SOWING TIME AND NUTRIENT MANAGEMENT FOR PRODUCTIVITY ENHANCEMENT OF UPLAND RICE (*Oryza sativa* L.)

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(2018-11-059)

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by

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THESIS

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2020

DECLARATION

I, hereby declare that this thesis entitled **“SOWING TIME AND NUTRIENT MANAGEMENT FOR PRODUCTIVITY ENHANCEMENT 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, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"SOWING TIME AND NUTRIENT MANAGEMENT FOR PRODUCTIVITY ENHANCEMENT OF UPLAND RICE(*Oryza sativa* L.)"** is a record of research work done independently by Ms. Gunturi Alekhya (2018-11-055) 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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LIST OF ABBREVATIONS

BCR	:	Benefit cost ratio
CD (0.05)	:	Critical difference at 5 % level
Cm	:	Centimetre
DAS	:	Days after sowing
DMP	:	Dry matter production
et al.	:	Co-workers/ Co-authors
FYM	:	Farmyard manure
Fig.	:	Figure
FW	:	Fresh weight
G	:	Gram
g^{-1}	:	Per gram
Ha	:	Hectare
ha^{-1}	:	Per hectare
HI	:	Harvest index
$hill^{-1}$	:	Per hill
K	:	Potassium
KAU	:	Kerala Agricultural University
KUE	:	Potassium use efficiency
Kg	:	Kilogram
kg^{-1}	:	Per kilogram
LAI	:	Leaf area index
m^2	:	Square metre
m^{-2}	:	Per square metre
m^{-3}	:	Cubic metre
mg	:	Milligram
Mg	:	Mega gram
mm	:	Millimetre
MSL	:	Mean sea level
N	:	Nitrogen
NS	:	Non-significant

NUE	:	Nitrogen use efficiency
P	:	Phosphorus
$Panicle^{-1}$	:	Per panicle
PGPR MIX I	:	Plant growth promoting rhizobacteria mixture I
pH	:	Potenz hydrogen
PTB	:	Pattambi
RBD	:	Randomized block design
RLWC	:	Relative leaf water content
SPAD	:	Soil plant analysis development
SEm	:	Standard error of mean
SW	:	South-west
t	:	Tonnes

LIST OF SYMBOLS

%	:	Per cent
@	:	at the rate of
ºC	:	Degree Celsius
µ	:	Micro
₹	:	Rupee

Introduction

1. INTRODUCTION

Rice is one of the major food grains of the world. India has large area under rice cultivation, as it is one of the principle food crops. Rice provides food for more than half of the world's population. It is grown in both upland and wetland conditions and over a wide range of latitudes. Population growth, urbanization, industrialization and adoption of other cash crops instead of rice reduce the area of paddy cultivation.The wetland rice cultivation has a role in global warming. It results in the emission of green house gas methane, which in turn acts as a factor for rise in global mean temperature. So here comes the need for significant transformation in rice cultivation. That is giving more importance to upland rice cultivation, which also requires less water than wetland rice and mainly cultivated as rainfed.

Nutrient management is an important factor, which influences upland rice production. Suitable nutrient management practices must be adopted to overcome the constraint of low productivity in upland rice. Nitrogen is one of the major nutrients, which influence the productivity of upland rice. It is the integral part of chlorophyll, amino acids and genetic material (DNA and RNA) and plays a significant role in enhancing the milling quality and protein content of rice grain (Nawaz *et al.*, 2017). Nitrogen increases rice yield through improving dry matter yield, increasing number of panicles and panicle length (Fageria and Baligar, 2001).

Potassium is essential for photosynthetic activity and helps in inducing drought tolerance, disease resistance and production of stiff stalks and stem prevents lodging. It is required by plants throughout crop growth but with varying intensity, acute shortage during critical stages are detrimental to crop growth and yield (Elrewainy, *et al.*, 2011). In addition, increased potassium levels enhance water use efficiency, root growth and water absorption, especially under upland condition. Also improves tillering, dry matter production, number of filled grains and grain weight. Potassium is described as the quality element ensuring optimum quality of agricultural produce.

The increased dose of N and K improves photosynthesis and other physiological and metabolic processes like enzyme activation, protein synthesis and cell expansion coupled with higher nutrient uptake, DMP and efficient translocation to sink. The effect of major nutrients on yield attributes is primarily a function of assimilate accumulation and in turn facilitated higher nutrient assimilation with adequate supply of photosynthates to grain and increased crop uptake resulting in better crop growth. Higher dose of N and K provided continuous and steady supply of nutrients into the soil solution to match the nutrient requirement of crop which consequently resulted in the production of longer panicles with more number of filled grains panicle $^{-1}$ which increases the yield. Kumar (2016) reported higher yield attributes and yield at N and K applied at 120:60 kg ha^{-1} in upland rice.

Use of biofertilizers like PGPR MIX 1 positively affects rice yield and its attributes and contribute to reducing the use of chemical fertilizers as well as minimizing the cost of inputs and environmental pollution. Organic materials such as FYM have traditionally been used by rice farmers. FYM application improves crop growth by supplying plant nutrients as well as improving soil physical, chemical and biological properties (Choudhary and Suri, 2014).

Time of sowing is the one of the most critical aspect of direct seeding of rice. Optimum planting time is important for realizing higher yields. Early or delay in sowing leads to lower production in upland rice. Optimum sowing time has to be standardized for realizing higher yields of upland rice, for every agro- ecological situation for success of upland rice.

By this, the study entitled “Sowing time and nutrient management for productivity enhancement of upland rice (*Oryza sativa* L.)” was conducted with the following objectives.

- To study the influence of different levels of N and K, their ratios and time of sowing on growth and yield of upland rice
- To work out the economics of cultivation

Review of Literature

2. REVIEW OF LITERATURE

Rice is the staple food crop of the world. The major constraints for the low productivity of upland rice are improper nutrient management, weed infestation, various biotic and abiotic stresses. The optimum time of sowing is also important for higher yield. Supplying nutrients in proper ratios at critical stages of crop growth is an important factor determining crop productivity. Hence a field experiment was conducted to study the effect of NK ratios and time of sowing on growth and yield of upland rice. The available literature on the influence of N and K, their ratios and time of sowing on growth, yield attributes, yield, physiological attributes, soil properties, incidence of weeds and economics of cultivation are briefly reviewed.

2.1 INFLUENCE OF NUTRIENTS

2.1.1 Growth characters

2.1.1.1 Nitrogen

Nitrogen is the most important and yield-limiting nutrient in rice production worldwide (Lin *et al.*, 2006). It is associated with photosynthesis, vegetative growth and other physiological process.

Anu (2001) obtained taller plants at 80 kg N ha^{-1} in upland rice. The tallest plants in rice were produced when N was applied at 175 kg ha^{-1} (Maheswari *et al.*, 2007). Gewaily *et al.* (2018) reported that application of N at 220 kg ha^{-1} increased the plant height. Suman (2018) recorded the maximum plant height at N 90 kg ha^{-1} in upland rice. Greeshma (2019) stated that application of 120 kg N ha^{-1} produced taller plants in upland rice.

Mini (2005) obtained the maximum number of tillers m^{-2} at 100 kg N ha^{-1} in upland rice. Adhikari *et al.* (2018) recorded the maximum number of tillers m^{-2} when N was applied at 120 kg ha^{-1} in rice. Increased application of N to 120 kg ha^{-1} resulted in higher tiller number in rice (Jahan *et al*., 2014). Kumar (2016) obtained the highest tiller number in upland rice at 120 kg N ha^{-1}. Application of 120 kg N ha^{-1} produced the maximum number of tillers m^{-2} in rice (Kumar *et al*., 2017). Tiller number was significantly influenced by increasing the N levels and highest number of tillers m^{-2} was produced at 120 kg ha^{-1} (Greeshma, 2019).

Ranjini (2002) reported higher LAI at 90 kg N ha^{-1} in upland rice. Lampayan *et al*. (2010) recorded the highest LAI with increased N level to 150 kg ha^{-1} in rice. The LAI was increased with higher levels of N and the highest LAI was obtained at 220 kg N ha^{-1} (Abou-Khalifa, 2012). Abid *et al*. (2015) obtained the maximum leaf area index at 175 kg N ha^{-1} in rice.

Meena *et al*. (2003) opined that DMP increased with increased application of N up to 200 kg ha^{-1}. Mini (2005) obtained the maximum DMP in upland rice by the application of N at 100 kg ha^{-1}. The DMP increased by increasing N levels from 50 to 150 kg ha^{1} and the highest DMP was at 150 kg N ha^{-1} in rice (Pandey *et al*., 2008). Maheswari *et al*. (2007) recorded the highest DMP, when N was applied at 150 kg ha^{-1}. Artacho *et al*. (2009) opined that the maximum DMP was attained with N applied at 200 kg ha^{-1} in rice. Rao *et al*. (2014) reported that application of 100 kg N ha^{-1} produced the maximum DMP in rice. Kumar (2016) reported the highest DMP in upland rice at N applied at 120 kg ha^{1}. When N was applied at 90 kg ha^{1}, the DMP attained the maximum value in upland rice (Suman, 2018). Greeshma (2019) stated a significant increase in DMP due to N levels and the maximum DMP was obtained at 120 kg N ha^{-1} in upland rice.

2.1.1.2 Potassium

Potassium plays a key role in the plant nutrition. It strengthens the cell wall, helps in the growth of meristematic tissue and enables the plant to withstand biotic and abiotic stresses.

In upland rice, the tallest plants were obtained with higher levels of K application up to 45 kg ha^{-1} (Ranjini, 2002). The height of rice plants significantly increased with higher levels of K from 0 to 90 kg ha^{-1} (Bagheri *et al*., 2011). Akanda *et al*. (2012) obtained the tallest plants by the application of 35 kg K_2O ha^{-1} in aromatic rice. Kumar (2016) reported the maximum plant height at 60 kg K_2O ha^{-1}.

Greeshma (2019) obtained the tallest plants of upland rice when K was applied at 60 kg ha^{-1}.

Application of K at 45 kg ha^{-1} produced the maximum number of tillers m^{-2} in upland rice (Anu, 2001; Ranjini, 2002). Kalita *et al.* (2002) recorded the highest number of tillers m^{-2} at 40 kg K_2O ha^{-1}. Increased application of K up to 50 kg ha^{-1} produced the maximum number of tillers in upland rice (Mini, 2005). Uddin *et al.* (2013) reported that the maximum number of tillers at 40 kg K_2O ha^{-1} in rice. Nath *et al.* (2016) stated that the maximum number of tillers m^{-2} was attained when K was applied at 60 kg ha^{-1}. Greeshma (2019) obtained the maximum number of tillers m^{-2} in upland rice at 90 kg K_2O ha^{-1}.

Vijayalakshmi and Mathan (2004) reported that increasing the dose of K to 35 kg ha^{-1} produced the maximum leaf area index. Akanda *et al.* (2012) reported that application of K at 35 kg ha^{-1} in aromatic rice increased the leaf area index. LAI in upland rice was increased due to K application at 60 kg ha^{-1} (Kumar, 2016). Suman (2018) recorded the highest LAI at 45 kg K_2O ha^{-1} in upland rice.

Ranjini (2002) reported the maximum DMP in upland rice at 45 kg K_2O ha^{-1}. Meena *et al.* (2003) recorded the maximum DMP when K was applied at 62.5 kg ha^{-1} in rice. Mini (2005) obtained the highest DMP in upland rice at 50 kg K_2O ha^{-1}. Increasing the levels of K significantly increased the DMP in upland rice and the highest DMP was obtained at 60 kg ha^{-1} in upland rice (Kumar, 2016). Suman (2018) obtained the highest DMP in upland rice at 45 kg K_2O ha^{-1}. Application of K at 60 kg ha^{-1} resulted in the maximum DMP in upland rice (Greeshma, 2019).

2.1.1.3 Combined effect of nitrogen and potassium

Anu (2001) observed increased growth characters in upland rice when N and K were applied at 80:45 kg ha^{-1}. Application of increased levels of N and K up to 200 and 62.5 kg ha^{-1} respectively significantly increased the growth characters in hybrid rice (Meena *et al.*, 2003). Akanda *et al.* (2012) reported increased growth characters when N and K were applied at 75 and 35 kg ha^{-1} in aromatic rice. Kumar (2016) reported that there was a significant increase in the growth characters when 120 kg N ha^{-1} and 60 kg K_2O ha^{-1} were applied in upland rice. The combined effect of nitrogen and potassium improved the growth of rice compared to the use of N or K alone (Nath *et al.*, 2016). With N and K applied at 90:45 kg ha^{-1}, there was improvement in the growth characters in upland rice (Suman, 2018). Greeshma (2019) obtained better growth characters due to the combined application of N and K at 120:60 kg ha^{-1} (2:1 ratio) in upland rice.

2.1.2 Yield and yield attributing characters

2.1.2.1 Nitrogen

Hossain *et al.* (2008) obtained higher number of productive tillers m^{-2} in aromatic rice due to application of N at 60 kg ha^{-1}. Chakraborty (2011) reported a significant increase in number of productive tillers m^{-2} with 100 kg N ha^{-1} in rice. Uddin *et al.* (2013) obtained the maximum number of productive tillers m^{-2} in rice when N was applied at 60 kg ha^{-1}. Jahan *et al.* (2014) recorded the maximum number of productive tillers m^{-2} at 60 kg N ha^{-1} and further increase in the N dose reduced their number in rice. Nawaz *et al.* (2017) reported the highest number of productive tillers per plant when N was applied at 255 kg ha^{-1} in rice. Increased level of N to 120 kg ha^{-1} increased the number of productive tillers m^{-2} in upland rice (Greeshma, 2019).

Islam *et al.* (1997) obtained the longest panicle in rice at 80 kg N ha^{-1}. Nitrogen application up to 210 kg ha^{-1} significantly influenced the panicle length in rice (Fageria and Baligar, 2001). Jahan *et al.* (2014) reported greater panicle length at 60 kg N ha^{-1}. Adhikari *et al.* (2018) reported that the panicle length increased with application of N up to 80 kg ha^{-1} and further increase of N did not show any increase in panicle length in rice. Gewaily *et al.* (2018) recorded the maximum panicle length in rice at 220 kg N ha^{-1}. Greeshma (2019) obtained higher panicle length in upland rice at 120 kg N ha^{-1}.

Anu (2001) observed the maximum grain weight panicle^{-1} in upland rice at 80 kg N ha^{-1}. Mini (2005) reported the highest grain weight panicle^{-1} in upland rice at 100 kg N ha^{-1}. Kumar (2016) obtained the maximum grain weight panicle^{-1} in upland rice at 120 kg N ha^{-1}. Nawaz *et al.* (2017) obtained the maximum grain weight panicle^{-1} at 255 kg N ha^{-1}. Greeshma (2019) recorded the maximum grain weight panicle^{-1} in upland rice at 120 kg ha^{-1}. Langangmeilu (2019) reported the maximum grain weight panicle^{-1} in upland rice at 120 kg N ha^{-1}

Anu (2001) obtained the maximum number of spikelets panicle^{-1} at 80 kg N ha^{-1}. Bahmanyar and Mashaee (2010) recorded the maximum number of spikelets panicle^{-1} at 46 kg N ha^{-1} in rice. Akanda *et al.* (2012) reported the maximum number of spikelets panicle^{-1} at 75 kg N ha^{-1} in rice. Ghanbari-Malidareh (2011) obtained the highest number of spikelets panicle^{-1} in rice at 138 kg N ha^{-1}. Kumar (2016) obtained the highest number of spikelets panicle^{-1} in upland rice at 120 kg N ha^{-1}. Langangmeilu (2019) reported the highest number of spikelets panicle^{-1} in upland rice at 120 kg N ha^{-1}.

The highest number of filled grains panicle^{-1} in rice was obtained at 80 kg N ha^{-1} (Islam *et al.,* 1997). Jahan *et al*. (2014) obtained the highest number of filled grains in rice at 35 kg N ha^{-1}. Kumar (2016) found that increased N levels to 120 kg ha^{-1} improved the percentage of filled grains in upland rice. Application of N at 120 kg ha^{-1} in rice recorded higher number of filled grains panicle^{-1} (Kumar *et al*., 2017). The application of 120 kg N ha^{-1} produced the maximum percentage of filled grains panicle^{-1} in upland rice (Greeshma, 2019).

Ghanbari-Malidareh (2011) obtained the highest 1000 grain weight when N was applied at 138 kg ha^{-1}. Application of N at 120 kg ha^{-1} resulted in the maximum test weight (Kumar 2016). Application of N at 150 kg ha^{-1} produced the maximum 1000 grain weight in rice (Sorour *et al*., 2016). Gewaily *et al*. (2018) reported maximum 1000 grain weight at 220 kg N ha^{-1}.

Mini (2005) obtained the highest grain and straw yields at 100 kg N ha^{-1} in upland rice. Maheswari *et al*. (2007) reported the maximum grain and straw yields at 250 kg N ha^{-1} in rice. Pandey *et al*. (2008) recorded the highest grain and straw yields at 150 kg N ha^{-1}. Lampayan *et al*. (2010) recorded the maximum grain and straw yields in aerobic rice, when the levels of N were increased from 60 to 150 kg ha^{-1}. Application of 140 kg N ha^{-1} produced the maximum grain and straw yields in rice (Chakraborty, 2011). Ghanbari-Malidareh (2011) recorded the maximum grain and straw yields in rice at 138 kg N ha^{-1}. Jahan *et al*. (2014) reported the maximum grain yield in rice at 60 kg N ha^{-1}. Mishra *et al*. (2015) stated that the higher N level in rice increased the grain yield and the maximum grain yield was obtained when N was applied at 225 kg ha^{-1}. Djaman *et al*. (2016) obtained the maximum grain and straw yields in basmati rice at 150 kg N ha^{-1}. Kumar (2016) obtained the maximum grain and straw yields in upland rice at 120 kg N ha^{-1}. Javed *et al*. (2017) obtained the highest grain and straw yields at 60 kg N ha^{-1}. Nawaz *et al*. (2017) recorded the maximum grain yield due to the increased N application to 255 kg ha^{-1}. Adhikari *et al*.

(2018) opined that the maximum grain and straw yields were obtained when N was applied at 80 kg ha^{-1}. Suman (2018) obtained the highest grain and straw yields in upland rice at 90 kg N ha^{-1}. Greeshma (2019) stated that the increased application of N increases the yield and the maximum grain and straw yields were obtained when N applied at 120 kg ha^{-1}. Langangmeilu (2019) obtained the highest grain and straw yields in upland rice at 120 kg N ha^{-1}.

Anu (2001) recorded the maximum harvest index in upland rice at 80 kg N ha^{-1}. Ranjini (2002) obtained the maximum harvest index when N was applied at 90 kg ha^{-1}. Jahan *et al.* (2014) reported the highest harvest index in aromatic rice when the N was applied at 60 kg ha^{-1}. Kumar (2016) obtained the highest harvest index at 120 kg N ha^{-1}. Langangmeilu (2019) obtained the highest harvest index of 0.45 at 120 kg N ha^{-1}.

2.1.2.2. Potassium

Velayudham and Velayudham (1991) obtained the highest number of grains $panicle^{-1}$ when K was applied at 45 kg ha^{-1}. Ranjini (2002) revealed that the application of K at 45 kg ha^{-1} produced the highest number of productive tillers m^{-2}, number of spikelets $panicle^{-1}$, grain weight $panicle^{-1}$, 1000 grain weight and percentage of filled grains $panicle^{-1}$. Bagheri *et al.* (2011) recorded the maximum number of productive tillers m^{-2} when the K was applied at 90 kg ha^{-1}. Akanda *et al.* (2012) found that number of productive tillers m^{-2}, filled grains $panicle^{-1}$ and 1000 grain weight increased with K applied at 25 kg ha^{-1} in aromatic rice. Islam and Muttaleb (2016) recorded the maximum number of productive tillers m^{-2} and percentage of filled grains $panicle^{-1}$ when K was applied at 100 kg ha^{-1}. Wakeel *et al.* (2017) reported that increased rate of K up to 180 kg ha^{-1} increased the number of spikelets $panicle^{-1}$. Greeshma (2019) recorded the maximum yield attributing characters like number of productive tillers m^{-2}, number of spikelets $panicle^{-1}$, grain weight $panicle^{-1}$, 1000 grain weight and percentage of filled grains $panicle^{-1}$ when K was applied at 60 kg ha^{-1}.

Ranjini (2002) reported the maximum grain and straw yields in upland rice at 45 kg K_2O ha^{-1}. Meena *et al.* (2003) recorded the maximum grain and straw yields when K was applied at 62.5 kg ha^{-1} in rice. Mini (2005) obtained the highest grain and straw yields in upland rice at 50 kg K_2O ha^{-1}. Increasing the levels of K significantly increased the grain and straw yields in upland rice and the highest yield was obtained at 60 kg ha^{-1} in upland rice (Kumar, 2016). Suman (2018) obtained the highest grain and straw yields in upland rice at 45 kg K_2O ha^{-1}. Application of K at 60 kg ha^{-1} resulted in the maximum grain and straw yields in upland rice (Greeshma, 2019).

2.1.2.3 Combined effect of nitrogen and potassium

Anu (2001) obtained the higher yield attributes and yield in upland rice when N and K were applied at 80:45 kg ha^{-1}. Application of increased levels of N and K up to 200 and 62.5 kg ha^{-1} respectively significantly increased the yield attributes and yield in hybrid rice (Meena *et al*., 2003). Mini (2005) reported that application of 100 kg N and 50 kg K_2O produced the maximum number of spikelets $panicle^{-1}$, length of panicle, weight of panicle, 1000 grain weight, grain and straw yields in upland rice. Akanda *et al*. (2012) reported increased yield attributing characters when N and K were applied at 75 and 35 kg ha^{-1} respectively in aromatic rice. Kumar (2016) reported that there was a significant increase in the yield attributes and yield when 120 kg N ha^{-1} and 60 kg K_2O ha^{-1} were applied in upland rice. The combined effect of nitrogen and potassium improved the yield of rice compared to the use of N or K alone (Nath *et al*., 2016). Greeshma (2019) obtained better yield attributes and yield in upland rice due to the combined application of N and K at 120:60 kg ha^{-1} (2:1 ratio).

2.1.3 Physiological estimation

2.1.3.1 Nitrogen

Akanda *et al.* (2012) obtained maximum chlorophyll content in aromatic rice at 75 kg N ha^{-1}. Barrari *et al.* (2013) observed the influence of different levels of N on chlorophyll content in rice and found that Soil Plant Analysis Development (SPAD) reading is influenced by N levels and SPAD reading at all stages was positively correlated with rice yield. Suman (2018) recorded the highest value of chlorophyll in upland rice at 120 kg N ha^{-1}.

Ranjini (2002) observed the highest value of relative leaf water content (RLWC) in upland rice at 90 kg N ha^{-1}. The highest RLWC in upland rice was registered at 100 kg N ha^{-1} (Mini, 2005). Maheswari (2006) found higher RLWC at higher N level of 175 kg ha^{-1} in rice.

Anu (2001) revealed that the highest nitrogen use efficiency was at 80 kg N ha^{-1} in upland rice. Fageria and Baligar (2003) reported that higher levels of nitrogen reduced the nitrogen use efficiency in rice. Saleque *et al.* (2004) reported that agronomic efficiency was usually greater in rice at lower dose of N fertilizer application. Mini (2005) found that application of 100 kg N ha^{-1} gave the maximum nitrogen use efficiency in upland rice. Greeshma (2019) recorded the highest nitrogen use efficiency at 60 kg N ha^{-1} in upland rice.

Pattil and Mishra (1994) opined that highest N uptake in rice was at 75 kg N ha^{-1}. Duhan and Mahendera (2002) recorded the highest nutrient uptake at 120 kg N ha^{-1}. Sim and Place (2002) reported the highest nutrient uptake at 157 kg N ha^{-1} in rice. Singh *et al.* (2006) recorded the highest nutrient uptake in rice at 180 kg N ha^{-1}. Ghoneim (2014) obtained higher nutrient uptake at 100 kg N ha^{-1}. Nayak *et al.* (2015) observed the higher N uptake in rice at 80 kg N ha^{-1}. Kumar (2016) reported that application of 120 kg N ha^{-1} resulted the highest NPK uptake by grain and straw in upland rice. Maximum N uptake was obtained when N was applied at 120 kg ha^{-1} in rice (Suman, 2018).

Swaroopa and Lakshmi (2015) recorded maximum value of grain protein content at 135 kg N ha^{-1} in rice. Kumar (2016) found that application of N at 120 kg ha^{-1} increases the grain protein content in upland rice. Greeshma (2019) reported the highest grain protein content at 120 kg N ha^{-1} in upland rice.

2.1.3.2 Potassium

Mini (2005) obtained the highest chlorophyll content in upland rice at 50 kg K_2O ha^{-1}. Bagheri *et al.* (2011) found that highest chlorophyll content was at 90 kg K_2O ha^{-1}. Wakeel *et al.* (2017) recorded the maximum chlorophyll content at 180 kg K_2O ha^{-1} in aerobic basmati rice.

The maximum uptake of potassium in rice was observed at 80 kg K_2O ha^{-1} (Kabir *et al.*, 2011). Yajjala (2011) obtained the maximum uptake of K in hybrid rice at 80 kg K_2O ha^{-1}. Murthy *et al.* (2014) reported that K application @ 50 kg K_2O ha^{-1} in *rabi* rice resulted in higher uptake of nutrients. Maximum uptake of K by rice was obtained at 60 kg K_2O ha^{-1} (Huda *et al.*, 2016). Greeshma (2019) observed the highest potassium uptake at 60 kg K_2O ha^{-1} in upland rice.

Ranjini (2002) observed the highest grain protein content in upland rice at 45 kg K_2O ha^{-1}. Mini (2005) recorded the highest grain protein content at 50 kg K_2O

ha^{-1} in upland rice. Kumar (2016) obtained the highest grain protein content in upland rice at 50 kg K_2O ha^{-1}.

2.1.3.3 Combined effect of nitrogen and potassium

Nitrogen use efficiency (NUE) of upland rice increased with increasing N level with maximum at 80 kg N ha^{-1} and 45 kg K_2O ha^{-1} (Anu, 2001). Mini (2005) obtained maximum NUE in upland rice at 100 kg N ha^{-1} and 50 kg K_2O ha^{-1}.

Mini (2005) reported an increase in post-harvest available N and K status of soil at higher levels of N and K (120 kg N: 90 kg K_2O ha^{-1}) application for upland rice. She also obtained higher P status of soil at 80 kg N and 40 kg K_2O ha^{-1}. Greeshma (2019) obtained similar result in upland rice.

Ranjini (2002) obtained the maximum nutrient uptake in upland rice with 90 kg N and 45 kg K_2O ha^{-1}. Mini (2005) obtained higher nutrient uptake at 120 kg N: 90 kg K_2O in upland rice. Application of 120 kg N ha^{-1} and 60 kg K_2O ha^{-1} resulted in higher nutrient uptake in upland rice (Kumar, 2016).

2.1.4 Major weeds

Upland rice is most sensitive to weed competition up to 15 to 30 days after sowing (DAS) and grasses and sedges constituted 75 per cent and dicots 25 per cent of total weed flora (Sarma, 1987). Weeds compete with rice plants for light, nutrients, especially N and K and moisture resulting in yield reduction (Babu *et al.*, 1992).

2.1.5 Pest and disease incidence

The incidence of dead heart (DH) and white head (WH) was 175 and 206 per cent higher than the control, when the field was fertilized with 140 kg N ha^{-1} (Chakraborty, 2011). Application of K @ 50 kg K_2O ha^{-1} was the most effective strategy in inhibiting rice pest incidence in rice (Sarwar, 2011). The lowest incidence of dead hearts, leaf folder, stem borer and disease incidence like leaf blight, grain discoloration and brown spot was observed at N application level of 125 kg ha^{-1} (Malav and Ramani, 2015). Application of N at 200 kg ha^{-1} resulted in maximum incidence of green leaf hoppers and white ears in rice (Kumar *et al.*, 2017).

2.1.6 Economics of cultivation

The highest gross returns and net returns were recorded with application of NK at 210: 40 kg ha^{-1} (Murthy *et al.*, 2014). The highest gross return, net return and benefit cost ratio (BCR) were obtained with the application of 225 kg N ha^{-1} in rice (Mishra *et al*, 2015). Mini (2005) obtained the highest BCR in upland rice with the application of 100 kg N and 50 kg K_2O ha^{-1}. Greeshma (2019) obtained the highest BCR with the application of 120:60 kg NK ha^{-1} in upland rice.

2.1.7 Effect of PGPR MIX I

2.1.7.1 Growth characters

Use of PGPR MIX-I along with chemical inputs significantly increased the DMP of rice (Ali *et al*., 1995). Raj *et al*. (2013) reported that the plant growth was influenced by the inoculation of PGPR MIX-I when it was applied with half the recommended dose of NPK (45:22.5:7.5 kg ha^{-1}) in rice. Application of PGPR MIX I promoted the growth characters in rice plant (Halimi *et al.,* 2015). Tan *et al*. (2015) reported that the inoculation of PGPR MIX-I with chemical fertilizer promotes crop growth in rice.

2.1.7.2 Yield attributes and yield

According to Cummings (2009), the yield attributing characters of rice increased with PGPR MIX I (6 kg ha^{-1}) application. Lavakush *et al.* (2014) obtained higher yield attributes and yield when PGPR MIX I was applied along with 60 kg ha^{-1} of phosphorus in rice. Regar and Yadav (2017) reported that application of PGPR MIX I (10 kg ha^{-1}) significantly influenced the grain yield, straw yield and harvest index in rice. Tan *et al.* (2017) obtained higher number of spikelets $panicle^{-1}$, productive tillers m^{-2}, grain weight $panicle^{-1}$ and yield when rice was inoculated with PGPR MIX I and supplied with minimal N rate.

2.1.8 Effect of FYM

2.1.8.1 Growth characters

Integrated use of FYM (5 t ha^{-1}) along with chemical fertilizers resulted in higher growth characters in rice (Satyanarayana *et al.,* 2002). Usman *et al*. (2003) reported that application of FYM @ 15 t ha^{-1} produced the highest number of tillers m^{-2} and dry matter production in rice. Banik *et al.* (2006) obtained the tallest plants when 25% of the inorganic fertilizer was substituted by FYM in rice. Banterng *et al.* (2010) reported that application of FYM (10 t ha^{-1}) along with chemical fertilizers increased the tiller number, leaf area index and dry matter production. Choudhary and Suri (2014) obtained the tallest plant and greatest number of tillers in rice @ 5 t ha^{-1} of FYM.

2.1.8.2 Yield attributes and yield

Babu *et al.* (2001) opined that application of FYM at 10 t ha^{-1} increased the yield attributing characters in rice. Shekara *et al.* (2010) recorded higher yield attributing characters in rice with FYM was applied @ 20 t ha^{-1}. Hossaen *et al.* (2011) reported that application of FYM @ 15 t ha^{-1} resulted in higher yield attributes and yield. When 25% of recommended dose of fertilizer was substituted with FYM, the number of grains $panicle^{-1}$, panicle length, number of panicles $hill^{-1}$, 1000 grain weight, grain yield, straw yield and harvest index were significantly influenced (Arif *et al.*, 2014). Gangmei and George (2017) obtained maximum grain yield in black rice with the application of 10 t ha^{-1} FYM.

2.1.9 Combined effect of PGPR MIX I & FYM on growth characters, yield attributes and yield

According to Kumudha and Gomathinayagam (2007), growth parameters in rice were significantly influenced by the integrated application of plant growth promoting rhizobacteria and farmyard manure (15 t ha^{-1}). Hien *et al.* (2014) obtained higher dry matter production with the application of PGPR MIX I and FYM (10 t ha^{-1}) in rice. Yadav (2017) reported that combined application of PGPR (10 kg ha^{-1}) and farmyard manure (10 t ha^{-1}) significantly influenced the growth characters in rice. The growth characters like tiller number and dry matter production were influenced by the combined application of PGPR (6 kg ha^{-1}) and FYM (10 t ha^{-1}) in rice (Vimal and Singh, 2019).

Combined application of PGPR and FYM (20 t ha^{-1}) increased the yield attributing characters in basmati rice (Ram *et al.,* 2011). Umesha *et al.* (2014) opined that application of PGPR (6 kg ha^{-1}) and FYM (10 t ha^{-1}) resulted in higher yield attributes and yield in rice. Yuvaraj (2016) obtained the maximum grain yield when PGPR MIX I (8 kg ha^{-1}) and FYM (15 t ha^{-1}) were applied together in rice. Yadav (2017) obtained the maximum grain yield in rice with the combined application of PGPR and farmyard manure (20 t ha^{-1}).

2.2 INFLUENCE OF TIME OF SOWING

2.2.1 Growth characters

Pandey *et al*. (2001) reported that early sowing in rice increased the dry matter accumulation and tiller number. Baloch *et al.* (2006) obtained the maximum plant height, tiller number, leaf area index in rice when transplanted on June. Khakwani *et al*. (2006) recorded the tallest plants when sown during last week of May. Akram *et al*. (2007) observed that late sowing reduced the rice growth characters like plant height, tiller number and leaf area index. Similar findings were reported by Muhammad *et al*. (2008) in rice. Maximum growth characters were obtained in hybrid rice sown on July 5th (Pandey *et al*., 2008). Rai and Kushwaha (2008) reported that delay in sowing reduced the plant height, tiller number and leaf area index in rice. Khalifa (2009) reported that early date of sowing was the best time of sowing for rice for improved growth characters. Abou-Khalifa (2012) reported that early sowing gave the maximum value for growth characters like plant height, number of tillers m^{-2} and leaf area index. Ehsanullah *et al*. (2014) also reported that late planting of rice resulted in poor growth than early planting. Abid *et al*. (2015) obtained the tallest plants and higher number of tillers when sown on June 20th.

2.2.2 Yield attributes and yield

Biswas and Salokhe (2001) reported that early sowing gave more productive tillers m^{-2}, grain weight panicle^{-1} and percentage of filled grains panicle^{-1} in rice. Nayak *et al*. (2003) opined that date of sowing had significant role in the yield of rice. Singh *et al*. (2004) obtained maximum yield attributing characters in rice sown on July 3rd. Shah and Bhurer (2005) reported the maximum number of productive tillers m^{-2} in rice when sown on June 1st week. Singh *et al.* (2005) obtained the maximum yield in rice sown during June 1st week. Gill *et al.* (2006) stated that early sowing significantly influenced the yield attributes and yield in rice. Khakwani *et al*. (2006) revealed that delay in seeding reduced the yield of rice. Vange and Obi (2006) found that sowing date significantly influenced the yield attributes and yield of rice. Pandey *et al*. (2008) obtained higher yield attributes and yield when sown on July 5th in hybrid rice. Mishra and Salokhe (2008) stated that there was significant effect on productive tillers with varying transplanting dates. Brar *et al*. (2012) stated that transplanting dates were crucial in relation to yield and yield components of rice. Abid *et al*. (2015)

obtained the maximum grain weight panicle^{-1}, 1000 grain weight, grain yield and straw yield when sown at June 20th.

2.2.3 Physiological and chemical estimations

Yawinder *et al.* (2006) reported that late sowing reduced the chlorophyll content in rice. Pandey *et al.* (2008) obtained the maximum value for chlorophyll content in hybrid rice sown on July 5th.

Singh *et al.* (2004) reported that nutrient use efficiency was highest when sown on July 3rd. In hybrid rice the maximum nutrient uptake was observed when sown on 5th July (Pandey *et al.*, 2008). Planting on 5th July resulted in significantly higher NPK uptake over 25th July and 4th August (Chaudhary *et al.*, 2011)

2.2.4 Economics of cultivation

Early seeding gave maximum net returns and BCR in rice (Arshad-Ullah *et al.*, 2007). Planting on July 5th resulted in the maximum gross and net incomes in rice (Pandey *et al.*, 2008). Abou-Khalifa (2012) obtained maximum net returns on early sowing in rice. Abid *et al*. (2015) obtained higher net income and BCR when sown on June 20th.

2.3 STATUS OF PRESENT RESEARCH AND RESEARCH GAPS

Optimum time of sowing is important for realizing higher yields in upland rice. Early or late sowing leads to lower production. The soil moisture content is an important factor for attaining higher yields. As upland rice is mainly grown as a rainfed crop, correct time of sowing with the onset of SW (sowing one week after the commencement of SW monsoon or two weeks after the commencement of SW monsoon) is of great importance for the proper germination and growth. Studies on time of sowing of upland rice as a rainfed crop in Kerala are limited. It is therefore important to know the optimum time of sowing (sowing one week after the commencement of SW monsoon or two weeks after the commencement of SW monsoon), so that farmers can sow the seeds at the correct time for realizing higher yields.

Nutrient management is an important factor, which influences upland rice production. Suitable nutrient management practices must be adopted to overcome the constraint of low productivity. As per the KAU Package of Practice (2016), an N K dose of 60:30 kg ha^{-1} is recommended for upland rice. The results on nutrient management of upland rice so far revealed response to levels of N and K beyond 60 and 30 kg ha^{-1} as evident from the works of Anu (2001) 80:45 kg N and K_2O ha^{-1}, Ranjini (2002) 90 kg N and 45 kg K_2O ha^{-1} and Mini (2005) 100 kg N and 50 kg K_2O ha^{-1}. Studies by Kumar (2016) revealed that application of 120 kg N and 60 kg K_2O ha^{-1} favourably influenced the growth and yield of upland rice. These research findings revealed the positive influence of upland rice to higher doses of N and K.

Studies on combined effect of time of sowing and higher levels of N and K on growth and yield of upland rice are limited in Kerala. The present experiment is therefore envisaged to study the combined effect of time of sowing and nutrient management on growth, yield and economics of upland rice.

Materials and Methods

3. MATERIALS AND METHODS

The field experiment on "Sowing time and nutrient management for productivity enhancement of upland rice (*Oryza sativa* L.)" was laid out at College of Agriculture, Vellayani, during *Kharif*, 2019. The objective of the experiment was to study the influence of different levels of N and K, their ratios and time of sowing on growth and yield of upland rice and also to work out the economics of cultivation. The materials and methods used are given below.

3.1 MATERIALS

3.1.1 Experimental site

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

3.1.2 Soil

The soil was sandy clay loam. The physico-chemical properties of the soil were the field experiment was conducted is given in Table 1.

3.1.3 Climate

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

The daily weather parameters like mean temperature, relative humidity and rainfall were recorded during the cropping period. The amount of rainfall received was 1066.5 mm in 54 rainy days during the cropping season from 13/06/2019 to 21/10/2019. The mean maximum and minimum temperature recorded during the crop season were 32.6°C and 23°C respectively. The maximum and minimum relative humidity during crop season was 96.75 % and 70 % respectively.

3.1.4 Season

The field experiment was conducted during *Kharif* season (*Virippu*) of 2019. The first time of sowing was on 13th June 2019 (one week after the commencement of south-west monsoon, 2019) and the next sowing was on 21st June 2019 (two weeks after the commencement of south-west monsoon, 2019).

Table 1.Physico-chemical properties of the soil before experiment

Particulars	Value	Method used
A.Particle size composition		
Course sand (%)	16.79	Bouyoucos Hydrometer (Bouyoucos, 1962)
Fine sand (%)	30.55	
Silt (%)	23.90	
Clay (%)	25.88	
Texture	Sandy clay loam	
B. Physical properties		
Bulk density (Mg m^{-3})	1.56	Core method (Blake, 1965)
Porosity (%)	40.15	
Water holding capacity (%)	19.08	
C. Chemical properties		
pH	4.6 (Very strongly acidic)	pH meter with glass electrode (Jackson, 1973)
Organic carbon	0.72 (medium)	Walkley and Black rapid titration method (Walkley and Black, 1934)
Available N (kg ha^{-1})	252 (low)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	30.20 (high)	Bray extraction and photoelectric calorimetry (Jackson, 1973)
Available K (kg ha^{-1})	220 (medium)	Neutral normal ammonium acetate extract using flame photometry (Jackson, 1973)

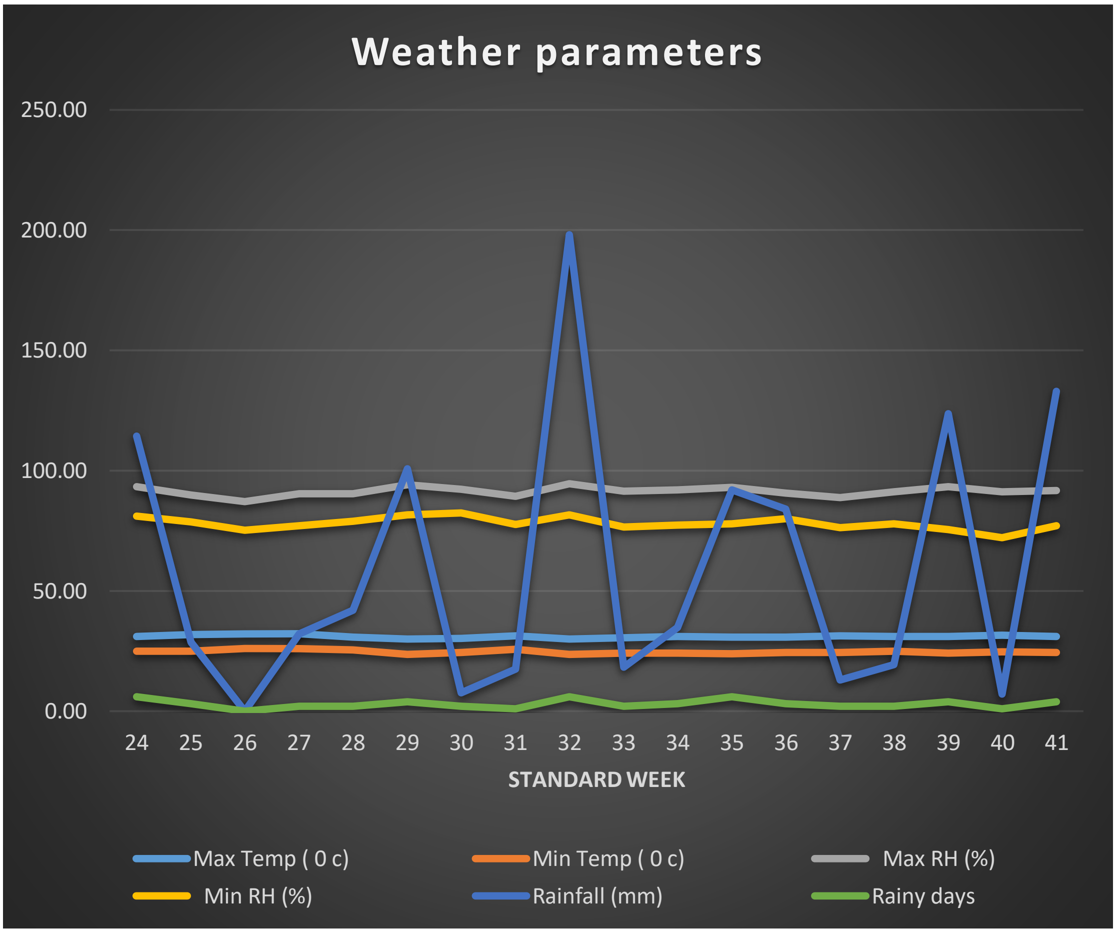

Fig. 1. Weather parameters during cropping period (13th June – 21st October 2019)

3.1.5 Crop and Variety

The rice variety used for the field experiment was Aiswarya (PTB 52) released from Regional Agricultural Research Station (RARS), Pattambi. It is a medium duration (120-125 days), photosensitive and semi-tall variety with red, medium and bold grains. It is resistant to blast and blight diseases as well as BPH.

3.1.6 Source of Seed Material

Seeds of rice variety Aiswarya (PTB 52) were purchased from RARS, Pattambi.

3.1.7 Manures and Fertilizers

Major source of organic manure was farmyard manure, which contains 0.50 per cent N, 0.20 per cent P_2O_5 and 0.40 per cent K_2O. Fertilizers were given as per the treatments.

3.1.8 Irrigation

Irrigation was provided as and when needed.

3.2 DESIGN AND LAY OUT

Design : Factorial RBD

Treatment: 12

Replication : 3

Plot size : 5 m x 4 m

Variety : Aiswarya (PTB 52)

Season : *Kharif*, 2019

3.2.1 Treatments

1) NK Levels (l) (kg ha^{-1} at 2:1 and 2:1.5 ratios)

l_1 : 60 kg N : 30 kg K_2O (control-1)

l_2 : PGPR MIX-I 6 kg + FYM 5 t (control-2)

l_3 : 120 kg N : 60 kg K_2O (2:1)

l_4 : 120 kg N : 90 kg K_2O (2:1.5)

l_5 : 140 kg N : 70 kg K_2O (2:1)

l_6 : 140 kg N : 105 kg K_2O (2:1.5)

2) Time of sowing (s)

(Usually SW monsoon commences on June 1st)

s_1 : one week after the commencement of SW monsoon, 2019

s_2 : two weeks after the commencement of SW monsoon, 2019

Treatment combinations: 6 x 2 = 12

P_2O_5 : Uniform dose of 30 kg ha^{-1} P_2O_5 to all treatments, as per the POP recommendation for upland rice (KAU, 2016).

3.3 CULTIVATION PRACTICES

3.3.1 Field preparation and lay out

The land was ploughed and levelled by using tractor. Bunds were formed with 30 cm width. Then it was divided into small plots of size 5 m x 4 m.

3.3.2 Seeds and Sowing

Seeds were sown 3 cm deep with seed rate of 90 kg ha^{-1} at a spacing of 20 cm x 10 cm.

3.3.3 Application of Manures and Fertilizers

Farmyard manure was applied as a source of organi manure at the rate of 5 t ha^{-1} at the time of land preparation. Fertilizers were applied according to the treatments. Urea as a source of nitrogen was applied at three equal split doses at basal, active tillering and panicle initiation stages. Raj phos as a source of phosphorus was applied full dose as basal and muriate of potash as a source of potassium was given two equal split doses at basal and at panicle initiation stages. And also one treatment of PGPR MIX-I with FYM at three equal split doses at basal, active tillering and panicle initiation stages were given.

3.3.4 Thinning and Gap filling

Seeds germinated within a week. Thinning and gap filling were done to maintain optimum plant population at 20 DAS

3.3.5 Water management

Life saving irrigation was given as and when required

3.3.6 Weed management

One manual weeding was given at 25 DAS and for the control of broad leaved weeds, Bispyribac sodium 0.25 kg ha^{-1} was sprayed.

3.3.7 Plant Protection

For rice gundhi bug attack, Thiomethoxam @ 125 g ha^{-1} was sprayed at panicle emergence stage. For grain discolouration, Carbendazim @ 500 g $ha^{-1}$was sprayed.

N

R I	RII	R III
l_1s_1	l_2s_2	l_1s_2
l_2s_1	l_1s_1	l_3s_1
l_1s_2	l_4s_1	l_6s_2
l_3s_1	l_6s_2	l_1s_1
l_4s_1	l_1s_2	l_2s_2
l_2s_2	l_2s_1	l_4s_1
l_6s_1	l_4s_2	l_2s_1
l_3s_2	l_6s_1	l_6s_1
l_5s_2	l_3s_1	l_5s_2
l_4s_2	l_5s_1	l_4s_2
l_6s_2	l_3s_2	l_6s_1
l_5s_1	l_5s_2	l_5s_1

4 m

5 m

Fig. 2. Lay out plan of the experiment

3.3.8 Harvest

The first harvest was on 14/10/2019 and second harvest was on 21/10/2019. After harvest, the crop was threshed, winnowed and grain and straw yield were taken separately and expressed in standard units on dry weight basis.

3.4 OBSERVATIONS

3.4.1 Growth characters

3.4.1.1 Plant height

From each plot, five plants were selected randomly avoiding border rows and tagged. Then measured the length of the plant from the base of the stem to the tip of the longest leaf. Then found out the mean value at 30, 60 DAS and at harvest.

3.4.1.2 Number of tillers per m^2

Tiller number m^{-2} was recorded at 60 DAS from the tagged plants and mean value was calculated.

3.4.1.3 Leaf Area Index (LAI)

Leaf area was estimated at 60 DAS, using the length width method.

Leaf area = k x l x w

Where, k – crop factor (0.75), l – length of the leaf, w – maximum width of the leaf

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}}$$

3.4.1.3 Dry Matter Production (DMP)

Dry matter production was determined at 60 DAS and harvest. Five plants were uprooted from each plot, washed, air dried and then oven dried at 80°C to constant weight. Dry weight was taken and expressed in standard units.

3.4.2 Yield attributes

3.4.2.1 Productive tillers per m^2

Number of productive tillers per m^2 was recorded at harvest from the net plot area and the mean value was taken.

3.4.2.2 Length of panicle

Length of panicle from the tagged plants were taken from the point of scar to the tip of the central panicle and expressed in cm.

3.4.2.3 Grain weight per panicle

The panicle taken for measuring the length was collected and weighed in an electronic balance and mean weight was recorded and expressed in g.

3.4.2.4 Number of spikelets per panicle

From the five tagged plants of every plot, spikelets were removed rom each panicle and counted and mean value was found out.

3.4.2.5 Percentage of filled grains per panicle

Number of filled grains per panicle from sample plants were counted and expressed in percentage.

3.4.2.6 Grain Yield ha^{-1}

Grains were harvested separately from each plot and solar dried to a moisture level of 14 per cent and weighed and expressed in kg ha^{-1}

3.4.2.7 Straw Yield ha^{-1}

Straw harvested from each plot was sun dried separately for three or four consecutive days and weighed and expressed in kg ha^{-1}

3.4.2.8 Harvest Index

Harvest index can be calculated from the formula given by Donald and Hamblin (1976).

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

3.4.3 Physiological Estimations

3.4.3.1 Proline Content

Proline content was estimated at panicle initiation stage by using the method of Bates *et al*. (1973) and expressed in µmol g^{-1} of fresh weight

3.4.3.2 Relative Leaf Water Content

Relative leaf water content at flowering stage was estimated by the method suggested by Weatherly (1950) and modified by Slatyer and Barrs (1965). Expressed in percentage

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

3.4.3.3 Chlorophyll Content

Chlorophyll content can be determined by the method of Reddy *et al.* (1992) at panicle emergence stage. Chlorophyll content can be estimated by calculating the amount of pigment present by using the formula given below.

$$\text{Chlorophyll a} = [12.7\ (OD_{\text{at } 663}) - 2.69\ (OD_{\text{at } 645})] \times \frac{V}{W \times 1000}$$

$$\text{Chlorophyll b} = [22.9\ (OD_{\text{at } 645}) - 4.68\ (OD_{\text{at } 663})] \times \frac{V}{W \times 1000}$$

$$\text{Total Chlorophyll} = [20.2\ (OD_{\text{at } 645}) + 8.02\ (OD_{\text{at } 663})] \times \frac{V}{W \times 1000}$$

3.4.4 Chemical Analysis

3.4.4.1 Nutrient Use Efficiency

Nutrient use efficiency was determined using the formula:

$$NUE = \frac{\text{Yield from fertilized plot}}{\text{Nutrient applied in kg ha}^{-1}}$$

3.4.4.2 Soil Analysis

During the field preparation, status of major nutrients like NPK and organic carbon were estimated using standard procedures. After the harvest of crop also composite samples were collected from 15 cm depth from each plot and chemical analysis was done.

3.4.4.3 NPK uptake

NPK uptake by crop at harvest can be estimated by the following formula and expressed in kg ha^{-1}.

$$\text{Nutrient uptake} = \frac{\text{Percentage of nutrient} \times \text{Total dry matter production (kg ha}^{-1})}{100}$$

3.4.4.4 Protein content of grain

Nitrogen content of the grain was estimated multiplied with the factor 6.25 and then expressed in percentage (Simpson *et al.*, 1965), protein content can be computed.

3.4.5 Observations on major weeds of upland rice

Major weeds of upland rice were observed and identified.

3.4.6 Pest and Disease Incidence of rice

Observations on major pests and diseases were done

3.4.7 Economic Analysis

3.4.7.1 Gross Income

3.4.7.2 Net Income

Net income was calculated by using the formula

Net income = Gross income – Cost of cultivation

3.4.7.3 B:C Ratio

Benefit cost ratio was woked out by the following formula

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

3.4.8 Statistical Analysis

The data obtained from the field experiment was subjected to statistical analysis (analysis of varience) and the significance was tested using F-test. At five per cent probability level, critical difference was found out, when the data was significant.

Plate 1.General view of the experimental plot

Seedling stage

Tillering stage

Panicle initiation stage

Maturity stage

Plate 2. Different growth stages

<u>Results</u>

4. RESULTS

The data on growth characters, yield attributes and yield, physiological parameters, soil physical and chemical properties and economics of cultivation were statistically analyzed and results are presented as follows.

4.1 GROWTH CHARACTERS

4.1.1 Plant height

The data on plant height at 30 DAS, 60 DAS and at harvest are shown in Tables 2a and 2b.

The results revealed no significant influence of NK ratios on plant height at 30 DAS, but significantly influenced at later stages of the growth (60 DAS and harvest). Time of sowing at 30 DAS was not significantly influenced by NK ratios, but there was significant influence at later stages of growth. The combined effect due to NK levels and time of sowing was not profound.

At 60 DAS, l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) producing the tallest plants (89.22 cm) and was significantly superior to the treatments, followed by treatment l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) resulting in a height of 86.92 cm. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}) produced the shortest plants of 82.58 cm. Regarding time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the tallest plants of 85.96 cm and was significantly superior to s_2 (sowing two weeks after the commencement of SW monsoon, 2019) resulting in a plant height of 84.73 cm. The interaction effect due to NK levels and time of sowing was not significant.

At harvest, the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the tallest plants of 99.23 cm and was significantly superior to rest of the treatments, followed by the treatment l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) producing plants of height 97.63 cm and was on par with l_4 (120:90 kg ha^{-1} of N K at 2:1.5 ratio) and significantly superior to rest of the treatments. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}) produced the shortest plants of 92.62 cm. Regarding time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the tallest plants (96.77 cm) and was significantly superior to s_2 (two weeks after the commencement of S-W monsoon, 2019).

The interaction effect due to NK levels and time of sowing was significant at harvest. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) produced the tallest plants of 101.70 cm and was significantly superior to rest of the treatment combinations, followed by the treatment combination l_5s_1 (140:70 kg ha^{-1} of NK at 2:1ratio and sowing one week after the commencement of SW monsoon, 2019) recording a height of 99.56 cm. The shortest plants of 92.14 cm were produced by l_2s_2 (PGPR MIX 1, 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019).

4.1.2 Number of tillers m^{-2} (60 DAS)

The number of tillers m^{-2} influenced by NK ratios and time of sowing are given in the Tables 3a and 3b.

The results revealed significant influence of NK ratios and time of sowing on number of tillers m^{-2}. The treatment l_6 (140:105 kg ha^{-1} of NK atr2:1.5 ratio) produced maximum number of tillers (378.83) and was superior to all other treatments, followed by l_5 (140:70 kg ha^{-1} of NK at 2:1ratio) recording 361.66 tillers. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}) produced lowest tillers of 286.66. Regarding time of sowing maximum number of tillers (345.00) was observed in s_1 (sowing one week after the commencement of SW monsoon, 2019) and was significantly superior to s_2.

The interaction effect due to NK ratios and time of sowing was significant. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) produced the maximum tiller number of 415.67 and was significantly superior to all other treatment combinations. The treatment combination l_2s_2 PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) produced the minimum tillers of 285.67.

4.1.3 Leaf Area Index at 60 DAS

The mean data of leaf area index as influenced by treatments are given in the Tables 3a and 3b.

Neither the NK ratios and time of sowing nor their interaction significantly influenced the leaf area index at 60 days after sowing.

Table 2a. Effect of NK ratios and time of sowing on plant height, cm

Treatments	Plant height		
	30 DAS	60 DAS	At harvest
NK levels and ratios (L)			
l_1 (60:30)	45.15	82.64	92.95
l_2 (PGPR MIX I 6 kg + FYM 5 t)	45.03	82.58	92.62
l_3 (120:60)	46.90	83.79	95.62
l_4 (120:90)	47.60	86.90	96.87
l_5 (140:70)	48.74	86.92	97.63
l_6 (140:105)	49.45	89.22	99.23
SEm(±)	0.17	0.24	0.32
CD (0.05)	NS	0.722	0.966
Time of sowing			
s_1	47.57	85.96	96.77
s_2	46.72	84.73	94.87
SEm(±)	0.10	0.14	0.18
CD (0.05)	NS	0.417	0.558

Table 2b. Interaction effect of NK ratios and time of sowing on plant height, cm

Treatments	Plant height		
(l x s interaction)	30 DAS	60 DAS	At harvest
l_1s_1	45.53	83.39	93.09
l_1s_2	44.78	81.90	92.82
l_2s_1	45.30	83.48	93.10
l_2s_2	44.76	81.68	92.14
l_3s_1	47.53	83.95	95.78
l_3s_2	46.27	83.63	95.47
l_4s_1	47.63	87.74	97.43
l_4s_2	47.58	86.06	96.32
l_5s_1	49.36	87.29	99.56
l_5s_2	48.11	86.56	95.71
l_6s_1	50.05	89.90	101.70
l_6s_2	48.85	88.55	96.77
SEm(±)	0.24	0.34	0.46
CD (0.05)	NS	NS	1.367

4.1.4 Dry matter production (DMP) (60 DAS and harvest)

The DMP at 60 DAS and harvest as influenced by treatments are given in Tables 4a and 4b.

At 60 DAS, the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produceed the significantly highest dry matter production of 2181 kg ha^{-1}, followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) producing 2047 kg ha^{-1} and was on par with l_4 (120:90 kg ha^{-1} of NK at 2:1.5 ratio) recording 2028 kg ha^{-1}. The lowest DMP of 1149 kg ha^{-1} was recorded by l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}). The treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the maximum dry matter production of 1992 kg ha^{-1} and was significantly superior to s_2.

At harvest, treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) was significantly superior with a DMP of 5073 kg ha^{-1}, followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) recording 4937 kg ha^{-1}. The lowest DMP of 2927 kg ha^{-1}was recorded by the treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}). Regarding the time of sowing, treatments differed significantly and s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the maximum DMP of 4618 kg ha^{-1}.

The interaction effect due to NK ratios and time of sowing significantly influenced the DMP both at 60 DAS and at harvest. At 60 DAS treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) produced the maximum DMP of 2258 kg ha^{-1} and was superior to all other treatments, followed by the treatment combination l_5s_1 (140:70 kg ha^{-1} of NK at 2:1 ratio and time of sowing one week after the commencement of SW monsoon, 2019) with 2129 kg ha^{-1} and was on par with l_6s_2 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing two weeks after the commencement of SW monsoon, 2019), l_5s_2 (140:70 kg ha^{-1} of NK at 2:1 ratio and sowing two weeks after the commencement of SW monsoon, 2019) and l_4s_1 (120:90 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) . The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) produced the minimum DMP of 1123 kg ha^{-1}.

At harvest, the treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) produced the maximum DMP of 5256 kg ha^{-1} and was on par with l_5s_1 (140:70 kg ha^{-1} of NK at 2:1 ratio and sowing one week after the commencement of SW monsoon, 2019) with a DMP of 5180 kg ha^{-1} and significantly superior to all other treatment combinations. The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) produced the minimum DMP of 2897 kg ha^{-1}.

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Productive tillers m^{-2}

The data of productive tillers m^{-2} is presented in the Tables 5a and 5b.

The treatments exerted a significant influence on productive tillers m $^{-2}$. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the significantly highest number of productive tillers of 310.33. This was followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) 297.50. The lowest number of productive tillers of 261.00 was recorded by l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}). With respect to time of sowing, the treatments differed significantly and s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the maximum productive tillers of 285.72.

Interaction effect due to NK ratios and time of sowing significantly influenced productive tillers. The treatment combination of l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) produced the maximum productive tillers of 312.67 and was on par with l_6s_2 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing two weeks after the commencement of SW monsoon, 2019) recording 308.00 and significantly superior to all other treatments. The treatment l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) produced the lowest value of 260.33.

4.2.2 Length of panicle

The data of length of panicle as influenced by treatments are given in the Tables 5a and 5b.

Table 3a. Effect of NK ratios and time of sowing on number of tillers m $^{-2}$ and leaf area index at 60 days after sowing

Treatments	Number of tillers m^{-2}	Leaf area index
NK levels and ratios (L)		
l_1 (60:30)	294.00	3.12
l_2 (PGPR MIX I + FYM)	287.00	3.09
l_3 (120:60)	311.00	3.30
l_4 (120:90)	338.00	3.46
l_5 (140:70)	362.00	3.52
l_6 (140:105)	379.00	3.84
SEm(±)	2.56	0.02
CD (0.05)	7.585	NS
Time of sowing		
s_1	345.00	3.42
s_2	312.00	3.35
SEm(±)	1.48	0.01
CD (0.05)	4.379	NS

Table 3b. Interaction effect of NK ratios and time of sowing on number of tillers m^{-2} and leaf area index at 60 days after sowing

Treatments	Number of tillers m^{-2}	Leaf area index
(l x s interaction)		
l_1s_1	300.00	3.13
l_1s_2	289.00	3.11
l_2s_1	288.00	3.14
l_2s_2	286.00	3.04
l_3s_1	320.00	3.32
l_3s_2	302.00	3.28
l_4s_1	359.00	3.52
l_4s_2	317.00	3.40
l_5s_1	389.00	3.58
l_5s_2	334.00	3.49
l_6s_1	416.00	3.95
l_6s_2	342.00	3.73
SEm(±)	3.63	0.03
CD (0.05)	10.726	NS

Table 4a. Effect of NK ratios and time of sowing on dry matter production at different growth stages, kg ha^{-1}

Treatments	Dry matter production	
	60 DAS	Harvest
NK levels and ratios (L)		
l_1 (60:30)	1421	3473
l_2 (PGPR MIX I + FYM)	1149	2927
l_3 (120:60)	1863	4316
l_4 (120:90)	2028	4540
l_5 (140:70)	2047	4937
l_6 (140:105)	2181	5073
SEm(±)	23	21
CD (0.05)	66.4	61.9
Time of sowing		
s_1	1992	4618
s_2	1923	4369
SEm(±)	13	12
CD (0.05)	38.3	35.76

Table 4b. Interaction effect of NK ratios and time of sowing on dry matter production at different growth stages, kg ha^{-1}

Treatments	Dry matter production	
(l x s interaction)	60 DAS	At harvest
l_1s_1	1425	3516
l_1s_2	1416	3429
l_2s_1	1175	2956
l_2s_2	1123	2897
l_3s_1	1889	4405
l_3s_2	1837	4226
l_4s_1	2041	4678
l_4s_2	1927	4402
l_5s_1	2129	5180
l_5s_2	2052	4693
l_6s_1	2258	5256
l_6s_2	2104	4891
SEm(±)	32	30
CD (0.05)	93.9	87.6

The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the maximum panicle length of 22.72 cm and was superior to all other treatments, followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with 21.68 cm. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) recorded the shortest panicle length of 20.79 cm. Time of sowing had a profound influence on panicle length and the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the maximum panicle length of 21.85 cm and was significantly superior to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effect due to NK ratios and time of sowing did not significantly influence the length of panicle.

4.2.3 Grain weight panicle^{-1}

The data of grain weight panicle^{-1} as influenced by treatments are shown in the Tables 5a and 5b.

The NK ratios significantly influenced the grain weight panicle^{-1}. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the maximum value of 3.14 g, which was on par with l_5 (140:70 kg ha^{-1} of NK at 2:1ratio) with 3.09 g and was significantly superior to rest of the treatments. The treatment l_2 (PGPR MIX 1 6kg + FYM 5t ha^{-1}) resulted in the lowest value of 2.35 g. The time of sowing did not significantly influence grain weight panicle^{-1}.

The interaction effect of NK ratios and time of sowing did not significantly influence grain weight panicle^{-1}.

4.2.4 Number of spikelets panicle^{-1}

The data on number of spikelets panicle^{-1} as influenced by treatments are given in the Tables 6a and 6b.

Both the NK ratios and time of sowing significantly influenced the number of spikelets panicle^{-1}. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced significantly highest value of 132.33. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) resulted in the lowest value of 114.50. The time of sowing differed significantly and the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the highest value of 125.16.

The interaction effect due to NK ratios and time of sowing significantly influenced number of spikelets panicle^{-1}. The treatment combination l_6s_1 (140:105

kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) produced the maximum number of spikelets panicle^{-1} of 135.67 and was significantly superior to the treatment combinations. The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) produced the minimum number of spikelets panicle^{-1} of 113.33.

4.2.5 Percentage of filled grains

The data on percentage of filled grains is given in the Tables 6a and 6b.

The NK ratios and time of sowing significantly influenced the percentage of filled grains. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the maximum value of 87.33 per cent and was significantly superior to rest of the treatments. The lowest value of 79.50 per cent was recorded by the treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}). In the case of time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) recorded the highest value of 83.77 per cent and was significantly superior to s_2.

The interaction effect of NK ratios and time of sowing did not significantly influence the percentage of filled grains.

4.2.6 1000 grain weight

The data on grain yield as influenced by treatments and their interactions are furnished in the Tables 6a and 6b.

The NK ratios significantly influenced 1000 grain weight. Among the treatments, l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the highest 1000 grain weight (25.37 g) and was on par with l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) producing a value of 25.25 g and was superior to all other treatments. The lowest 1000 grain weight of 23.39 g was recorded by the treatment l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}).

Neither the time of sowing nor their interactions significantly influenced the 1000 grain weight.

4.2.7 Grain yield ha^{-1}

The data on grain yield as influenced by treatments and their interactions are furnished in the Tables 7a and 7b.

Table 5a. Effect of NK ratios and time of sowing on productive tillers m^{-2}, length of panicle and grain weight panicle^{-1}

Treatments	Productive tillers m^{-2}	Length of panicle (cm)	Grain weight panicle^{-1} (g)
NK levels and ratios (L)			
l_1 (60:30)	264.00	20.85	2.49
l_2 (PGPR MIX I + FYM)	261.00	20.79	2.35
l_3 (120:60)	275.00	21.42	2.51
l_4 (120:90)	285.00	21.53	2.89
l_5 (140:70)	297.00	21.68	3.09
l_6 (140:105)	310.00	22.72	3.14
SEm(±)	1.17	0.25	0.04
CD (0.05)	3.446	0.727	0.123
Time of sowing			
s_1	285.00	21.85	2.80
s_2	279.00	21.14	2.69
SEm(±)	0.67	0.14	0.02
CD (0.05)	1.990	0.420	NS

Table 5b. Interaction effect of NK ratios and time of sowing on productive tillers m^{-2}, length of panicle and grain weight panicle^{-1}

Treatments (l x s interaction)	Productive tillers m^{-2}	Length of panicle (cm)	Grain weight panicle^{-1} (g)
l_1s_1	264.00	20.90	2.51
l_1s_2	262.00	20.66	2.49
l_2s_1	261.00	20.60	2.38
l_2s_2	260.00	21.09	2.32
l_3s_1	278.00	22.03	2.53
l_3s_2	271.00	20.83	2.49
l_4s_1	292.00	22.20	2.97
l_4s_2	279.00	20.87	2.82
l_5s_1	302.00	22.18	3.19
l_5s_2	292.00	21.19	3.00
l_6s_1	312.00	23.23	3.31
l_6s_2	308.00	22.21	3.05
SEm(±)	1.65	0.35	0.06
CD (0.05)	4.874	NS	NS

Table 6a. Effect of NK ratios and time of sowing on number of spikelets $panicle^{-1}$, percentage of filled grains $panicle^{-1}$, and 1000 grain weight

Treatments	Number of spikelets $panicle^{-1}$	Percentage of filled grains $panicle^{-1}$	1000 grain weight (g)
NK levels and ratios (L)			
l_1 (60:30)	117.00	80.50	24.10
l_2 (PGPR MIX I + FYM)	115.00	79.50	23.39
l_3 (120:60)	122.00	81.50	24.32
l_4 (120:90)	124.00	82.50	25.08
l_5 (140:70)	129.00	85.33	25.25
l_6 (140:105)	132.00	87.33	25.37
SEm(±)	0.69	0.44	0.10
CD (0.05)	2.038	1.283	0.280
Time of sowing			
s_1	125.00	83.77	24.69
s_2	121.00	81.77	24.42
SEm(±)	0.40	0.25	0.06
CD (0.05)	1.17	0.741	NS

Table 6b. Interaction effect of NK ratios and time of sowing on number of spikeletspanicle^{-1}, percentage of filled grains panicle^{-1}, and 1000 grain weight

Treatments (l x s interaction)	Number of spikelets panicle^{-1}	Percentage of filled grains panicle^{-1}	1000 grain weight (g)
l_1s_1	117.00	81	24.11
l_1s_2	116.00	80	24.09
l_2s_1	116.00	80	23.59
l_2s_2	113.00	79	23.19
l_3s_1	123.00	82	24.54
l_3s_2	120.00	81	24.08
l_4s_1	127.00	84	25.08
l_4s_2	120.00	81	25.07
l_5s_1	132.00	87	25.42
l_5s_2	126.00	84	25.07
l_6s_1	136.00	89	25.72
l_6s_2	129.00	86	25.31
SEm(±)	0.98	0.62	0.14
CD (0.05)	2.883	NS	NS

Both the NK ratios and time of sowing significantly influenced the grain yield. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the highest grain yield of 2841 kg ha^{-1} and was significantly superior to rest of the treatments. This was followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with an yield of 2758 kg ha^{-1}. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) produced the lowest grain yield of 850 kg ha^{-1}. With regard to time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the highest grain yield of 2338 kg ha^{-1} as compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019) with a grain yield of 2187 kg ha^{-1}.

The interaction effects showed significant difference on grain yield. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) produced the significantly highest grain yield of 2983 kg ha^{-1}, followed by l_5s_1 (140:70 kg ha^{-1} of NK at 2:1 ratio and sowing one week after the commencement of SW monsoon, 2019) producing 2850 kg ha^{-1}. The lowest grain yield of 842 kg $ha^{-1}$was recorded in the treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019).

4.2.8 Straw yield ha^{-1}

The data on straw yield as influenced by treatments and their interactions are given in the Tables 7a and 7b.

Both the NK ratios and time of sowing differed significantly on straw yield. The maximum straw yield of 3441 kg ha^{-1} was recorded in the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) and was on par with l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with a straw yield of 3358 kg ha^{-1} and significantly superior to rest of the treatments. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) produced the lowest straw yield of 1560 kg ha^{-1}. With respect to time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the highest straw yield of 2962 kg ha^{-1} compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019) with a straw yield of 2809 kg ha^{-1}.

The interaction effect showed significant difference on straw yield. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) produced the highest straw yield of 3583 kg ha^{-1} and was on par with l_5s_1 (140:70 kg ha^{-1} of NK at 2:1 ratio and sowing one week after the commencement of SW monsoon, 2019) producing 3466 kg ha^{-1}. The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) produced the lowest straw yield of 1531 kg ha^{-1}.

4.2.9 Harvest index

The data on harvest index as influenced by treatments are shown in the Tables 7a and 7b.

Neither the NK ratios, time of sowing nor their interactions significantly influenced the harvest index.

4.3 PHYSIOLOGICAL ESTIMATIONS

4.3.1 Proline content at panicle initiation

The data on proline content as influenced by treatments are shown in the Tables 8a and 8b.

Neither the NK ratios, time of sowing nor their interactions significantly influenced the proline content.

4.3.2 Relative LWC at flowering stage

The data on RLWC as influenced by treatments are given in the Tables 8a and 8b.

Neither the NK ratios, time of sowing nor interactions significantly influenced RLWC.

4.3.3 Chlorophyll content at panicle emergence stage

The data on chlorophyll content as influenced by treatments are given in the Tables 8a and 8b.

Neither the NK ratios, time of sowing nor their interactions significantly influenced the chlorophyll content.

4. CHEMICAL ANALYSIS

4.4.1 Nutrient use efficiency

4.4.1.1 Nitrogen use efficiency (NUE)

Table 7a.Effect of NK ratios and time of sowing on grain yield, straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
NK levels and ratios (L)			
l_1 (60:30)	1895	2520	0.43
l_2 (PGPR MIX I + FYM)	850	1560	0.36
l_3 (120:60)	2558	3208	0.44
l_4 (120:90)	2675	3225	0.45
l_5 (140:70)	2758	3358	0.45
l_6 (140:105)	2841	3441	0.45
SEm(±)	27	33	0.01
CD (0.05)	82.5	96.9	NS
Time of sowing			
s_1	2338	2962	0.44
s_2	2187	2809	0.43
SEm(±)	16	19	0.01
CD (0.05)	87.8	55.9	NS

Table 7b. Interaction effect of NK ratios and time of sowing on grain yield, straw yield and harvest index

Treatments (l x s interaction)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
l_1s_1	1920	2552	0.43
l_1s_2	1869	2489	0.43
l_2s_1	858	1589	0.35
l_2s_2	842	1531	0.35
l_3s_1	2666	3250	0.45
l_3s_2	2450	3166	0.44
l_4s_1	2750	3333	0.45
l_4s_2	2600	3116	0.45
l_5s_1	2850	3466	0.45
l_5s_2	2666	3250	0.44
l_6s_1	2983	3583	0.46
l_6s_2	2700	3300	0.45
SEm(±)	39	46	0.01
CD (0.05)	78.9	137.1	NS

Table 8a. Effect of NK ratios and time of sowing on proline content, relative leaf water content and chlorophyll content

Treatments	Proline content (µmol g^{-1} FW)	Relative leaf water content(%)	Chlorophyll content (mg g^{-1} FW)
NK levels and ratios (L)			
l_1 (60:30)	0.42	78.25	0.90
l_2 (PGPR MIX I + FYM)	0.41	77.58	0.89
l_3 (120:60)	0.44	78.66	0.92
l_4 (120:90)	0.45	79.79	0.94
l_5 (140:70)	0.48	80.31	0.95
l_6 (140:105)	0.48	81.38	0.98
SEm(±)	0.01	0.06	0.01
CD (0.05)	NS	NS	NS
Time of sowing			
s_1	0.46	80.19	0.95
s_2	0.44	78.47	0.91
SEm(±)	0.01	0.04	0.01
CD (0.05)	NS	NS	NS

Table 8b. Interaction effect of NK ratios and sowing time on proline content, relative leaf water content and chlorophyll content

Treatments (l x s interaction)	Proline content (µmol g^{-1} FW)	Relative leaf water content(%)	Chlorophyll content (mg g^{-1} FW)
l_1s_1	0.42	78.82	0.91
l_1s_2	0.43	77.68	0.89
l_2s_1	0.41	78.09	0.90
l_2s_2	0.40	77.07	0.89
l_3s_1	0.45	79.26	0.93
l_3s_2	0.42	78.07	0.90
l_4s_1	0.47	80.96	0.96
l_4s_2	0.44	78.61	0.92
l_5s_1	0.49	81.46	0.98
l_5s_2	0.46	79.17	0.92
l_6s_1	0.49	82.52	1.02
l_6s_2	0.46	80.24	0.94
SEm(±)	0.01	0.09	0.01
CD (0.05)	NS	NS	NS

Table 9a. Effect of NK ratios and sowing time on nitrogen use efficiency, phosphorus use efficiency and potassium use efficiency

Treatments	Nitrogen use efficiency (kg of grain kg^{-1} N)	Potassium use efficiency (kg of grain kg^{-1} K_2O)
NK levels and ratios (L)		
l_1 (60:30)	31.58	63.17
l_2 (PGPR MIX I + FYM)	34.00	34.00
l_3 (120:60)	21.31	42.63
l_4 (120:90)	22.29	29.72
l_5 (140:70)	19.70	39.40
l_6 (140:105)	20.29	27.05
SEm(±)	0.50	0.46
CD (0.05)	1.498	1.356
Time of sowing		
s_1	25.51	40.43
s_2	24.21	38.25
SEm(±)	0.29	0.25
CD (0.05)	0.865	0.732

Table 9b. Effect of NK ratios and sowing time on nitrogen use efficiency, phosphorus use efficiency and potassium use efficiency

Treatments (l x s interaction)	Nitrogen use efficiency (kg of grain kg^{-1} N)	Potassium use efficiency (kg of grain kg^{-1} K_2O)
l_1s_1	32.00	64.00
l_1s_2	31.15	62.30
l_2s_1	34.32	34.32
l_2s_2	33.68	33.68
l_3s_1	22.21	44.43
l_3s_2	20.41	40.83
l_4s_1	22.91	30.55
l_4s_2	21.67	28.89
l_5s_1	20.36	40.71
l_5s_2	19.04	38.09
l_6s_1	21.31	28.41
l_6s_2	19.28	25.71
SEm(±)	1.25	1.16
CD (0.05)	3.567	2.986

The data on NUE as influenced by treatments and their interactions are given in the Tables 9a and 9b.

Both the NK ratios and time of sowing significantly influenced the NUE. Among the treatments, l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) resulted in the highest nitrogen use efficiency of 32.00 kg of grains kg^{-1} N and was significantly superior to rest of the treatments. The treatment l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) had the lowest NUE (19.70 kg of grains kg^{-1} N). With regard to time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the highest value of 25.51 kg of grains kg^{-1} N and was significantly superior to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effects due to NK ratios and sowing time significantly influenced the NUE. The treatment combination l_2s_1 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing one week after the commencement of SW monsoon, 2019) had the highest value of 34.32 kg of grains kg^{-1} N and was on par with l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019), l_1s_1 (60:30 kg ha^{-1} of NK at 2:1 ratio and sowing one week after the commencement of SW monsoon, 2019) and l_1s_2 (60:30 kg ha^{-1} of NK at 2:1 ratio and sowing two weeks after the commencement of SW monsoon, 2019). The treatment combination l_5s_2 (140:70 kg ha^{-1} of NK at 2:1 ratio and sowing two weeks after the commencement of SW monsoon, 2019) registered the lowest value of 19.04 kg of grains kg^{-1} N.

4.4.2 Potassium use efficiency (KUE)

The data on KUE as influenced by treatments and their interactions are given in the Tables 9a and 9b.

Both the NK ratios and time of sowing significantly influenced the potassium use efficiency. Among the treatments, l_1 (60:30 kg ha^{-1} of NK at 2:1 ratio) resulted in the highest KUE of 63.17 kg of grains kg^{-1} K_2O and was significantly superior to rest of the treatments. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the lowest KUE (27.05 kg of grains kg^{-1} K_2O). With regard to time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest value of 40.43 kg of grains kg^{-1} K_2O and was significantly superior to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effects due to NK ratios and sowing time significantly influenced the KUE. The treatment combination l_1s_1 (60:30 kg ha^{-1} of NK at 2:1 ratio and sowing one week after the commencement of SW monsoon, 2019) resulted in the highest value of 64.00 kg of grains kg^{-1} K_2O and was on par with l_1s_2 (60:30 kg ha^{-1} of NK at 2:1 ratio and sowing two weeks after the commencement of SW monsoon, 2019) with a value of 62.30 kg of grains kg^{-1} K_2O. The treatment combination l_6s_2 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) had the lowest value of 25.71 kg of grains kg^{-1} K_2O.

4.4.2 Soil analysis after harvest

4.4.2.1 Available Nitrogen in soil

The data on available nitrogen in soil as influenced by treatments are given in the Tables 10a and 10b.

The NK ratios and time of sowing significantly influenced the available nitrogen in soil. Among the treatments, l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the highest available nitrogen of 319.50 kg ha^{-1} and was followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with a status of 315.07 kg ha^{-1}. The treatment l_2 (PGPR MIX 1 6kg + FYM 5t ha^{-1}) had the lowest available nitrogen (266.50 kg ha^{-1}). In the case of time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest value of 302.98 kg ha^{-1} compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effect due to NK ratios and time of sowing did not significantly influence the available nitrogen in the soil.

4.4.2.2. Available Phosphorus in soil

The data on available phosphorus in soil as influenced by treatments are given in the Tables 10a and 10b.

NK ratios, sowing time and their interactions did not significantly influence available phosphorus in soil.

4.4.2.3 Available Potassium in soil

The data on available potassium in soil as influenced by treatments are given in the Tables 10a and 10b.

The NK ratios and time of sowing significantly influenced the available potassium in soil. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the highest available potassium (343.91 kg ha^{-1}) and was followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with K status of 335.97 kg ha^{-1} and significantly superior to other treatments. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) had the lowest value (201.97 kg ha^{-1}). Regarding the time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest value of 272.36 kg ha^{-1}compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effect due to NK ratios and time of sowing did not influence significantly on available potassium in the soil.

4.4.2.4 Organic carbon content

The data on organic carbon content in soil as influenced by treatments are given in the Tables 10a and 10b.

NK ratios, sowing time and its interactions did not significantly influence organic carbon content in soil.

4.4.3 NPK uptake by crop at harvest

4.4.3.1 Uptake of Nitrogen

The data on uptake of nitrogen as influenced by treatments are given in the Tables 11a and 11b.

The NK ratios and time of sowing significantly influenced the uptake of nitrogen. The maximum uptake of nitrogen (89.68 kg ha^{-1}) was observed in the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) and was followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with a value of 86.80 kg ha^{-1} and significantly superior to other treatments. The treatment l_2 (PGPR MIX 1 6kg + FYM 5t ha^{-1}) had the lowest value (11.21 kg ha^{-1}). With respect to time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest value of 61.54 kg ha^{-1} compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

Table 10a. Effect of NK ratios and sowing time on available NPK and organic carbon status of the soil after harvest

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic carbon content (%)
NK levels and ratios (L)				
l_1 (60:30)	290.15	32.21	209.55	0.74
l_2 (PGPR MIX I + FYM)	266.50	31.09	201.97	0.72
l_3 (120:60)	308.92	33.30	245.53	0.74
l_4 (120:90)	310.08	33.78	287.88	0.74
l_5 (140:70)	315.07	34.25	335.97	0.75
l_6 (140:105)	319.50	34.89	343.91	0.75
SEm(±)	0.37	0.19	0.32	0.01
CD (0.05)	1.101	NS	0.951	NS
Time of sowing				
s_1	302.98	33.73	272.36	0.74
s_2	300.42	33.39	269.23	0.73
SEm(±)	0.22	0.08	0.19	0.01
CD (0.05)	0.636	NS	0.549	NS

Table 10b. Interaction effect of NK ratios and sowing time on available NPK and organic carbon status of the soil after harvest

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic carbon content (%)
(l x s interaction)				
l_1s_1	291.49	34.60	210.09	0.74
l_1s_2	288.80	31.22	209.01	0.73
l_2s_1	268.10	30.97	202.93	0.72
l_2s_2	264.90	32.14	201.01	0.71
l_3s_1	310.09	34.25	247.57	0.74
l_3s_2	307.74	34.35	243.48	0.73
l_4s_1	311.62	34.18	289.16	0.74
l_4s_2	308.53	34.13	286.60	0.74
l_5s_1	317.04	34.67	336.69	0.75
l_5s_2	313.10	34.43	335.25	0.75
l_6s_1	319.56	33.73	347.77	0.75
l_6s_2	319.45	34.05	340.05	0.74
SEm(±)	0.53	0.28	0.46	0.01
CD (0.05)	NS	NS	NS	NS

The interaction effect showed significant difference on uptake of nitrogen. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) showed the highest uptake of nitrogen (90.10 kg ha^{-1}) and was on par with l_6s_2 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing two weeks after the commencement of SW monsoon, 2019) recording 89.25 kg ha^{-1}.The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) had the lowest uptake of nitrogen (11.16 kg ha^{-1}).

4.4.3.2 Uptake of Phosphorus

The data on uptake of phosphorus as influenced by treatments are given in the Tables 11a and 11b.

Both the NK ratios and time of sowing significantly influenced the uptake of phosphorus. Among the treatments, l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the maximum uptake of phosphorus (13.20 kg ha^{-1}), followed by l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with uptake of 12.80 kg ha^{-1} which were on par. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) had the lowest uptake of phosphorus (3.07 kg ha^{-1}). With regard to time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest value of 10.89 kg ha^{1} compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019) but was on par with s_2.

The interaction effect due to NK ratios and time of sowing differed significantly. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) showed the highest phosphorus uptake (13.25 kg ha^{-1}) and was on par with l_6s_2 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing two weeks after the commencement of SW monsoon, 2019), l_5s_1 (140:70 kg ha^{-1} of NK at 2:1 ratio and time of sowing one week after the commencement of SW monsoon, 2019) and l_5s_2 (140:70 kg ha^{-1} of NK at 2:1 ratio and sowing two weeks after the commencement of SW monsoon, 2019) . The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) had the lowest value of 3.04 kg ha^{-1}.

4.4.3.3 Uptake of Potassium

The data on uptake of potassium as influenced by treatments are given in the Tables 11a and 11b.

The NK ratios and time of sowing significantly influenced the uptake of potassium. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the maximum uptake of potassium (75.17 kg ha^{-1}), followed by l_4 (120:90 kg ha^{-1} of NK at 2:1.5 ratio) with uptake of 51.73 kg ha^{1} and significantly superior to rest of the treatments. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) showed the lowest uptake of potassium (12.35 kg ha^{-1}). Regarding time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had significantly higher value of 40.42 kg ha^{-1} compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effect showed significant difference on uptake of potassium. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of S-W monsoon, 2019) had the highest uptake of potassium (76.12 kg ha^{-1}). The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) had the lowest value of 12.26 kg ha^{-1}.

4.4.4 Protein content of grain

The mean data on protein content of grain as influenced by different treatments are given in the Tables 12a and 12b.

NK ratios significantly influenced the grain protein content. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the highest grain protein content (5.34 per cent) and was on par with l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with protein content of 5.13 per cent. The lowest grain protein content of 4.17 per cent was recorded in the treatment l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}). Sowing time and its interaction did not significantly influence the protein content of grain.

4.5 OBSERVATIONS ON MAJOR WEEDS OF UPLAND RICE

The major weeds observed in the field were grasses: *Cynodon dactylon, Echinochloa colona* and *Dactyloctnium aegyptium.* Broad leaved weeds: *Alternanthera sessilis, Phyllanthus niruri, Mimosa pudica and Amaranthus sp.* Sedges: *Cyperus rotundus.*

Table 11a. Effect of NK ratios and time of sowing on N, P and K uptake by crop at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
NK levels and ratios (L)			
l_1 (60:30)	35.20	11.25	20.14
l_2 (PGPR MIX I + FYM)	11.21	3.07	12.35
l_3 (120:60)	72.79	12.32	35.69
l_4 (120:90)	72.19	12.54	51.73
l_5 (140:70)	86.80	12.80	45.17
l_6 (140:105)	89.68	13.20	75.17
SEm(±)	0.32	0.15	0.18
CD (0.05)	0.94	0.465	0.543
Time of sowing			
s_1	61.54	10.89	40.42
s_2	60.75	10.79	39.66
SEm(±)	0.18	0.12	0.11
CD (0.05)	0.542	0.378	0.314

Table 11b. Interaction effect of NK ratios and time of sowing on N, P and K uptake by crop at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
(l x s interaction)			
l_1s_1	35.26	11.29	20.22
l_1s_2	35.14	11.08	20.05
l_2s_1	11.26	3.10	12.45
l_2s_2	11.16	3.05	12.26
l_3s_1	72.14	12.24	35.65
l_3s_2	71.45	12.18	35.74
l_4s_1	72.32	12.55	52.00
l_4s_2	72.06	12.46	51.45
l_5s_1	88.15	12.91	46.10
l_5s_2	85.45	12.82	44.24
l_6s_1	90.10	13.25	76.12
l_6s_2	89.25	13.14	74.22
SEm(±)	0.45	0.14	0.26
CD (0.05)	1.328	0.431	0.768

Table 12a. Effect of NK ratios and sowing time on protein content of grain, %

Treatments	Protein content of grain
NK levels and ratios (L)	
l_1 (60:30)	4.37
l_2 (PGPR MIX I + FYM)	4.17
l_3 (120:60)	4.57
l_4 (120:90)	4.89
l_5 (140:70)	5.13
l_6 (140:105)	5.34
SEm(±)	0.14
CD (0.05)	0.389
Time of sowing	
s_1	4.83
s_2	4.66
SEm(±)	0.01
CD (0.05)	NS

Table 12b. Interaction effect of NK ratios and sowing time on protein content of grain, %

Treatments	Protein content of grain
(l x s interaction)	
l_1s_1	4.40
l_1s_2	4.34
l_2s_1	4.24
l_2s_2	4.10
l_3s_1	4.66
l_3s_2	4.48
l_4s_1	4.94
l_4s_2	4.83
l_5s_1	5.23
l_5s_2	5.02
l_6s_1	5.48
l_6s_2	5.19
SEm(±)	0.02
CD (0.05)	NS

4.6 PEST AND DISEASE INCIDENCE

The major pest observed in the field was rice gundhi bug (*Leptocorisa acuta*) and the disease incidence was grain discolouration. Suitable control measures as detailed in the materials and methods were adopted.

4.7 ECONOMIC ANALYSIS

4.7.1 Gross income

The mean data on gross income as influenced by different treatments are given in the Tables 13a and 13b.

The NK ratios and time of sowing significantly influenced the gross income. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the highest gross income (₹130845 ha $^{-1}$) and was on par with l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with ₹ 127110 ha^{-1} and l_4 (120:90 kg ha^{-1} of NK at 2:1.5 ratio) with ₹ 123125 ha $^{-1}$. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}) resulted in the lowest gross income of ₹ 41800 ha $^{-1}$. In the case of time of sowing, treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest gross income (₹108324 ha $^{-1}$) compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effect showed significant difference on gross income. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) resulted in the highest gross income of ₹137235 ha^{-1} and was on par with l_5s_1 (140:70 kg ha^{-1} of NK at 2:1 ratio and sowing one week after the commencement of SW monsoon, 2019) and l_4s_1 (120:90 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of S-W monsoon, 2019). The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) had the lowest gross income of ₹41335 ha^{-1}.

4.7.2 Net income

The mean data on net income as influenced by different treatments are given in the Tables 13a and 13b.

The NK ratios and time of sowing significantly influenced net income. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the highest net income (₹ 55941 ha $^{-1}$) and was on par with l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio) with a profit of ₹ 53342 ha^{-1}. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}) had the lowest net income of ₹ 10372 ha $^{-1}$. In the case of time of sowing, the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in highest net income (₹ 44243 ha $^{-1}$) compared to s_2 (sowing two weeks after the commencement of SW monsoon, 2019).

The interaction effect showed significant difference on net income. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) had the highest net income of ₹ 62331 ha^{-1} and was on par with l_5s_1 (140:70 kg ha^{-1} of NK at 2:1 ratio and time of sowing one week after the commencement of SW monsoon, 2019) and l_4s_1 (120:90 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019). The treatment combination l_2s_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and sowing two weeks after the commencement of SW monsoon, 2019) resulted in the lowest net income of ₹ 9907 ha^{-1}.

4.7.3 B:C ratio

The data on benefit cost ratio as influenced by different treatments are given in the Tables 13 a and 13b

NK ratios significantly influenced B:C ratio. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the highest BC ratio (1.74) and was on par with l_5 (140:70 kg ha^{-1} of NK at 2:1 ratio), l_4 (120:90 kg ha^{-1} of NK at 2:1.5 ratio) and l_3 (120:60 kg ha^{-1} of NK at 2:1ratio). The treatment l_2 (PGPR MIX 1 6kg + FYM 5t ha^{-1}) resulted in the lowest B:C ratio (1.33).Sowing time and its interaction with NK ratios did not significantly influence B:C ratio.

Table 13a. Effect of NK ratios and sowing time on gross income, net income and benefit cost ratio

Treatments	Gross income (₹ha^{-1})	Net income (₹ ha^{-1})	Benefit cost ratio
NK levels and ratios (L)			
l_1 (60:30)	88400	27684	1.46
l_2 (PGPR MIX I + FYM)	41800	10372	1.33
l_3 (120:60)	118360	47546	1.67
l_4 (120:90)	123125	50250	1.68
l_5 (140:70)	127110	53342	1.72
l_6 (140:105)	130845	55941	1.74
SEm(±)	4507	1056	0.04
CD (0.05)	10854.2	4563.2	0.124
Time of sowing			
s_1	108324	44243	1.63
s_2	101557	38757	1.53
SEm(±)	2265	856	0.025
CD (0.05)	6246.8	3568.2	NS

Table 13b. Interaction effect of NK ratios and sowing time on gross income, net income and benefit cost ratio

Treatments	Gross income (₹ ha^{-1})	Net income (₹ha^{-1})	Benefit cost ratio
(l x s interaction)			
l_1s_1	89560	28861	1.47
l_1s_2	87205	26506	1.44
l_2s_1	42265	10837	1.34
l_2s_2	41335	9907	1.31
l_3s_1	122890	52076	1.73
l_3s_2	113830	43016	1.61
l_4s_1	126665	53790	1.73
l_4s_2	119580	46705	1.64
l_5s_1	131330	57562	1.78
l_5s_2	122890	49122	1.67
l_6s_1	137235	62331	1.83
l_6s_2	124500	49596	1.66
SEm(±)	4625	2546	0.02
CD (0.05)	12368.2	9756.4	NS

Discussion

5. DISCUSSION

The results of the field experiment entitled “Sowing time and nutrient management for productivity enhancement of upland rice (*Oryza sativa* L.)” conducted at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram are briefly discussed here under.

5.1 GROWTH CHARACTERS

The NK ratios, time of sowing and their interactions significantly influenced the growth parameters like plant height and dry matter production at 60 DAS and harvest, while tiller number m^{-2} was significantly influenced by treatments at 60 DAS.

The NK ratios and time of sowing did not significantly influence plant height at 30 DAS, but there was significant influence on later stages (60 DAS and harvest) as evident from Table 2a and Fig 3. Growth is an irreversible progressive development of crop over a period of time. There was progressive increase in growth measured in terms of plant height, DMP and leaf area index as the crop advanced to maturity. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the tallest plants, both at 60 DAS and at harvest. It is mainly attributable to higher doses of nitrogen and potassium (l_6) over other treatments. Nitrogen is one of the major nutrients needed for the plant growth. It is essential for the synthesis of proteins, a constituent of protoplasm which is considered as physiological basis of life. N is important for chloroplast synthesis. The increased plant height is mainly due to cell elongation, meristematic activity and increased photosynthetic rate. Kumar (2016) reported that application of 120 kg N ha^{-1} produced the tallest plants at 60 DAS and harvest. According to Gewaily *et al* (2018), the tallest plants were obtained when 220 kg N ha^{-1} was applied. Greeshma (2019) also made similar observation in upland rice. Favourable effect on plant height due to K application was noticed at 60 DAS and at harvest. Application of K at 105 kg ha^{-1} significantly influenced plant height (Tables 2a and 2b). Potassium strengthens the cell wall, helps in the growth of meristematic tissue, and enables the plant to withstand biotic and abiotic stresses. Ranjini (2002) obtained higher plant height in upland rice at higher K levels up to 45 kg ha^{-1}. Mini (2005) reported increased plant height in upland rice due to K application up to 50 kg ha^{-1}. This is in conformity with the findings of Kumar (2016) and Greeshma (2019) in upland rice.

The time of sowing significantly influenced the plant height at 60 DAS and harvest. The treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the tallest plants (Table 2a and Fig 3). The SW monsoon commenced on 04/06/2019 with a rainfall of 58.9 mm and sowing as per treatment s_1 was done on 13/06/2019. There was an effective rainfall of 960.7 mm in 50 rainy days for treatment s_1 during the growing period. With respect to treatment s_2 (sowing two weeks after the commencement of SW monsoon), sowing was done on 21/06/2019 and there was an effective rainfall of 754.6 mm in 40 rainy days during the growing period. The treatment s_1 received an additional 206.1 mm of rainfall. This might have improved moisture content of the soil and favoured the microclimate, thereby helped the plant to put forth more height. The abiotic stress, especially moisture stress was reduced to a considerable extent during early stages of crop growth in treatment. The improved growth in s_1 can be attributed to optimum environmental conditions such as moisture availability for crop development and the availability of prolonged period for vegetative growth compared to s_2. This corroborates with the findings of Bashir *et al.* (2010) and Abid *et al.* (2015) in rice. The favourable microclimate created in s_1 helped the rice plant to put forth faster growth as compared to s_2.The interaction effect was not significant at 60 DAS, but significant at harvest (Table 2b). The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) produced the tallest plants. The better utilization of N and K with optimum moisture might have helped the plants to grow taller.

The NK ratios, time of sowing and their interactions significantly influenced the number of tillers m^{-2} at 60 DAS (Tables 3a and 3b). The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the maximum tillers. Application of higher levels of N and K (140:105 kg ha^{-1}at 2:1.5 ratio) favourably influenced tillering. This might be due to more availability of N and K for crop growth. Higher levels of K improved tillering by way of favouring protein synthesis and imparting drought tolerance. Kumar (2016) obtained increased tillering when N and K were applied at 120 kg and 60 kg ha $^{-1}$ respectively. Application of N at 180 kg ha^{-1} produced the maximum tillers in rice (Sivasabari and Jothimani, 2017).Greeshma (2019) reported the maximum tiller number m^{-2} at the NK level of 120:90 kg ha^{-1} (2:1.5 ratio) in upland rice. Ranjini

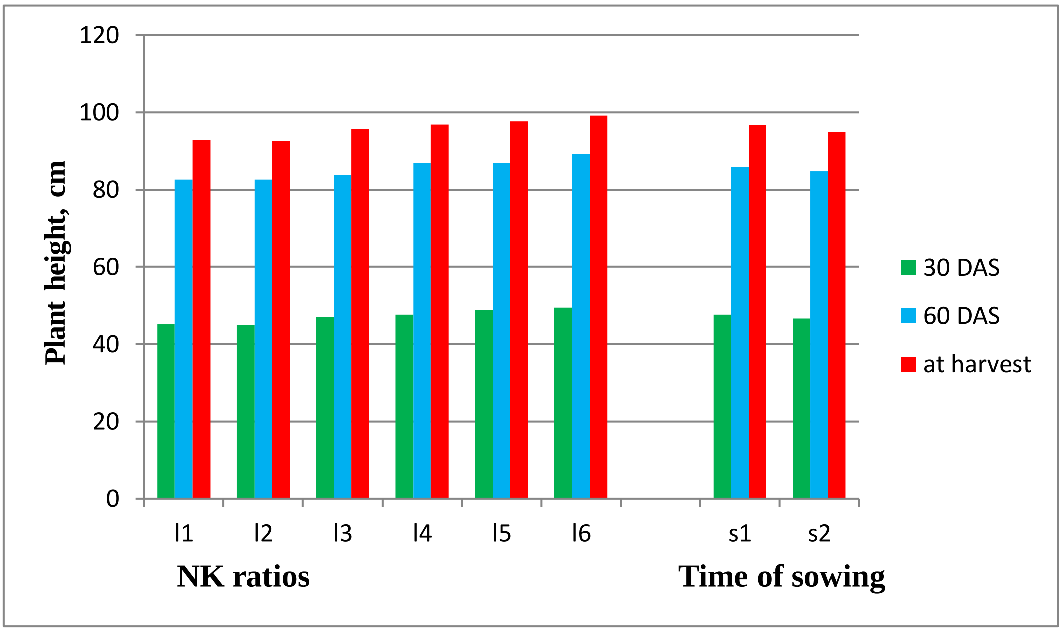

Fig. 3 Effect of NK ratios and time of sowing on plant height, cm

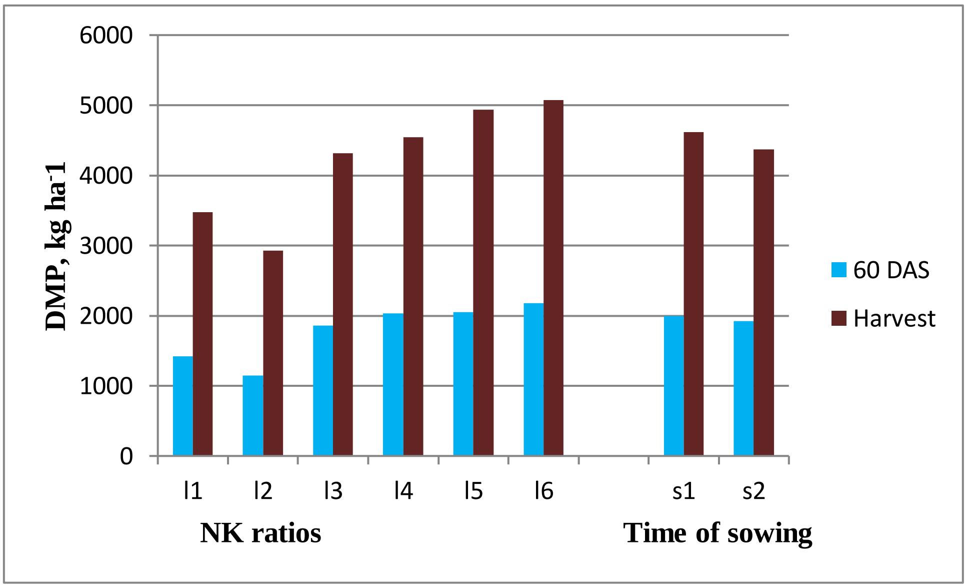

Fig. 4 Effect of NK ratios and time of sowing on dry matter production, kg ha^{-1}

(2002) reported that application of 90 kg N and 45 kg K_2O ha $^{-1}$ increased tillering in upland rice. Further it was observed that increased levels of N and K promoted absorption of nutrients, accumulation of photosynthates and ultimately increased growth characters. Time of sowing showed significant difference on tiller number. The maximum tiller production was recorded in the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019). Late sowing reduced tillering. The supremacy of s_1 over s_2 might be due to the longer vegetative period, better microclimate coupled with higher moisture content, thereby enabling the plant to produce more tillers. This was in conformity with the findings of Rai and Kushwaha (2008) in rice. Among the treatment combinations, l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) produced the maximum tiller number. Better microclimate and increased moisture availability coupled with minimum abiotic stress in s_1 might have helped the plants to produce more tillers with higher availability of nutrients, especially N and K in treatment l_6.

The results revealed that the leaf area index at 60 DAS was not significantly influenced by the NK ratios, time of sowing and their interaction (Table 3). Though not significant, the treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum leaf area index.

The DMP was significantly influenced by the NK ratios and time of sowing and their interaction, both at 60 DAS and at harvest (Tables 4a, 4b and Fig. 4, 5). There was progressive increase in DMP with additional increment of N and K. The maximum DMP was observed in the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) at 60 DAS and harvest. Increased levels of N and K might have promoted vegetative growth in terms of height, tiller number and leaf area, there by leading to higher photosynthetic rate and better translocation of photosynthates. Anu (2001) obtained similar results in upland rice at 80:45 kg ha^{-1} N and K. Kumar (2016) obtained the highest DMP at NK applied at 120 kg and 60 kg ha^{-1}in upland rice. Greeshma (2019) reported the maximum DMP at NK applied at 120:60 kg ha^{-1}in upland rice. The time of sowing imparted significant difference on DMP both at 60 DAS and at harvest. The highest DMP was recorded by the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019). The better utilization of resources such as moisture and nutrients coupled with favourable microclimate in s_1 might have helped the crop to tap more photosynthates thereby leading to higher DMP. This is in conformity with the findings of Gill *et al.* (2006) in direct sown rice. The treatment combinations l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum DMP due to the adequate availability of soil moisture and nutrients (Table 4b and Fig 5).

5.2 YIELD ATTRIBUTES AND YIELD

The results revealed that the yield attributes such as productive tillers m^{-2}, length of panicle, grain weight $panicle^{-1}$, number of spikelets $panicle^{-1}$, percentage of filled grains $panicle^{-1}$ and 1000 grain weight (Tables 5a, 6a and Fig. 6) and yield (Table 7a and Fig. 8) were significantly influenced by the NK ratios and time of sowing.

Among the treatments, l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the maximum value for the above mentioned yield attributing characters. The increased dose of N and K improved photosynthesis and other physiological and metabolic processes like enzyme activation, protein synthesis and cell expansion coupled with higher nutrient uptake, DMP and efficient translocation to sink. The effect of major nutrients on yield attributes is primarily a function of assimilate accumulation which in turn facilitated higher nutrient assimilation with adequate supply of photosynthates to grain increased crop uptake resulting in better crop growth. Potassium nutrition improved germination of pollen in the flore,t which led to high spikelet fertility in rice. Higher dose of N and K provided continuous and steady supply of nutrients into the soil solution to match the nutrient requirement of crop, which consequently resulted in the production of longer panicles with more number of filled grains $panicle^{-1}$. Mini (2005) reported higher values for yield attributes at NK ratios of 100:50 kg ha^{-1} in upland rice. Higher yield attributes were obtained with N and K applied at 50 and 25 kg ha^{-1} respectively (Akanda *et al*., 2012). Kumar (2016) reported higher yield attributes at N and K applied at 120:60 kg ha^{-1} in upland rice. Greeshma (2019) obtained higher yield attributes, when N and K were applied at

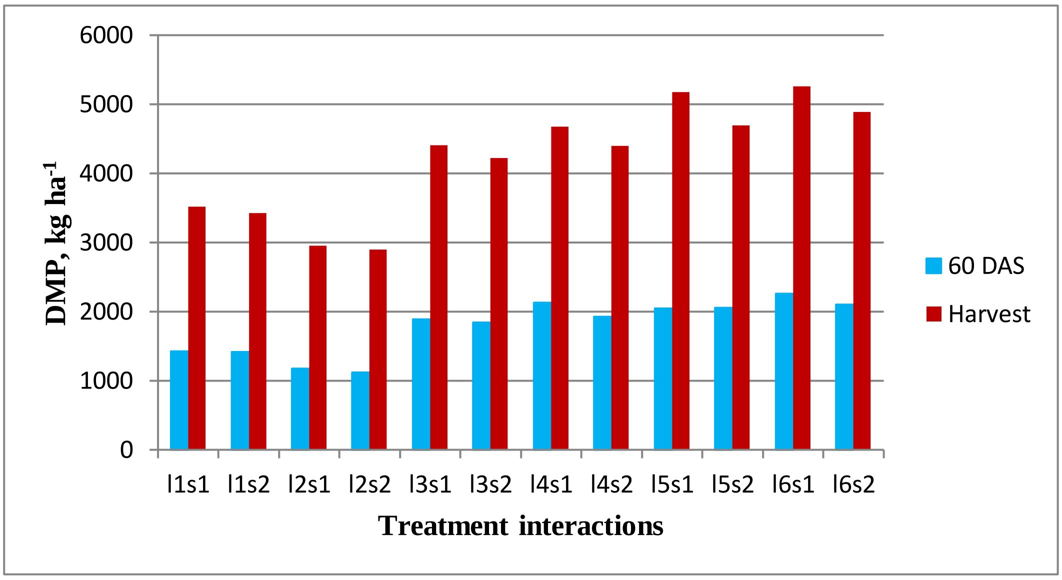

Fig. 5 Interaction effect of NK ratios and time of sowing on dry matter production, kg ha^{-1}

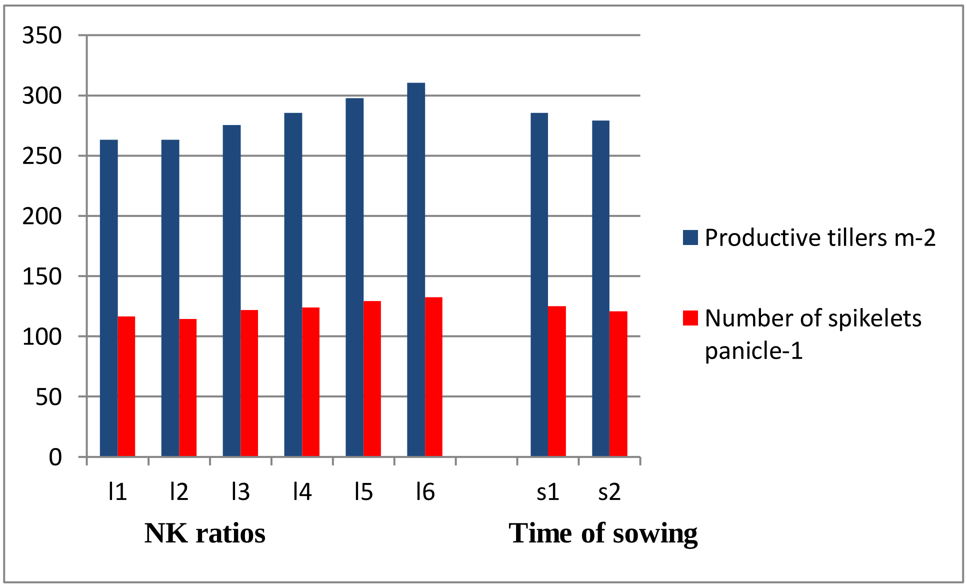

Fig. 6 Effect of NK ratios and time of sowing on productive tillers m^{-2} and number of spikelets panicle^{-1}

120:60 kg ha^{-1} in upland rice. The time of sowing significantly influenced the yield attributes like productive tillers m^{-2}, length of panicle, number of spikelets panicle^{-1}, percentage of filled grains panicle^{-1} and 1000 grain weight (Tables 5a and 6a). The treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the highest values for yield attributes compared to s_2. This is mainly due to the higher moisture content in the soil and better nutrient uptake and increased translocation of photosynthates from source to sink leading to the proper development of yield attributes. This is in conformity with the findings of Abid *et al.* (2015) in rice. The interaction effect due to NK ratios and time of sowing differed significantly for productive tillers m^{-2} and number of spikelets panicle^{-1}. Among the treatment combinations, l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) produced the maximum productive tillers m^{-2} and number of spikelets panicle^{-1} (Tables 5b, 6b and Fig.7). Higher soil moisture content coupled with higher levels of N and K favoured growth, resulted in high DMP and nutrient uptake and contributed to increased rate of photosynthesis and efficient translocation of photosynthates from source to sink resulting in better expression of yield attributes.

The NK ratios, time of sowing and their interactions showed significant difference in grain and straw yields (Tables 7a, 7b and Fig. 8, 9).Yield is the final product of various external and internal factors affecting crop growth and production. By the suitable manipulation of external factors the crop yield can be increased. Nutrients are one such factor affecting the yield. By the optimum nutrient dose and soil moisture availability, the plant nutrient uptake can be increased, which will directly reflect on yield attributes and finally yield. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the maximum grain and straw yields. An additional grain yield of 1991 kg ha^{-1} was obtained in l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) over l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}). The higher N and K levels resulted in improved growth characters and yield attributing characters which enhanced the grain and straw yields. The increased grain yield observed in l_6 might be due to the adequate supply, translocation and utilization of N and K within the plant resulting in the better expression of growth and yield attributes. The results revealed that l_6 resulted in higher number of fertile grains panicle^{-1}, test grain weight and grain weight panicle^{-1}

compared to the treatments. Adequate supply and availability of N and K provided continuous and steady supply of nutrients into the soil solution to match the nutrient requirement of crop, which consequently resulted in the production of longer panicles with more number of grains panicle $^{-1}$. Increasing N level results in more assimilation of photosynthates leading to greater number of tillers m^{-2}, DMP, productive tillers m^{-2} and number of filled grains and thus result in higher grain and straw yields. Higher levels of potassium increased the panicle length of rice, which could bear higher number of spikelets panicle^{-1}, resulting in higher grain and straw yields. Meena *et al* (2003) reported the maximum grain and straw yields when 200 kg N ha^{-1} and 62.5 kg K_2O ha $^{-1}$ were applied in rice. Mini (2005) found that increased application of N and K up to 100 kg and 50 kg ha^{-1}(2:1 ratio) resulted in higher grain and straw yields in upland rice. Similar findings were obtained by Kumar (2016) and Greeshma (2019) in upland rice. The time of sowing significantly influenced the grain and straw yields. The treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum grain and straw yields (Table 7a and Fig. 8). The early planting date enabled the plants to have longer time for growth before flowering and better utilization of soil moisture. Therefore the rice crop in s_1 planting had the potential for higher source capacity from which more dry matter could be produced for storage in the grains leading to higher grain and straw yields. This was in conformity with the findings of Vange and Obi (2006) in rice. The interaction effect due to NK ratios and time of sowing also influenced significantly the grain and straw yields. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted the highest grain and straw yields. The higher levels of N and K with increased soil moisture content led to more absorption of water and nutrients from the soil resulting in higher nutrient uptake, better translocation of nutrients from source to sink, high DMP and hence higher grain and straw yields.

The NK ratios, time of sowing and their interactions did not significantly influence the harvest index.

5.3 PHYSIOLOGICAL ESTIMATIONS

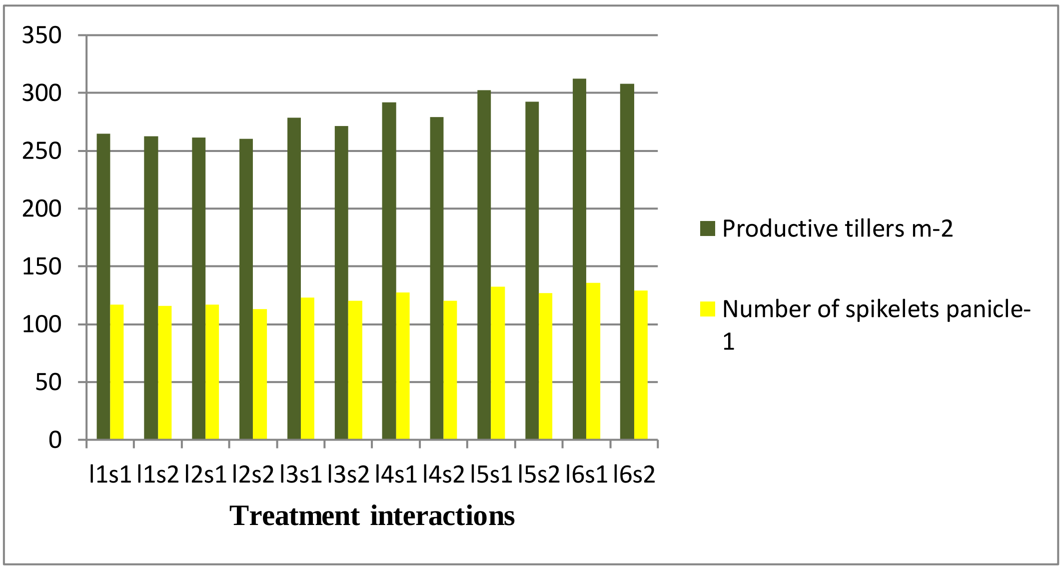

Fig. 7 Interaction effect of NK ratios and time of sowing on productive tillers m^{-2} and number of spikelets $panicle^{-1}$

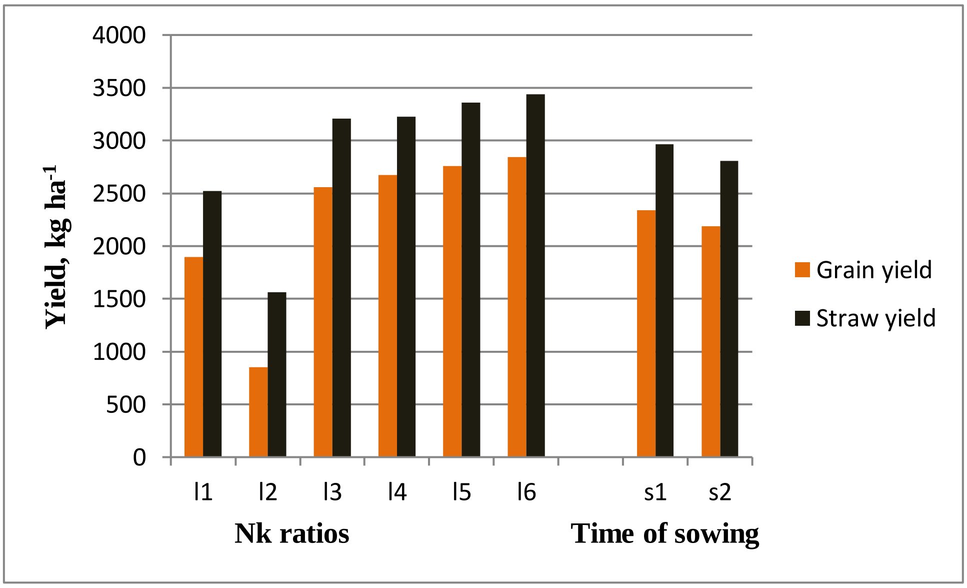

Fig. 8 Effect of NK ratios and time of sowing on grain and straw yields, kg ha^{-1}

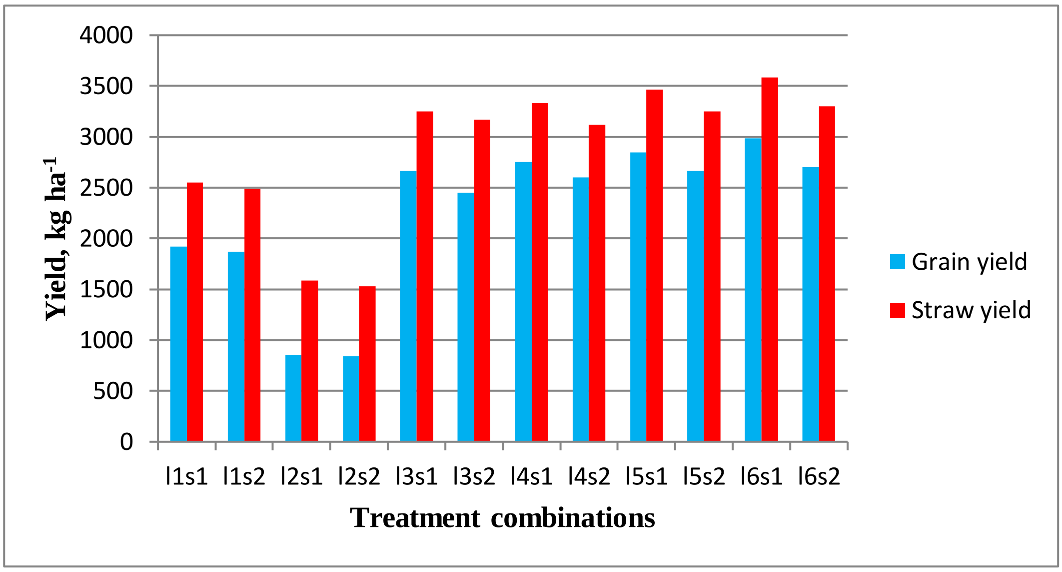

Fig. 9 Interaction effect of NK ratios and time of sowing on grain and straw yields, kg ha^{-1}

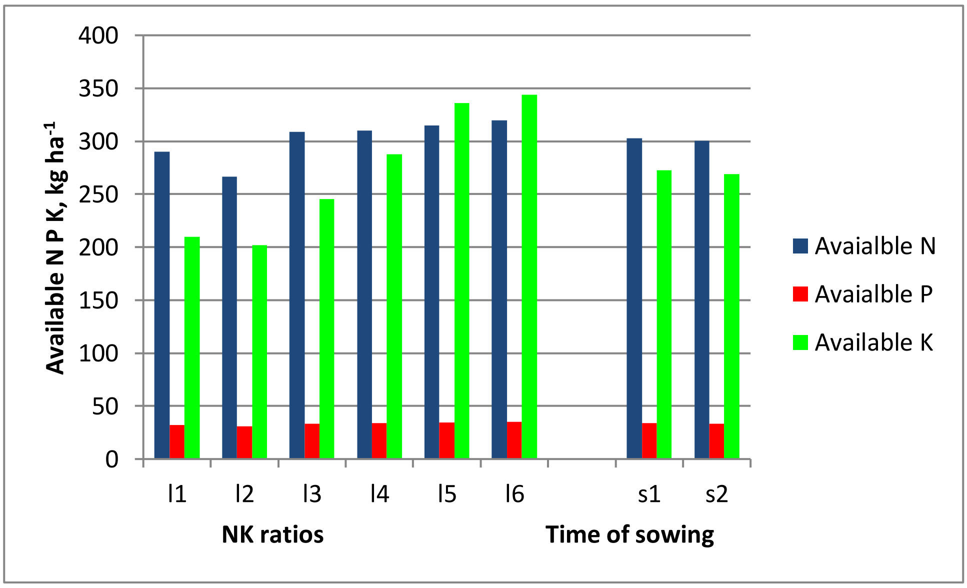

Fig. 10 Effect of NK ratios and time of sowing on available N, P, K, kg ha^{-1}

The proline content, relative leaf water content and chlorophyll content were not significantly influenced by the NK ratios, time of sowing and their interactions

(Tables 8a and 8b). Though not significant the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) reported the maximum value for these parameters. Among the treatment combinations, l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) recorded the highest value.

5.4 CHEMICAL ANALYSIS

5.4.1 NUTRIENT USE EFFICIENCY

The analysis of data revealed significant difference in nitrogen use efficiency due to NK ratios, time of sowing and their interactions (Tables 9a and 9b). Application of higher N and K decreased the nutrient use efficiency. The treatment l_2 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1}) resulted in the maximum nitrogen use efficiency. This is in conformity with the findings of Greeshma (2019) in upland rice who reported that at higher levels of N and K, NK losses were higher due to the inability of the crop in utilizing the nutrients. In the case of time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) had the maximum nutrient use efficiency. Higher levels of moisture available in s_1 might have helped the plant in utilizing the nutrients. Similar findings were reported by Pandey *et al.* (2008) in rice. Among the treatment combinations, l_2s_1 (PGPR MIX 1 6 kg + FYM 5 t ha^{-1} and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the highest nitrogen use efficiency.

The results revealed the significant influence of NK ratios, time of sowing and their interactions on potassium use efficiency (Tables 9a and 9b). Increased potassium application reduced the potassium use efficiency. The treatment l_1 (60:30 kg ha^{-1} of NK at 2:1 ratio) had the maximum potassium use efficiency. This was in conformity with the findings of Greeshma (2019). Regarding the time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) had the maximum potassium use efficiency. This was in conformity with the findings of Pandey *et al*. (2008). Among the treatment combinations, l_1s_1 (60:30 kg NK ha^{-1} 2:1 ratio and sowing one week after the commencement of SW monsoon) had the maximum potassium use efficiency.

5.4.2 SOIL ANALYSIS AFTER THE EXPERIMENT

The results revealed that NK ratios and time of sowing significantly influenced available N and K, but not influenced the available P and organic carbon content of the soil (Table 10a and Fig. 10). The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the maximum soil available N and K. Higher levels of N and K increased the concentration of nutrients in soil solution. This was in conformity with the findings of Mini (2005) who reported higher nutrient availability at 120:90 kg NK ha^{-1} in upland rice. Similar findings were reported by Greeshma (2019) in upland rice and she reported the maximum soil available N and P at 120:60 kg NK ha^{-1} and the maximum available soil K at 120:90 NK ha^{-1}. Regarding time of sowing, the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in higher available N and K (Table 10a). The interaction effects due to NK ratios and time of sowing did not significantly influence the nutrient availability in soil.

5.4.3 NPK UPTAKE BY THE CROP AT HARVEST

The NK ratios, time of sowing and their interactions significantly influenced the uptake of nutrients (Tables 11a, 11b and Fig. 11, 12).The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) had the maximum uptake of nutrients. Increased application of N and K helped the plants to improve their growth characters (plant height, DMP), yield attributes and yield, which contributed to higher nutrient uptake and also helped for proper root development, which in turn helped to absorb more nutrients. Higher yield attributes, such as number of panicle m^{-2}, number of spikelets $panicle^{-1}$, grain weight $panicle^{-1}$, test weight; percentage of filled grains coupled with increased DMP due to l_6 resulted in increased and steady supply of nutrients into the soil solution to match the nutrient requirement resulting in higher uptake of nutrients. Higher concentration of NPK in grain and straw resulted in higher uptake of nutrients. Kumar (2016) reported the highest nutrient uptake when N and K were applied at 120:60 kg ha^{-1} (2:1 ratio) in upland rice. Greeshma (2019) reported that application of 120:60 kg NK ha^{-1} resulted in the maximum uptake of nutrients in upland rice. With respect to time of sowing the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the maximum uptake of nutrients. The higher availability of soil moisture coupled with better yield attributes and DMP helped the plants to absorb more nutrients. Pandey *et al* (2008) reported similar findings. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the highest uptake of nutrients. The higher yield attributes increased availability of soil

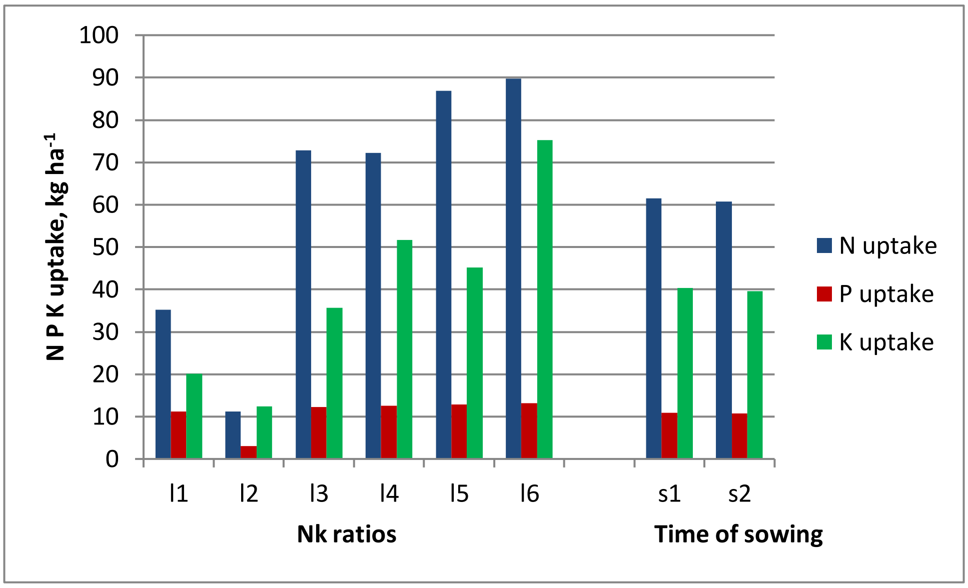

Fig. 11 Effect of NK ratios and time of sowing on nutrient uptake, kg ha^{-1}

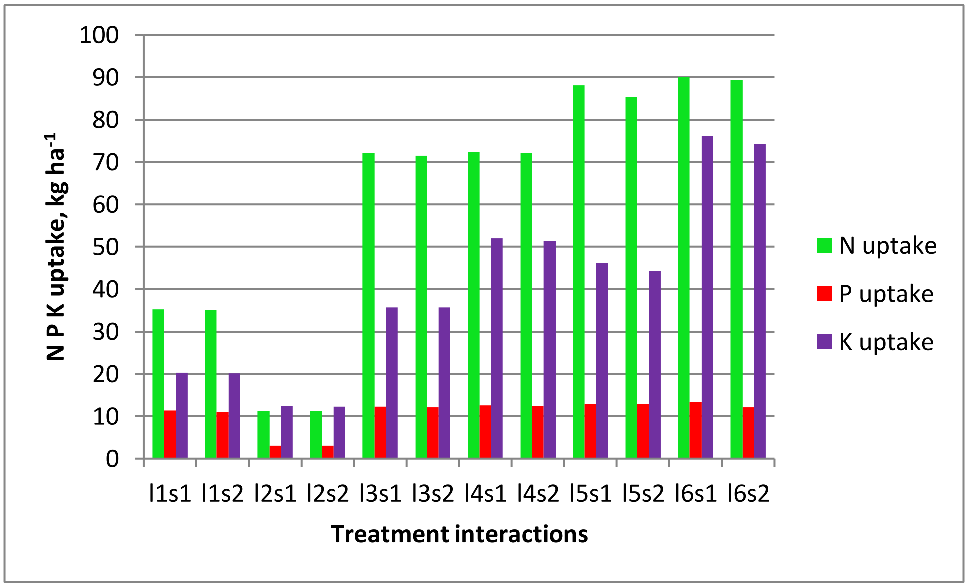

Fig. 12 Interaction effect of NK ratios and time of sowing on nutrient uptake, kg ha^{-1}

moisture coupled with higher DMP might have helped the plants to absorb more nutrients from the soil and hence higher uptake.

5.4.4 PROTEIN CONTENT OF GRAIN

The protein content of the grain was significantly influenced by the NK ratios (Table 12a). The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the maximum grain protein content due to higher N application helping the plant for increased synthesis of amino acids. This was in conformity with the findings of Mini (2005), Kumar (2016) and Greeshma (2019) in upland rice. It was found that neither time of sowing nor their interactions significantly influenced the grain protein content (Tables 12a and 12b).

5.5 OBSERVATIONS ON MAJOR WEEDS

The major weeds observed in the field were i. Grasses: (*Cynodondactylon, Echinochlo acolona* and *Dactyloctnium aegyptium).* ii. Broad leaved weeds: (*Alternanthera sessilis, Phyllanthus niruri, Mimosa pudica and Amaranthus sp.)* iii. Sedges: *Cyperus rotundus.* They did not adversely affect the yield of upland rice.

5.6 PEST AND DISEASE INCIDENCE

The major pest observed in the field was rice gundhi bug (*Leptocorisa acuta*) and the disease was grain discolouration. But they did not cause any yield reduction in upland rice.

5.7 ECONOMIC ANALYSIS

The NK ratios, time of sowing and their interactions significantly influenced the gross income and net income (Tables 13 a, 13b and Fig 13, 14). The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the maximum gross and net income. The higher grain and straw yields in l_6 contributed to higher gross income and net income. Similar findings were reported by Murthy *et al.* (2014) and Kumar (2016) in upland rice. Greeshma (2019) reported the maximum net income at 120:60 kg NK ha^{-1}.The treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the highest gross and net income. This was in conformity with the works of Bashir *et al.* (2010) in rice. Among the treatment combinations, l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) contributed to maximum gross and net income.

The results revealed that BCR was significantly influenced by the NK ratios (Table 13a and Fig. 15). The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) attained the highest BCR. This was in conformity with the findings of Mini (2005), Kumar (2016) and Greeshma (2019) in upland rice. But the time of sowing and their interactions did not significantly influence the BCR.

Results of the study revealed that the treatment combination l_6s_1 produced the highest grain yield, straw yield, yield attributes, DMP and nutrient uptake thereby revealing that sowing upland rice within one week after the commencement of SW monsoon with N and K applied at 140:105 kg NK favourably influenced the growth, yield, gross income and net income of upland rice.

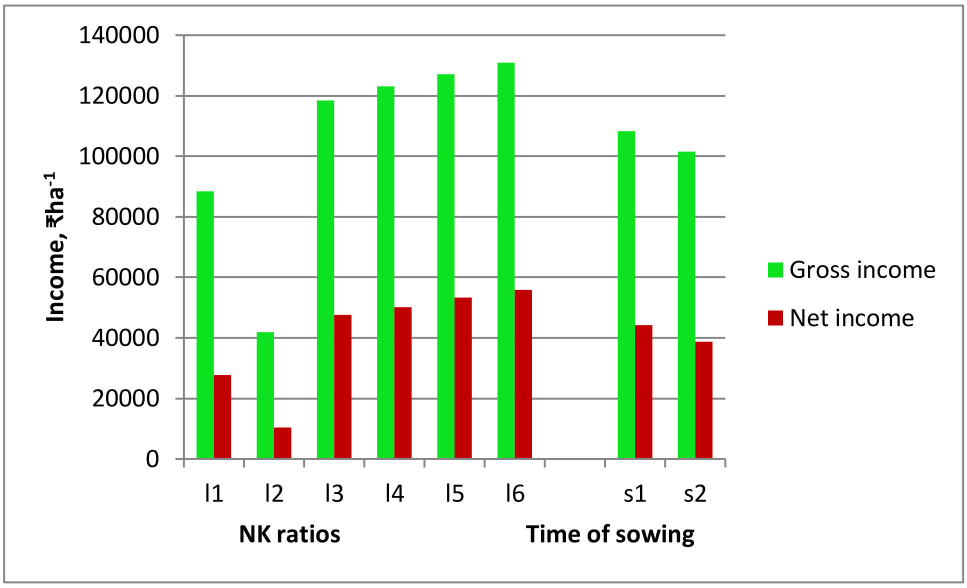

Fig. 13 Effect of NK ratios and time of sowing on gross and net incomes, ₹ ha^{-1}

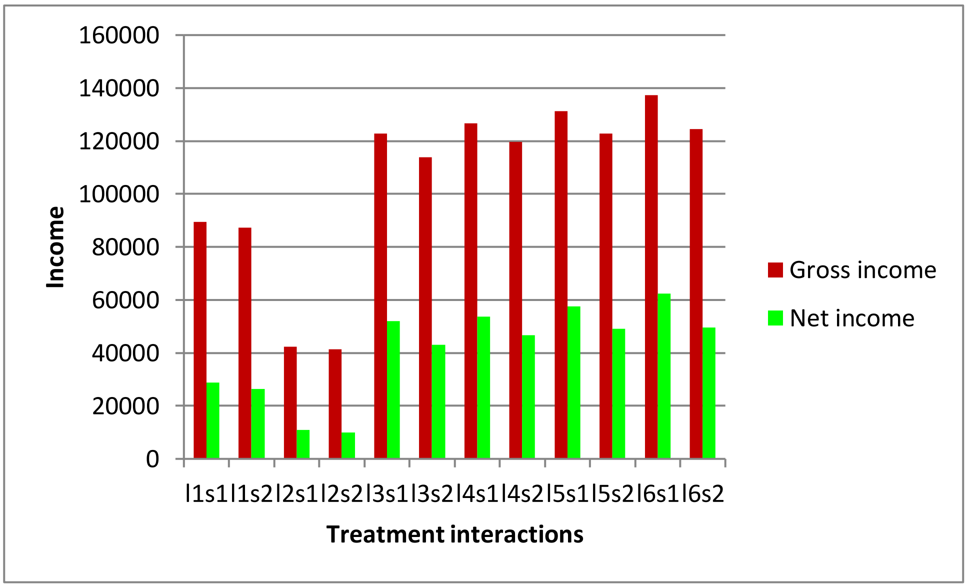

Fig.14 Interaction effect of NK ratios and time of sowing on gross and net incomes, ₹ha^{-1}

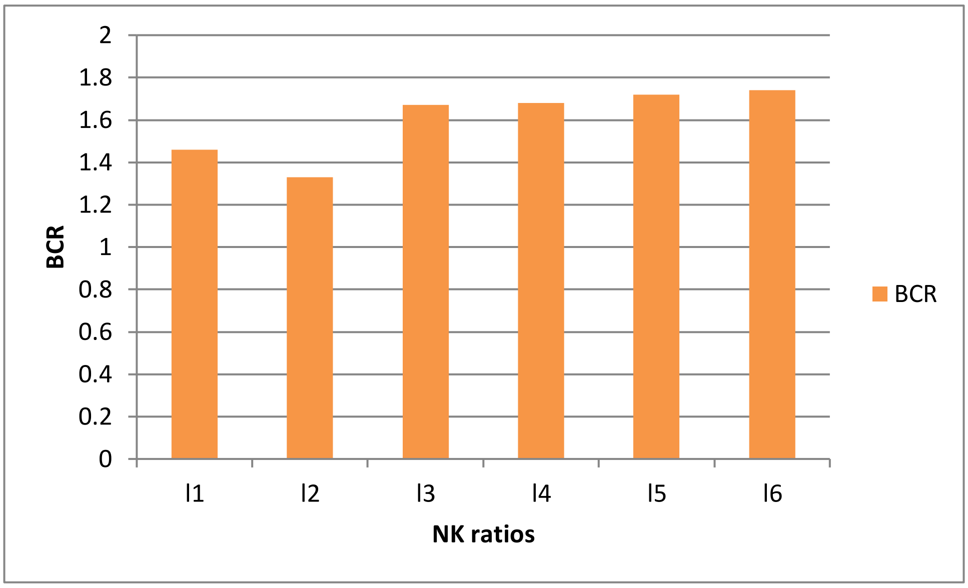

Fig. 15 Effect of NK ratios and time of sowing on BCR

Summary

6. SUMMARY

The field experiment entitled "Sowing time and nutrient management for productivity enhancement of upland rice (*Oryza sativa* L.)" was conducted during *Kharif* 2019 at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram .The variety used for the study was Aiswarya (PTB 52). The experiment was laid out in factorial RBD consisting of 12 treatment combinations and 3 replications. The treatments comprised of 6 levels of N and K in 2:1 and 2:1.5 ratios (l_1:60: 30 (control-1), l_2: PGPR MIX- I : 6 kg + FYM 5 t ha^{-1} (control-2), l_3 : 120: 60, l_4 :120: 90, l_5 : 140: 70 and l_6 :140:105) and 2 time of sowing (s_1: sowing one week after the commencement of S-W monsoon, 2019 and s_2: sowing two weeks after the commencement of S-W monsoon, 2019).A uniform dose of P_2O_5 (30 kg ha^{-1}) was applied to all the plots. The soil was sandy clay loam in texture and low in available N, high in available P and medium available K. The first sowing was done on 13/06/2019 and second sowing on 21/06/2019. The crop was harvested on the following dates of 14/10/2019 and 21/10/2019 respectively. The observations on growth characters, yield attributes, yield, physiological attributes, chemical analysis and economics were done and the data were analyzed statistically and presented in this chapter.

The plant height was significantly influenced by the treatments at 60 DAS and at harvest. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) produced the tallest plants. Regarding time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the tallest plants. Among the treatment combinations, l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum height. The NK ratios, time of sowing and their interactions significantly influenced the number of tillers m^{-2}. The treatments l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) and s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the maximum number of tillers m^{-2}. The treatment combination, l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) produced the maximum tiller number. The NK ratios, time of sowing and their interactions did not significantly influence the LAI. The DMP increased with higher levels of N and K up to 140:105 kg NK ha^{-1} at 60 DAS and harvest. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) produced the maximum DMP.

The results revealed that the yield attributes such as productive tillers m^{-2}, length of panicle, grain weight $panicle^{-1}$, number of spikelets $panicle^{-1}$, percentage of filled grains $panicle^{-1}$ and 1000 grain weight were significantly influenced by NK ratios. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the maximum value for the above mentioned yield attributing characters. The time of sowing showed significant difference on productive tillers m^{-2}, length of panicle and number of spikelets $panicle^{-1}$. The maximum value was recorded in the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019). The interaction due to NK ratios and time of sowing significantly influenced the productive tillers m^{-2} and number of spikelets $panicle^{-1}$. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) showed the maximum value for the yield attributes.

The grain and straw yields were significantly influenced by the NK ratios, time of sowing and their interactions. The application of N and K at 140:105 kg ha^{-1} (2:1.5 ratio) produced the maximum grain and straw yields. With regard to time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum grain and straw yields. The highest grain and straw yields were obtained in the treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019). The harvest index was not significantly influenced by the NK ratios, time of sowing and their interactions.

The physiological attributes such as proline, relative leaf water content and chlorophyll content were not significantly influenced by the treatments and their interactions.

The nutrient use efficiency was significantly influenced by NK levels, time of sowing and their interactions. The treatment l_2 (PGPR MIX 1 6kg + FYM 5t ha^{-1}) recorded the highest NUE and l_1 (60:30 kg ha^{-1} of NK at 2:1 ratio) resulted in the maximum KUE. Regarding time of sowing, the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum nutrient use efficiency. The treatment combination l_2s_1 (PGPR MIX 1 6 kg + FYM 5 t $ha^{-1}$and time of sowing one week after the commencement of SW monsoon, 2019) produced the maximum NUE and l_1s_1 (60:30 kg ha^{-1} of NK at 2:1 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the highest KUE.

The NK ratios and time of sowing significantly influenced the available N and K in the soil but not influenced the available P and organic carbon content. The highest availability of nutrients was recorded in the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) and s_1 (sowing one week after the commencement of SW monsoon, 2019). The interaction effect did not significantly influence the available N P K and organic carbon content of the soil.

The uptake of nutrients was significantly influenced by NK ratios, time of sowing and their interactions. The uptake of nutrients increased with incremental levels of N and K and the uptake was maximum at N and K applied at140:105 kg ha^{-1}. In the case of time of sowing, the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the highest nutrient uptake. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum uptake of nutrients.

The results revealed that the NK ratios imparted significant influence on protein content of the grain. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) showed the highest grain protein content. Neither the time of sowing nor their interaction significantly influenced the grain protein content.

There was a significant influence of NK ratios, time of sowing and their interactions on gross income and net income. The highest gross income, net income and BCR were recorded by the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio). Regarding time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum gross and net income. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the highest gross and net income. Neither the time of sowing nor their interactions significantly influenced the BCR.

Future line of work

Use of liquid fertilizers instead of chemical fertilizers, both inorganic and organic need to be evaluated. The scope of split application of nitrogen and potassium as basal and top dressing and also secondary and micronutrients preferably as foliar spray has to be explored.

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APPENDIX I

Weather parameters during the cropping period – 13th June to 21st October, 2019

Standard weeks	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Rainy days
	Max	Min	Max	Min		
24	31.13	24.83	93.37	81.17	114.40	6
25	31.91	24.93	90.00	78.71	28.60	3
26	32.09	26.06	87.14	75.29	0.00	0
27	32.20	25.91	90.29	77.14	32.10	2
28	30.79	25.37	90.29	79.00	42.10	2
29	30.06	23.74	94.14	81.57	100.80	4
30	30.37	24.33	92.29	82.43	7.70	2
31	31.46	25.63	89.29	77.57	17.50	2
32	30.00	23.61	94.57	81.71	198.10	6
33	30.44	24.07	91.57	76.57	18.20	2
34	31.11	24.23	92.14	77.43	34.90	3
35	30.67	23.91	93.14	77.86	91.90	6
36	30.87	24.37	90.57	80.14	84.00	3
37	31.33	24.39	88.86	76.43	12.90	2
38	30.94	24.90	91.14	77.86	19.40	2
39	31.01	24.21	93.29	75.57	123.80	4
40	31.50	24.57	91.29	72.14	7.00	1
41	31.10	24.40	91.71	77.00	133.10	4

Abstract

SOWING TIME AND NUTRIENT MANAGEMENT FOR PRODUCTIVITY ENHANCEMENT OF UPLAND RICE (*Oryza sativa* L.)

by

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ABSTRACT

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ABSTRACT

The field experiment entitled "Sowing time and nutrient management for productivity enhancement of upland rice (*Oryza sativa* L.)" was conducted during *Kharif* 2019 at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram with the objective to study the influence of different levels of N and K, their ratios and time of sowing on growth and yield of upland rice and to work out the economics of cultivation. The variety used for the study was Aiswarya (PTB 52). The experiment was laid out in factorial RBD consisting of 12 treatment combinations and 3 replications. The treatments comprised of 6 levels of N and K in 2:1 and 2:1.5 ratios (l_1:60: 30 (control-1), l_2: PGPR MIX- I : 6 kg + FYM 5 t ha^{-1} (control-2), l_3 : 120: 60, l_4 :120: 90, l_5 : 140: 70 and l_6 :140:105) and 2 time of sowing (s_1: sowing one week after the commencement of SW monsoon, 2019 and s_2: sowing two weeks after the commencement of SW monsoon, 2019). A uniform dose of P_2O_5 (30 kg ha^{-1}) was applied to all the plots.

The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted the tallest plants and highest DMP at 60 DAS and at harvest. The maximum number of tillers m^{-2} was produced in the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio). Regarding the time of sowing, s_1 (sowing one week after the commencement of SW monsoon, 2019) produced the tallest plants, maximum DMP and number of tillers m^{-2}. Growth characters were favoured in the treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019).

The yield attributes such as productive tillers m^{-2}, length of panicle, grain weight $panicle^{-1}$, number of spikelets $panicle^{-1}$**,** percentage of filled grains**,** 1000 grain weight, grain and straw yields were significantly influenced by the treatments. The treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the highest value. With respect to time of sowing, the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest values for the above mentioned characters. The interaction effect differed significantly only for productive tillers m^{-2}, number of spikelets $panicle^{-1}$**,** grain and straw yields. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) showed the maximum values.

The nutrient use efficiency was significantly influenced by the treatments. The maximum NUE was recorded by the treatment l_2 (PGPR MIX 1 6 kg + FYM 5t ha^{-1}). The treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) resulted in the highest NUE. Among the treatment combinations, l_2s_1 (PGPR MIX 1 6 kg + FYM 5 t $ha^{-1}$and time of sowing one week after the commencement of SW monsoon, 2019) had the maximum NUE. The treatment l_1 (60:30 kg ha^{-1} of NK at 2:1 ratio) had the maximum KUE. With respect to time of sowing, the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) had the highest KUE. The treatment combination l_1s_1 (60:30 kg ha^{-1} of NK at 2:1 ratio and sowing one week after the commencement of SW monsoon, 2019) had the highest KUE.

The results revealed that the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) resulted in the maximum nutrient uptake. With regard to time of sowing, the treatment s_1 (sowing one week after the commencement of SW monsoon, 2019) showed higher uptake of nutrients. The treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and time of sowing one week after the commencement of SW monsoon, 2019) resulted in the maximum uptake of nutrients.

The protein content of grain was significantly influenced by the NK ratios. Among the treatments, l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio) indicated the maximum grain protein content.

The economic analysis revealed that the treatment l_6 (140:105 kg ha^{-1} of NK at 2:1.5 ratio), s_1 (sowing one week after the commencement of SW monsoon, 2019) and the treatment combination l_6s_1 (140:105 kg ha^{-1} of NK at 2:1.5 ratio and sowing one week after the commencement of SW monsoon, 2019) fetched the maximum gross income, net income and BCR.

From this study, it can be concluded that the application of 140 kg N and 105 kg K_2O ha^{-1} (2:1.5 ratio) and sowing one week after the commencement of SW monsoon resulted in higher growth characters, yield attributes, yield, gross income and net income.

സംഗ്രഹം

കരനെല്കൃഷിയിലെ "നടീൽ സമയവും നൈട്രജൻ പൊട്ടാസ്യം അനുപാതവും" എന്ന വിഷയത്തിൽ ഒരു പഠനം വെള്ളായണി കാർഷിക കോളേജിലെ ഇൻസ്ട്രക്ഷണൽ ഫാർമിൽ നടത്തുകയുണ്ടായി. കരനെല്കൃഷിക്ക് അനുയോജ്യമായ അളവിലും അനുപാതത്തിലും നൈട്രജനും പൊട്ടാസിയവും ശരിയായ നടീൽ സമയവും കണ്ടുപിടിക്കുക എന്നതായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യം .പട്ടാമ്പി കാർഷിക ഗവേഷണ കേന്ദ്രത്തിൽ നിന്നും വികസിപ്പിച്ചെടുത്ത ഐശ്വര്യ എന്ന നെല്ലിനമാണ് പഠനത്തിന് ഉപയോഗിച്ചത് .

പരീക്ഷണത്തിൽ ഉപയോഗിച്ച വിവിധ അളവുകൾ താഴെ കൊടുത്തിരിക്കുന്നു.

l_1: 60 kg N : 30 kg K_2O

l_2: PGPR MIX- I : 6 kg + FYM 5 t ha^{-1}

l_3: 120 kg N : 60 kg K_2O (2:1)

l_4: 120 kg N : 90 kg K_2O (2:1.5)

l_5: 140 kg N : 70 kg K_2O (2:1)

l_6: 140 kg N : 105 kg K_2O (2:1.5)

നടീൽ സമയം

S_1 : തെക്കു പടിഞ്ഞാറൻ കാലവർഷം തുടങ്ങി ഒരാഴ്ചയ്ക്ക് ശേഷം , 2019

S_2 : തെക്കു പടിഞ്ഞാറൻ കാലവർഷം തുടങ്ങി രണ്ടാഴ്ചയ്ക്ക്

ശേഷം , 2019

മൊത്തം 12 ട്രീട്മെന്റുകളായി മൂന്നു തവണ ആവർത്തിച്ചു റാണ്ടമൈസെഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന രീതിയിലാണ് പഠനം നടത്തിയത്.

ഈ പഠനത്തിന്റെ പ്രധാന കണ്ടെത്തലുകൾ ഇവയാണ് 140 :105 kg NK ha^{-1} എന്ന അളവിൽ നൈട്രജനും പൊട്ടാസിയവും നൽകുന്നതും തെക്കു പടിഞ്ഞാറൻ കാലവർഷം തുടങ്ങി ഒരാഴ്ച കഴിഞ്ഞു നടുന്നതും കരനെല്കൃഷിയിലെ കൂടുതൽ വിളവിനും വൈക്കോൽ ഉദ്പാദനത്തിനും നല്ലതാണെന്ന് കണ്ടെത്തി . കൂടാതെ കർഷകന്റെ അറ്റാദായവും വർധിക്കുന്നതായി കണ്ടെത്തി.