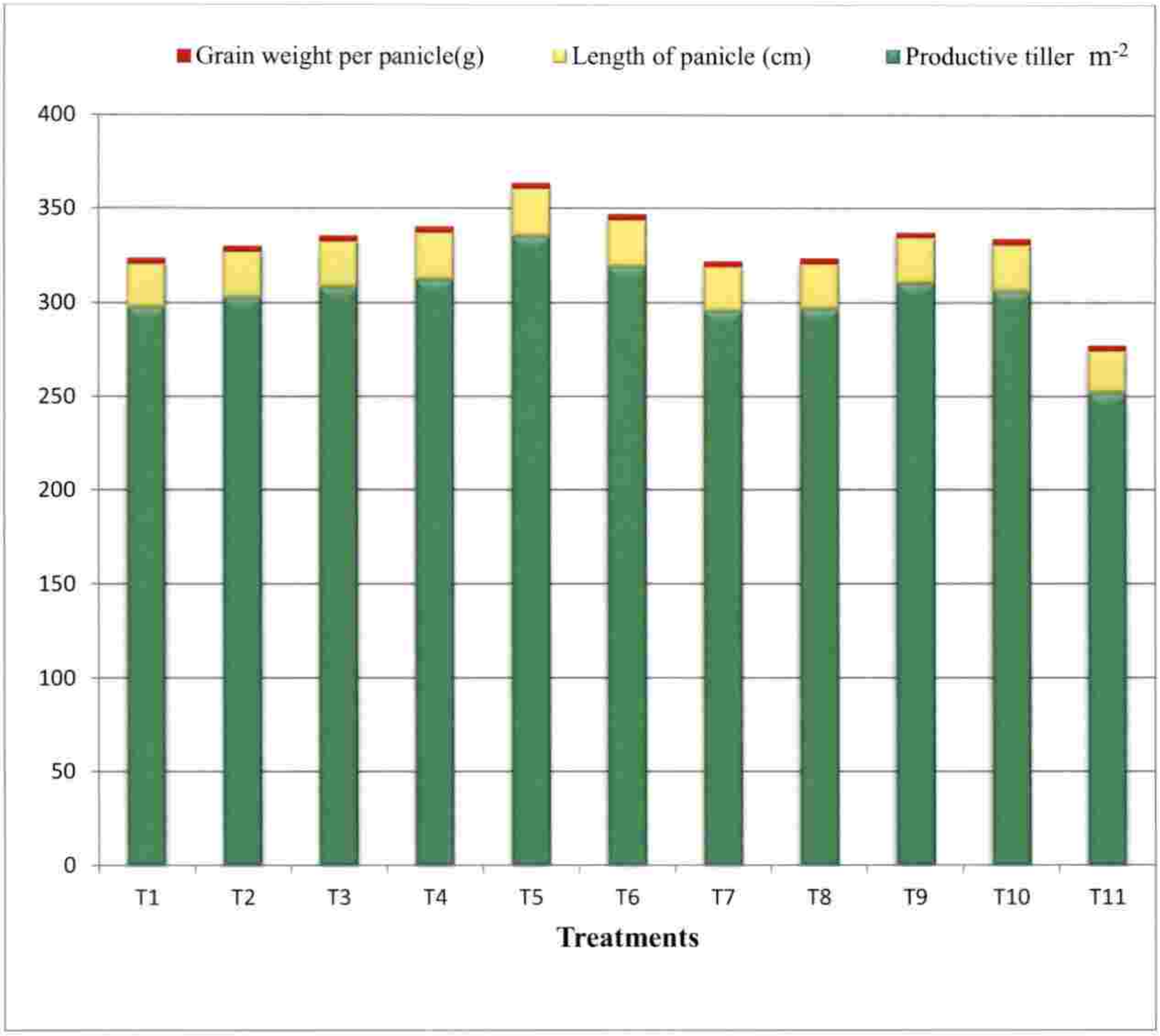


Fig.3. Effect of P levels and N sources on productive tiller $m^{-2}$, length of panicle and grain weight per panicle

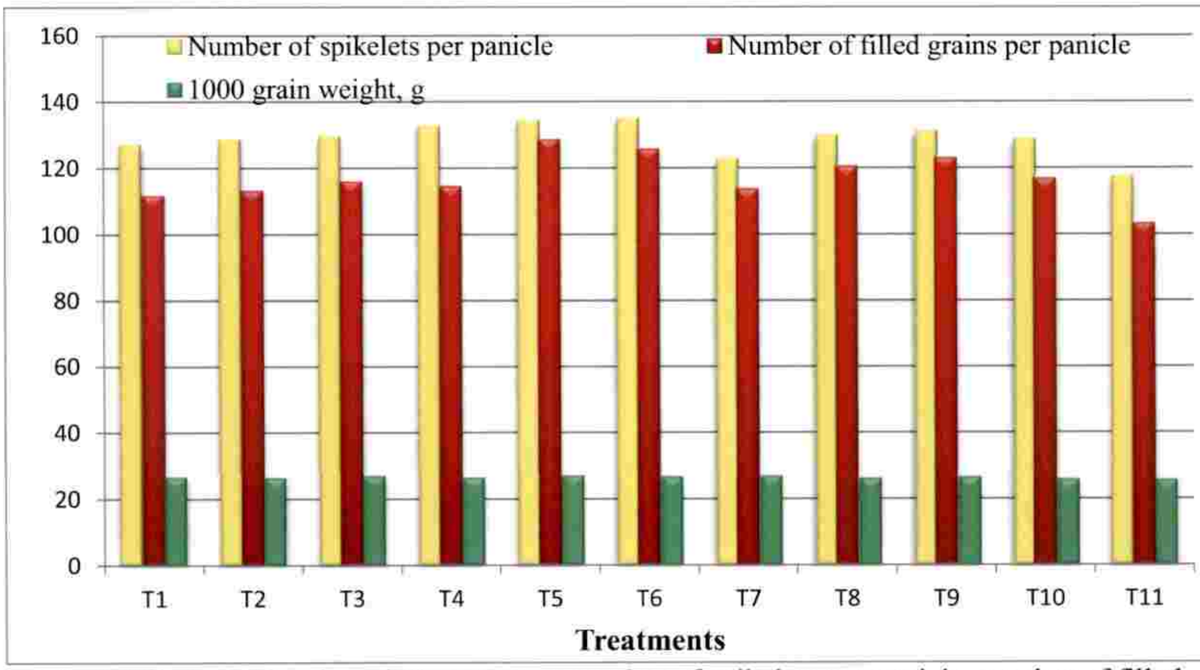


Fig.4. Effect of P levels and N sources on number of spikelets per panicle, number of filled grains per panicle and 1000 grain weight

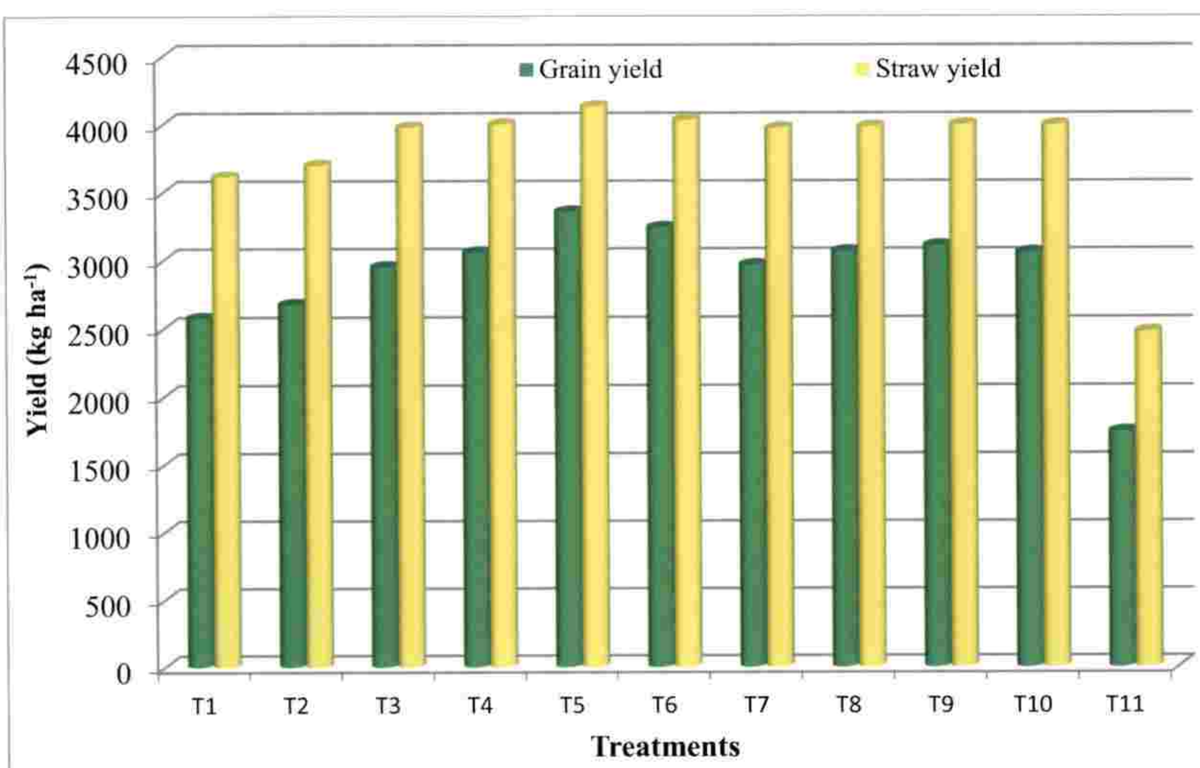


Fig.5. Effect of P levels and N sources on grain and straw yields



Plate 3.1. Plot without cowpea

Plate 3.2. Plot with cowpea

Plate 3.3. Cowpea nodules



Plate 3.4. Plot without cowpea

Plate 3.5. Plot after cowpea incorporation

Plate 3. Treatments at different stages

related to the plant and environment. Moreover, there are many relationships among these factors. Thus, in general, limits to crop yield cannot be attributed to just one factor. The favourable influence of INM on yield attributes might have reflected on higher yields. Pronounced increase in yields could be attributed to higher photosynthetic activities favouring better growth and yield attributes resulting in higher accumulation of dry matter. Efficient assimilation of photosynthates might have contributed to higher grain yield. Application of FYM and green manure cowpea in combination with CF significantly increased the grain and straw yields. Higher grain yield due to application of FYM, green manure cowpea and CF might be due to combined effect of nutrient supply, synergism and overall improvement in soil health. An additional rice grain yield of 1796 kg $ha^{-1}$ was obtained due to $T_5$ over $T_{11}$. The straw yield of rice followed the same trend as grain yield, an additional straw yield of 1709 kg $ha^{-1}$ was obtained with the treatment $T_5$ over $T_{11}$. It is clearly evident that combined application of CF and FYM and green manure cowpea produced higher grain and straw yields compared to sole application of N as CF. Application of FYM promoted the bacterial, actinomycetes and fungal population in soil and more biomass which served as a source of carbon and nutrients (Selvi *et al.*, 2004).The increased activity of micro organism in FYM might have attributed to faster decomposition of organic matter and succulent green manure cowpea, which favoured quick mineralization. The favourable effect of $T_5$ on plant height, tiller number, LAI, total DMP and yield attributes such as productive tillers, grain weight, number of spikelets and number of filled grains might have promoted higher grain and straw yields. Comparable results were presented by Ranjini (2002) and Kumar (2016) in upland rice.

The maximum HI of 0.45 was recorded by the treatments $T_5$ and $T_6$. Combined application of CF, FYM and green manure cowpea together with application of 30 or 45 kg $P_2O_5$ $ha^{-1}$ produced higher values of HI because of their favourable effects on yield and yield attributes as reported by Ranjini (2002) and Kumar (2016) in upland rice.

## 5.3 PHYSIOLOGICAL AND CHEMICAL ESTIMATIONS

The results of the study revealed favorable influence of treatments on physiological parameters *viz.*, RLWC, protein content of grain, total DMP and uptake of NPK at harvest.

The results in Table 7 revealed that RLWC at panicle initiation was not significant but significant at flowering stage. The treatment $T_6$ recorded the highest RLWC of 76.10 per cent and was on par with $T_5$, $T_9$ and $T_8$. Combined application of CF, FYM and green manure cowpea produced higher RLWC as FYM, VC and green manure cowpea application improved the soil physical, chemical and biological properties and helped in more moisture retention in the soil, more extraction of moisture from the soil and hence higher RLWC. Similar findings were reported by Ranjini (2002), Kumar (2016) and Aparna (2018).

The results in Table 7 revealed that protein content of grain was the highest for the treatment $T_4$ with 4.9 per cent and was on par with the rest except $T_2$, $T_3$, $T_9$ and $T_{11}$. Combined application of N through FYM and green manure cowpea improved the grain protein content as evident from the results of Ranjini (2002) and Kumar (2016) in upland rice.

The results in Table 8 (Fig. 6 and 7) revealed that total DMP and uptake of N, P and K were improved by the treatment $T_5$. Combined application of CF, FYM and green manure cowpea supplied nutrients continuously throughout the growth stage due to slow release of nutrients through decomposition of organic sources. The balanced nutrient supply enabled the plants to produce sufficient photosynthates and thus increased the total DMP. Superior growth characters, yield attributes and

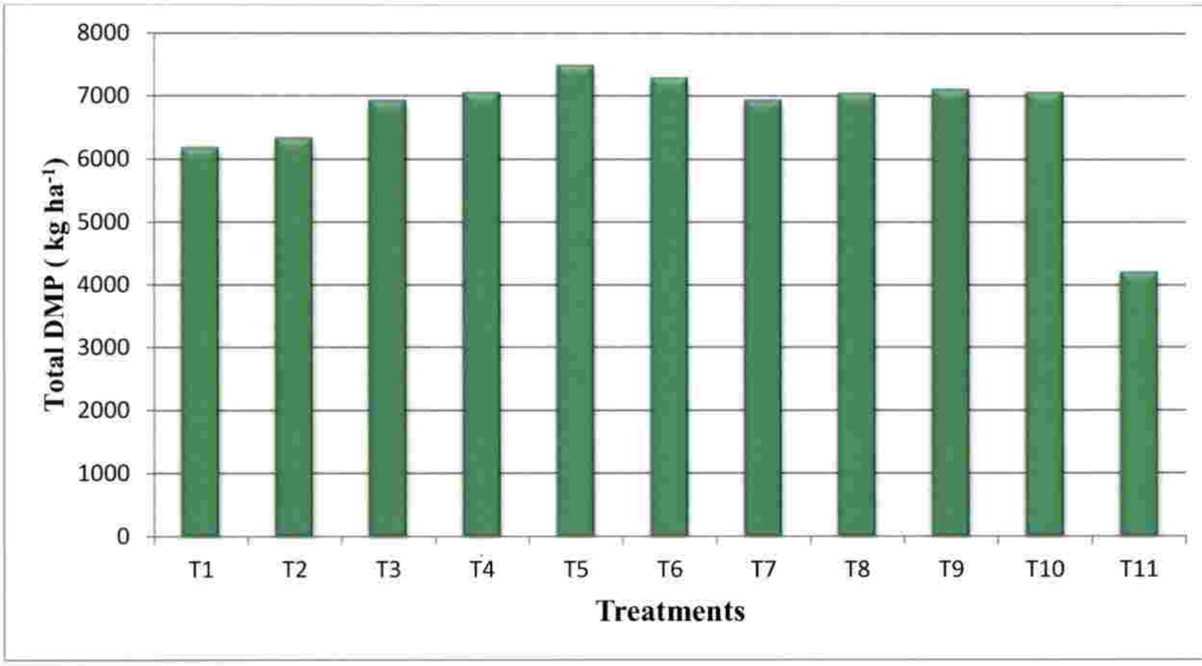


Fig.6. Effect of P levels and N sources on total dry matter production at harvest

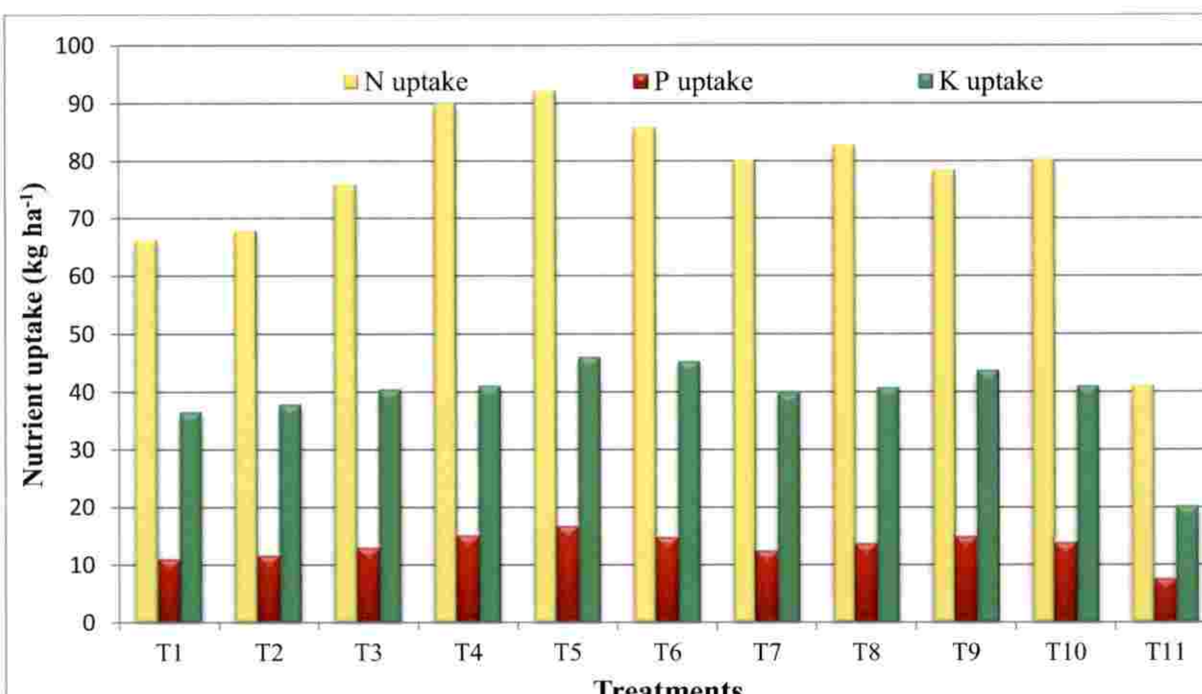


Fig.7. Effect of P levels and N sources on NPK uptake

yield might also lead to higher total DMP. The synergistic effect resulted in higher growth and total DMP which contributed to higher nutrient uptake as reported by Kumar (2016), Gangmei and George (2017), Yadav *et al.* (2017) and Aparna (2018). Increased uptake might be due to continuous supply of nutrients from the organic manures and improved soil environment for better root penetration and absorption of moisture and nutrients.

## 5.4 SOIL PROPERTIES

The results of the study revealed that the bulk density, porosity and WHC were not significantly influenced by the treatments. Available N, P and K status in the soil after the experiment were also significantly influenced by the treatments.

The results in Table 10 indicated that the treatment $T_5$ produced the highest available N and K while $T_9$ produced the highest available P. The combined application of CF and organics like FYM, VC and green manure cowpea increased the nutrient available pool of soil. Higher availability of N in soil might be due to conversion of organically bound N to inorganic form due to mineralization (Singh *et al.,* 2018). Application of low dose of P increased the mobilization and released the native P to the soil and this might have contributed to higher soil P due to application of 30 kg $P_2O_5$ $ha^{-1}$. Application of green manure along with VC increased the available P of soil. This might be due to greater mobilization of soil P, increased availability and release of organic acids by forming a protective cover over the sesquioxide and thus reduce the P fixation of soil. Combined application of CF and organic manures resulted in higher K availability in soils due to decrease in K fixation and release of more K that led to higher DMP and consequently higher uptake by rice. Similar findings were reported by Ranjini (2002), Yadav (2004), Banger *et al.* (2009), Kumar (2016) and Aparna (2018).

### 5.5 MAJOR WEEDS OF UPLAND RICE

The major weeds observed in the experimental plot were *Cynodon dactylon and Echinochloa colona* among grasses, *Cyperus rotundus* among sedges and *Phyllanthus niruri*, *Alternanthera sessilis* and *Mimosa pudica* among broad leaved weeds.

The results of the study revealed significant influence of the treatments on weed dry weight only at 45 DAS (Table 11). At 45 DAS, the treatment $T_5$ recorded the lowest weed dry weight. Combined application of CF, FYM and green manure cowpea decreased the weed population and weed dry weight due to the synergism and smothering effect of green manure cowpea. Comparable findings were recorded by Kayeke *et al*. (2007) and Aparna (2018).

### 5.6 ECONOMIC ANALYSIS

The results of the study presented in Table 12 and Fig. 8 revealed that net income and BC ratio were profoundly influenced by treatments. The treatment $T_5$ produced maximum net income of ₹ 47068 $ha^{-1}$ and BC ratio of 1.63. Combined application of CF, FYM and green manure cowpea improved the growth characters, yield attributes and yield and thereby recorded the highest net income. Application of CF and organic sources in integrated manner increased the cost of cultivation but compensated through the supplementary grain and straw yield. This is in conformity with the reports of Kumar (2016) and Aparna (2018) in upland rice.

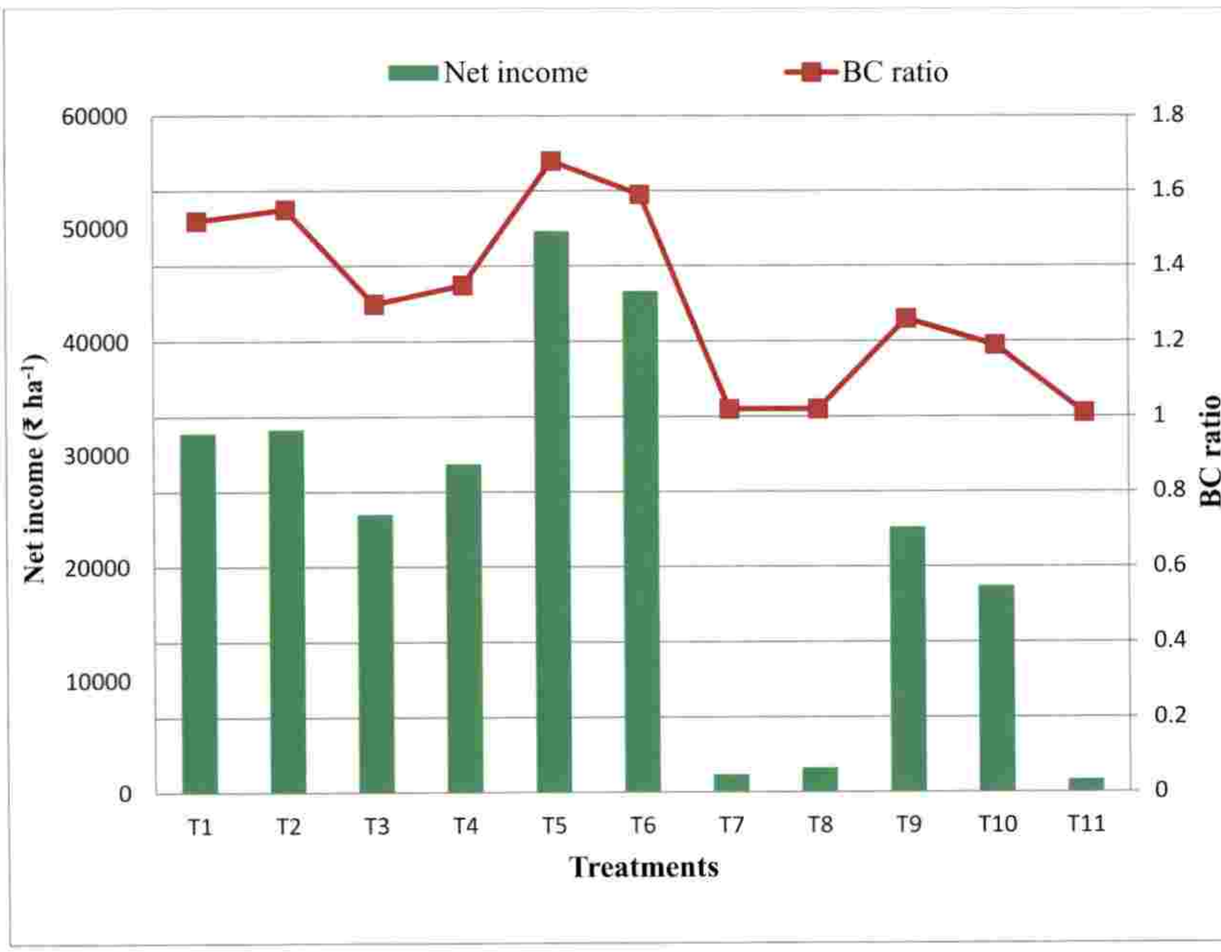


Fig.8. Effect of P levels and N sources on net income and benefit cost ratio

# Summary

# 6. SUMMARY

A field experiment on 'Phosphorus nutrition and partial N substitution of upland rice (*Oryza sativa* L.)' was conducted at the Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuram during *Kharif,* 2018 to study the influence of different levels of P, to assess the feasibility of partial substitution of inorganic N with FYM, VC and *in situ* green manure cowpea and to work out the economics of cultivation. The variety used was Aiswarya (PTB 52). The experiment was laid out in randomized block design with 11 treatments and three replications. The treatments were $T_1$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (100 % N as CF), $T_2$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (100% N as CF), $T_3$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as FYM), $T_4$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as FYM), $T_5$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea), $T_6$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea), $T_7$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as VC), $T_8$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as VC ), $T_9$ : 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF, 25% N as VC and *in situ* green manure cowpea), $T_{10}$ : 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF, 25% N as VC and *in situ* green manure cowpea) and $T_{11}$: 30 kg $P_2O_5$ ha$^{-1}$ and 60 kg N ha$^{-1}$ 100% N as CF (control). Uniform dose of 60 kg $K_2O$ ha$^{-1}$ was applied to all treatments except control where it was 30 kg $K_2O$ ha$^{-1}$.

Observations were recorded on growth characters, yield attributes and yield. Grain and straw yields were recorded at harvest and harvest index was worked out. The physiological and chemical estimations *viz.*, RLWC, proline content at panicle initiation stage, protein content of grain, total DMP and uptake of N, P and K were computed. Soil nutrient status before and after experiment was analysed. Economics was worked out based on the existing local market price of inputs and produce.

The data were statistically analysed, tabulated, and results of the study are briefly presented here under.

The plant height was significantly influenced by the levels of P and partial substitution of N with FYM and *in situ* green manure cowpea at harvest. Application of 45 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea) ($T_6$ ) recorded the tallest plant at harvest. The highest tiller number at 60 DAS and at harvest and LAI at 60 DAS were recorded by $T_5$: 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea).

The yield attributes and yield *viz.*, productive tillers $m^{-2}$, grain weight per panicle, number of spikelets per panicle, number of filled grains per panicle, grain and straw yields and HI were favourably influenced by the treatments. Maximum productive tillers, panicle weight, number of filled grains were recorded by the treatment $T_5$ and spikelets per panicle by $T_6$. The treatment $T_5$ recorded maximum grain and straw yields and harvest index.

The treatments showed favourable influence on physiological parameters *viz.*, RLWC at flowering, protein content of grain, total DMP and uptake of NPK at harvest. Application of 45 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea) ($T_6$) recorded the highest RLWC at flowering stage. Among the treatments, $T_4$ recorded the highest protein content. Application of 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ as 50% N as CF, 25% N as FYM and *in situ* green manure cowpea ($T_5$) recorded the highest total DMP and NPK uptake.

Available N, P and K status of soil after the experiment were significantly influenced by the treatments and the highest available N and K were recorded by the treatment $T_5$ and $T_9$ recorded the highest available phosphorus.

The important weeds observed were *Cynodon dactylon, Echinocloa colona* among grasses, *Cyperus rotundus* among sedges and *Phyllanthus niruri, Alternanthera sessilis* and *Mimosa pudica* among broad leaved weeds. The weed dry weight was significantly influenced by the treatments only at 45 DAS and the treatment $T_5$ recorded the lowest weed dry weight.

Pests observed in experimental field were leaf roller, gundhi bug and stem borer and the pest population did not exceed the economic threshold level. Blast incidence was noticed and control measures were taken.

The net income and BC ratio were significantly influenced by the treatments and application of 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea) ($T_5$) recorded the highest net income and BC ratio.

**Future line of work**

Integrated nutrient management in upland rice under different levels of shade has to be carried out as open upland area in Kerala is limited and the scope of intercropping upland rice in coconut gardens has to be explored.

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# Appendix

## APPENDIX 1

Weather parameters during the cropping period -29th May to 15th September, 2018

| Standard weeks | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Rainy days |
|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | | |
| 22 | 31.8 | 25 | 93.17 | 79.17 | 68 | 6 |
| 23 | 30.6 | 24.68 | 96.43 | 85.57 | 126.6 | 6 |
| 24 | 31.17 | 25.06 | 92 | 80.57 | 63.5 | 5 |
| 25 | 31 | 24.57 | 92.4 | 83.7 | 57 | 3 |
| 26 | 31.46 | 24.4 | 89.7 | 80.7 | 25.2 | 4 |
| 27 | 31.56 | 24.69 | 86.6 | 75.4 | 10.2 | 1 |
| 28 | 29.6 | 23 | 93.9 | 85.4 | 69.3 | 6 |
| 29 | 30.4 | 23.5 | 91.1 | 79.1 | 56.3 | 4 |
| 30 | 31.4 | 23.6 | 89.3 | 73.3 | 13.1 | 2 |
| 31 | 29.5 | 23.9 | 90.4 | 80.9 | 136.2 | 3 |
| 32 | 30.3 | 23.3 | 91 | 85.1 | 107.3 | 4 |
| 33 | 29.1 | 22.6 | 94.9 | 89.9 | 205.2 | 6 |
| 34 | 31 | 24 | 89 | 77 | 2.8 | 1 |
| 35 | 32 | 24.5 | 89.1 | 71.9 | 0 | 0 |
| 36 | 32.2 | 24.1 | 87.1 | 72 | 0 | 0 |
| 37 | 33 | 24.1 | 85.1 | 70.9 | 0 | 0 |

# PHOSPHORUS NUTRITION AND PARTIAL N SUBSTITUTION OF UPLAND RICE (*Oryza sativa* L.)

*by*

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## ABSTRACT

**Phosphorus nutrition and partial N substitution of upland rice (*Oryza sativa* L.)**

A field experiment on 'Phosphorus nutrition and partial N substitution of upland rice (*Oryza sativa* L.)' was conducted at the Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuram during *Kharif*, 2018 to study the influence of different levels of P, to assess the feasibility of partial substitution of inorganic N with FYM, VC and *in situ* green manure cowpea and to work out the economics of cultivation. The variety used was Aiswarya (PTB 52). The experiment was laid out in randomized block design with 11 treatments and three replications. The treatments were $T_1$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (100% N as CF), $T_2$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (100% N as CF), $T_3$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as FYM), $T_4$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as FYM), $T_5$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea), $T_6$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF, 25% N as FYM and *in situ* green manure cowpea), $T_7$: 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as VC), $T_8$: 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF + 50% N as VC ), $T_9$ : 30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ (50% N as CF, 25% N as VC and *in situ* green manure cowpea), $T_{10}$ : 45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ ( 50% N as CF, 25% N as VC and *in situ* green manure cowpea) and $T_{11}$: 30 kg $P_2O_5$ ha$^{-1}$ and 60 kg N ha$^{-1}$ 100% N as CF (control). Uniform dose of 60 kg $K_2O$ ha$^{-1}$ was applied to all treatments except control where it was 30 kg $K_2O$ ha$^{-1}$.

The results revealed that the treatment $T_6$ (45 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ with 50 % N as CF, 25 % N as FYM and *in situ* green manure cowpea) produced the tallest plants at harvest. The treatment $T_5$ (30 kg $P_2O_5$ ha$^{-1}$ and 120 kg N ha$^{-1}$ with 50 % N as CF, 25 % N as FYM and *in situ* green manure cowpea) recorded higher tiller number m$^{-2}$ at 60 DAS and harvest and the highest LAI at 60 DAS.

The yield attributes *viz.*, productive tillers $m^{-2}$, grain weight per panicle and number of filled grains per panicle was significantly higher with the treatment $T_5$ and $T_6$ registered higher number of spikelets per panicle. The treatment $T_5$ recorded maximum grain and straw yields of 3357 and 4133 kg $ha^{-1}$ respectively and was on par with $T_6$ and superior to other treatments. The maximum HI of 0.45 was recorded by the treatments $T_5$ and $T_6$.

The results showed favourable influence of treatments on physiological parameters *viz.*, RLWC at flowering, protein content of grain, total DMP and uptake of NPK at harvest. The treatment $T_6$ recorded the highest RLWC of 76.10 per cent and was on par with $T_5$, $T_3$, $T_9$ and $T_8$. The protein content of grain was the highest for treatment $T_4$ (4.9 per cent) and was on par with the rest except $T_2$, $T_9$ and $T_{11}$. The total DMP and uptake of N, P and K were improved by the treatment $T_5$.

The physical properties of soil *viz.,* bulk density, porosity and WHC were not significantly influenced by the treatments but available N, P and K status of the soil after the experiment were significantly influenced by the treatments. The treatment $T_5$ recorded the highest available N and K while $T_9$ produced the highest available P status in the soil.

The important weeds observed were *Cynodon dactylon, Echinocloa colona* among grasses, *Cyperus rotundus* among sedges and *Phyllanthus niruri*, *Alternanthera sessilis* and *Mimosa pudica* among broad leaved weeds. The weed dry weight was significantly influenced by the treatments only at 45 DAS and the treatment $T_5$ produced the lowest weed dry weight.

The pests observed in the experimental field were leaf roller, gundhi bug and stem borer and the pest population did not exceed the economic threshold level. Blast incidence was noticed and control measures were taken.

The net income and BC ratio were significantly influenced by treatments and $T_5$ produced maximum net income of ₹ 47068 $ha^{-1}$ and BC ratio of 1.63.

The result revealed higher growth characters, yield attributes and yield of upland rice due to $T_5$. The treatment $T_5$ recorded maximum net income and BC ratio and was followed by $T_6$. Therefore, the combined application of 30 kg $P_2O_5$ $ha^{-1}$ and 120 kg N $ha^{-1}$ applied as 50% N as CF, 25% N as FYM and *in situ* green manure cowpea along with 60 kg $K_2O$ $ha^{-1}$ could be recommended for upland rice.

## സംഗ്രഹം

കര നെൽ കൃഷിയിലെ ഫോസ്ഫറസ് പോഷണവും സംയോജിത വളപ്രയോഗവും എന്ന വിഷയത്തിൽ ഒരു പഠനം വെള്ളായണി കാർഷിക കോളേജ് ഫാമിൽ 2018 മെയ് 29 മുതൽ സെപ്റ്റംബർ 15 വരെ നടത്തുകയുണ്ടായി.കര നെൽ കൃഷിക്ക് അനുയോജ്യമായ ഫോസ്ഫറസിന്റെ അളവ് തിട്ടപ്പെടുത്തി സംയോജിത വള പ്രയോഗം എങ്ങനെ കാര്യക്ഷമമാക്കി നടപ്പാക്കാം എന്നതായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യം. ഐശ്വര്യ ഇനം നെൽ വിത്താണ് ഉപയോഗിച്ചത്.

പരീക്ഷണത്തിൽ ഉപയോഗിച്ച വിവിധ അളവുകൾ താഴെ കൊടുത്തിരിക്കുന്ന രീതിയിൽ ക്രമീകരിച്ചു.

$T_1$ : 30 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ രാസവളമായി മാത്രം

$T_2$ : 45 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ രാസവളമായി മാത്രം

$T_3$: 30 കിലോ.ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50% രാസവളമായും ബാക്കി കാലി വളമായും)

$T_4$: 45 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50 % രാസവളമായും ബാക്കി കാലി വളമായും)

$T_5$: 30 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50 % രാസവളമായും 25% കാലി വളമായും പയർ വിളയായും)

$T_6$: 45 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50 % രാസവളമായും 25 % കാലി വളമായും പയർ വിളയായും)

$T_7$: 30 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50 % രാസവളമായും 50 % മണ്ണിര കമ്പോസ്റ്റായും)

$T_8$: 45 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50 % രാസവളമായും 50 % മണ്ണിര കമ്പോസ്റ്റായും)

$T_9$: 30 കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50 % രാസവളമായും 25 % മണ്ണിര കമ്പോസ്റ്റായും പയർ വിളയായും)

$T_{10}$: 45കിലോ. ഫോസ്ഫറസ് + 120 കിലോ. നൈട്രജൻ ( 50 % രാസവളമായും 25 % മണ്ണിര കമ്പോസ്റ്റായും പയർ വിളയായും)

$T_{11}$: 30 കിലോ. ഫോസ്ഫറസ് + 60 കിലോ. നൈട്രജൻ രാസവളമായി മാത്രം

60 കിലോ പൊട്ടാഷ് $T_1$ മുതൽ $T_{10}$ വരെ എല്ലാ പ്ലോട്ടുകളിലും ഒരു പോലെ കൊടുത്തു. $T_{11}$ ൽ 30 കിലോ. പൊട്ടാഷ് കൊടുത്തു. റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പഠന രീതി ഉപയോഗിച്ചാണ് ഗവേഷണം നടത്തിയത്

പഠനത്തിന്റെ പ്രധാന നിഗമങ്ങൾ ഇവയാണ്

$T_5$, അതായത് 30 കിലോ. ഫോസ്ഫറസും 120 കിലോ. നൈട്രജൻ (50%രാസവളമായും 25% കാലി വളമായും പയർ വിളയായും) നൽകുന്നത് ചെടിയുടെ കൂടുതൽ ഉയരത്തിനും, കൂടുതൽ ചിനപ്പുകളുണ്ടാകുന്നതിനും, കൂടുതൽ നെല്മണികൾ ഉണ്ടാകുന്നതിനും നല്ലതാണെന്നു തെളിഞ്ഞു. നെല്ലിന്റെ വിളവിനും, കൂടുതൽ വൈക്കോൽ

ഉത്പാദനത്തിനും 30 കിലോ ഫോസ്സറസ്സും 120 കിലോ. നൈട്രജൻ (50% രാസവളമായും 25% കാലി വളമായും പയർ വിളയായും) കൊടുക്കുന്നത് ഉത്തമമാണെന്ന് കണ്ടു.

സംയോജിത വള പ്രയോഗം വഴി കളകളുടെ വളർച്ച കുറയുന്നതായും, മണ്ണിലെ മൂലകങ്ങളുടെ അളവ് കൂടുന്നതായും തെളിഞ്ഞു. കൂടാതെ 30 കിലോ ഫോസ്സറസും 120 കിലോ. നൈട്രജൻ (50% രാസവളമായും 25% കാലി വളമായും പയർ വിളയായും) നൽകുക വഴി കർഷകന്റെ ലാഭവും ഗണ്യമായി വർദ്ധിച്ചതായി കണ്ടു.

ഈ പരീക്ഷണത്തിൽ നിന്നും വ്യക്തമായത് 30 കിലോ ഫോസ്സറസും 120 കിലോ. നൈട്രജനും (50% രാസവളമായും 25% കാലി വളമായും പയർ വിളയായും) കൂടാതെ 60 കിലോ. പൊട്ടാഷും നൽകുന്നത് വഴി കരനെൽ ചെടിയുടെ വളർച്ചയും ഉല്പാദന ഘടകങ്ങളും കൂട്ടുവാനും അത് വഴി കൂടുതൽ വിളവ് ലഭിക്കുവാനും, കർഷകന്റെ ആദായം വർദ്ധിപ്പിക്കുവാനും സാധിക്കുന്നതായി തെളിഞ്ഞു