PRODUCTIVITY OF UPLAND RICE (*Oryza sativa* L.) AT DIFFERENT NK RATIOS AND SPACINGS

by

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DECLARATION

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

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LIST OF ABBREVATIONS

B: C	:	Benefit cost
CD (0.05)	:	Critical difference at 5 % level
DAS	:	Days after sowing
DMP	:	Dry matter production
dS m^{-1}	:	Deci Siemens per metre
EC	:	Electrical conductivity
et al.	:	Co-workers/ Co-authors
FYM	:	Farm yard manure
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
ha^{-1}	:	Per hectare
$hill^{-1}$	:	Per hill
i.e.	:	That is
K	:	Potassium
KAU	:	Kerala Agricultural University
kg^{-1}	:	Per kilogram
L	:	Litre
LAI	:	Leaf area index
m^2	:	Square metre
m^{-2}	:	Per square metre
mg	:	Milligram
mm	:	Millimetre
mL	:	Millilitre
M ha	:	Million hectare
MO	:	Moncompu
MSL	:	Mean sea level
N	:	Nitrogen

NS	:	Non-significant
No.	:	Number
P	:	Phosphorus
pH	:	Potenz hydrogen
RBD	:	Randomized block design
SPAD	:	Soil plant analysis development
SEm	:	Standard error of mean
t	:	Tonnes
viz.,	:	Namely

LIST OF SYMBOLS

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

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is an important food crop of the world. In India, rice is cultivated in more than 60 per cent of the area and contributes to major share of agrarian economy. The traditional practice of wetland rice cultivation cannot be expanded since the area under wetland rice is getting diminished and converted to other upland crops. Upland rice is now gaining popularity among farmers as it requires less water and less labour for land preparation. It is a resource conservation technology and is suitable for mechanization.Upland rice can be planted in sloping lands and is suitable for drought prone areas for soils with poor physical and chemical properties.

Upland rice constitutes 12% of global rice area (Bernier and Altin, 2014). In India, 13 per cent of total rice area is under upland rice cultivation but contributes only 4 per cent of rice production (Andhya *et al.*, 2015). In Kerala, upland rice is cultivated in 0.11 m ha and constitutes 13.4 per cent of total rice area with a productivity of less than 1 t ha^{-1} (Kumari *et al.*, 2011). The productivity of upland rice is low compared to low land rice. The major constraints in upland rice cultivation include weed infestation, abiotic stresses like water scarcity, salinity problems, low soil nutrient status, temperature stress and soil erosion. Higher productivity can be achieved by the proper management of both biotic and abiotic factors.

Nitrogen (N) is a key nutrient required for proper growth and development of rice. Plant growth is seriously hampered at lower levels of N which drastically reduces the yield. N serves as a constituent of plant components such as nucleic acids, amino acids, enzymes and enhances photosynthetic activity and carbohydrate metabolism.

Potassium (K) is one of the important nutrients required for proper growth and development of rice. It is essential for photosynthesis, modifies dozens of enzyme activation and controls stomatal movement. It increases pulpiness of grain, induces tolerance to drought and resistance to pests and diseases and promotes root growth.

Proper management of N and K is important for realizing higher yields. The present recommended dose of N and K is 60:30 (2:1 ratio) (KAU, 2016). It is found that there is higher uptake of N and K exceeding the recommended levels which may result in depletion of reserve N and K in soil. So proper maintenance of N and K balance is important.

The growth and yield of rice are influenced by an optimum plant stand which is further influenced by spacing. Optimum plant spacing is required to maintain uniform plant population so as to prevent inter row and intra row competition for resources.

With this background, the present study entitled "Productivity of upland rice (*Oryza sativa* L.) at different NK ratios and spacings was carried out with the following objectives.

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

Review of Literature

2. REVIEW OF LITERATURE

Upland rice cultivation is a very promising technology. The area under lowland rice is declining at a faster rate, and therefore it is necessary to focus more on upland rice to ensure food security. But the productivity of upland rice is less and is not comparable to that of lowland rice. The major constraints in upland rice are moisture stress, high weed infestation, nutrient imbalance, poor soil fertility and environmental changes. Nutrient availability is one of the critical determinants of potential productivity of the crop. Proper nutrient supply at right time and right quantity should be the basis for ensuring higher productivity. Maintenance of optimum plant population is important to assure higher productivity, reduce weed infestation and competition for nutrients, light and moisture. The literature on the effect of levels of N and K, ratios of N and K and spacing on growth characters, yield attributes, yield, nutrient uptake, physiological parameters and soil properties are reviewed in this chapter.

2.1. INFLUENCE OF NUTRIENTS

2.1.1. Growth Characters

2.1.1.1. Nitrogen

Geethadevi *et al.* (2000) obtained taller plants in hybrid rice with 150 kg N ha^{-1}. Anu (2001) reported that application of 80 kg N ha^{-1} in upland rice produced the tallest plant. Kumari *et al.* (2000) obtained taller rice plants at N applied at 120 kg ha^{-1}. Ranjini (2002) obtained taller plants in upland rice at N level of 90 kg ha^{-1}. According to Sindhu (2002), N levels significantly influenced plant height except at the maximum tillering stage in wetland Basmati rice and maximum plant height was observed at 120 kg N ha^{-1}. Plant height was significantly influenced by higher levels of N and maximum height was obtained at 200 kg N ha^{-1} (Ahmad *et al.*, 2005). The tallest plant was observed in upland rice when N was given at 100 kg ha^{-1} (Mini, 2005). Swaroopa and Lakshmi (2015) obtained maximum height in rice at 135 kg N ha^{-1}. Kumar (2016) obtained maximum plant height in upland rice when N was given at 120 kg ha^{-1}. According to Suman (2017), the tallest plant in upland rice was produced by the application of 120 kg N ha^{-1}.

Application of 90 kg N ha^{-1} produced maximum number of tillers m^{-2} in upland rice (Ranjini, 2002). Sindhu (2002) opined that tiller number was proportional to increasing levels of N at all growth stages in basmati rice and maximum number of tillers m^{-2} was found at 120 kg N ha^{-1}. Mini (2005) reported maximum number of tillers in upland rice at 100 kg N ha^{-1}. Awan *et al.* (2011) observed maximum tillering in rice at 156 kg N ha^{-1}. Abou-Khalifa (2012) observed maximum tillering at 220 kg N ha^{-1}in rice. According to Hebbal (2014), higher dry matter production (DMP), more number of tillers m^{-2} and higher leaf area in rice were observed at 125 kg N ha^{-1}. Swaroopa and Lakshmi (2015) obtained maximum number of tillers m^{-2} in rice at 135 kg N ha^{-1}. Suman (2017) observed that tiller number m^{-2} was significantly influenced by nutrient levels at all growth stages and 120 kg N ha^{-1} recorded the highest number of tillers m^{-2} in upland rice. The highest number of tillers m^{-2} was recorded at 80 kg N ha^{-1} in rice (Adhikari *et al.*, 2018).

Anu (2001) obtained higher leaf area index (LAI) in upland rice at 80 kg N ha^{-1}. Renjini (2002) obtained maximum LAI in upland rice at 90 kg N ha^{-1}. Increase in the level of N resulted in an increase in LAI at all stages of basmati rice and the highest LAI was observed at 120 kg N ha^{-1}(Sindhu, 2002). Somasundaram *et al.* (2002) reported significant increase in LAI and dry matter accumulation in rice with successive increase in N level upto 100 kg ha^{-1}. Leaf area index was the highest in upland rice at N level of 100 kg ha^{-1} (Mini, 2005).

Renjini (2002) reported maximum DMP in upland rice at 90 kg N ha^{-1}. The highest level of N (120 kg ha^{-1}) produced maximum DMP in basmati rice (Sindhu, 2002). Dry matter production was significantly influenced by application of N and application of 100 kg N ha^{-1} recorded the highest DMP in upland rice (Mini, 2005). Artacho *et al.* (2009) observed maximum DMP in rice at 200 kg N ha^{-1}. Murthy (2009) opined that, in rice, DMP increased with increasing levels of N from 120 to 180 kg ha^{-1} and further increase did not make any significant change. Rakesh (2012) obtained maximum DMP at 180 kg N ha^{-1} at all stages in rice. Anil (2013) observed higher DMP at all growth stages with the application of 240 kg N ha^{-1} than 120 kg N ha^{-1} in aerobic rice. Hirzel and Rodriguez (2013) observed higher total DMP when N was given at 160 kg ha^{-1} in rice. Kumar (2016) obtained maximum DMP at 120 kg N ha^{-1} while El – Hosiny *et al.* (2017) obtained maximum DMP at 144 kg N ha^{-1}.

2.1.1.2. Potassium

Potassium is essential for photosynthetic activity and helps in inducing drought tolerance and disease resistance and production of stiff stalks and stem. Application of K at correct stage of growth of upland rice is an effective means for reducing losses of nutrients and its increased availability thereby producing higher yield (Sarkar *et al.*, 1995).

It was observed that plant height increased with increase in K up to 45 kg ha^{-1} in case of upland rice (Anu, 2001; Ranjini, 2002). Mini (2005) observed an increase in plant height at 50 kg K_2O ha^{-1}. The maximum plant height in hybrid rice was recorded at 80 kg K_2O ha^{-1} (Yajjala, 2011). Application of K @ 25 kg K_2O ha^{-1} resulted in the tallest plant (Akanda *et al.*, 2012). Islam *et al.* (2015) obtained the tallest plant in aman rice at 80 kg K_2O ha^{-1}. Plant height responded well to different levels of applied K and the tallest plants were observed at 60 kg K_2O ha^{-1} (Huda *et al.*, 2016). Kumar (2016) recorded the tallest plants when K was given at 60 kg K_2O ha^{-1}. Birla (2017) obtained the tallest plants in rice at 96 kg K_2O ha^{-1}.

Application of K @ 45 kg K_2O ha^{-1} resulted in the highest number of tillers (Anu, 2001; Ranjini, 2002). Mini (2005) reported maximum tiller number at 50 kg K_2O ha^{-1}. The maximum number of tillers m^{-2} in hybrid rice was recorded at 80 kg K_2O ha^{-1} (Yajjala, 2011). Rakesh (2012) found a positive response on number of tillers m^{-2} with K application and maximum number of tillers m^{-2} was observed when K was given @ 80 kg ha^{-1} in aerobic rice. The highest number of total tillers was observed when potassium was given at 40 kg K_2O ha^{-1}(Uddin *et* *al.*, 2013). Islam *et al.* (2015) obtained maximum number of tillers m^{-2} in aman rice at 80 kg K_2O ha^{-1}. Huda *et al.* (2016) observed maximum number of tillers m^{-2} at 60 kg K_2O ha^{-1}. According to Kumar (2016), maximum number of tillers m^{-2} was observed when K was given @ 60 kg ha^{-1} in upland rice. Birla (2017) observed maximum number of tillers m^{-2} at 96 kg K_2O ha^{-1}.

Mini (2005) obtained the highest LAI in upland rice when K was given at 75 kg K_2O ha^{-1}. Akanda *et al.* (2012) obtained maximum LAI in aromatic rice at 35 kg K_2O ha^{-1}. Kumar (2016) observed higher LAI at 60 kg K_2O ha^{-1}.

Hati and Misra (1982) reported significant increase in DMP with increase in K level upto 60 kg K_2O ha^{-1}. Wilson *et al.* (1994) observed the highest DMP at mid tillering stage when K was given @ 90 kg K_2O ha^{-1}. Brohi *et al.* (1997) obtained maximum DMP in rice at 80 kg K_2O ha^{-1}. Ranjini (2002) reported maximum DMP in upland rice at 45 kg K_2O ha^{-1} while Mini (2005) found the same at 50 kg K_2O ha^{-1}. Maximum DMP in hybrid rice was recorded at 80 kg K_2O ha^{-1} (Yajjala, 2011). Islam *et al.* (2015) obtained maximum DMP in aman rice at 80 kg K_2O ha^{-1}. Kumar (2016) obtained maximum DMP in upland rice at 60 kg K_2O ha^{-1}.

2.1.1.3. Combined Effect of Nitrogen and Potassium

Anu (2001) reported an increase in growth characters of upland rice upon addition of NK @ 80:45 kg ha^{-1}. Ranjini (2002) found that NK application at 90:45 kg ha^{-1} resulted in higher growth and yield attributes in upland rice. Mini (2005) obtained significant increase in growth characters with 100:50 kg ha^{-1} of NK in the ratio of 2:1 compared to lower levels in upland rice. The interaction of N and K showed significant effect on growth attributes in upland rice variety NERICA 1 (Uddin *et al.*, 2013). According to them, combined application of 80 kg N ha^{-1} and 40 kg K_2O ha^{-1} in 2:1 ratio favourably influenced the growth attributes in NERICA 1 rice. Patel and Mishra (2015) obtained maximum number of tillers m^{-2} and the tallest plant at NK application of 90:40 kg ha^{-1}. Kumar (2016) reported that N and K applied at 120 kg N ha^{-1} and 60 kg K_2O ha^{-1} (2:1

ratio) recorded higher growth characters in upland rice. Suman (2017) found that growth attributes were favourably influenced by the application of N and K at 90:45 kg ha^{-1}(2:1) in upland rice.

2.1.2 Yield and Yield Attributing Characters

2.1.2.1 Nitrogen

Islam *et al.* (1997) recorded maximum number of productive tillers per plant in aus rice at 80 kg N ha^{-1}. According to Anu (2001), maximum number of productive tillers per plant was obtained at 80 kg ha^{-1} N for upland rice. Ranjini (2002) found that, in upland rice, the number of productive tillers per plant increased with increasing levels of N and maximum value was obtained at 90 kg ha^{-1}. Mini (2005) obtained maximum number of productive tillers per plant in upland rice at N applied at 100 kg N ha^{-1}. Murthy (2009) opined that in rice number of panicles m^{-2} increased with increasing levels of N from 120 to 180 kg ha^{-1} and further increase did not result in significant change. Hasanuzzaman *et al.* (2012) obtained maximum number of productive tillers per plant in hybrid rice at 120 kg N ha^{-1}. According to Ali *et al.* (2014), maximum number of productive tillers per plant was observed at 120 kg N ha^{-1}. Similar result was reported by Kumar (2016) and he found significant increase in number of productive tillers per plant with higher level of N @ 120 kg ha^{-1} in upland rice. Suman (2017) obtained maximum number of productive tillers per plant in upland rice at 90 kg N ha^{-1}. High rate of N application as high as 225 kg ha^{-1} resulted in maximum number of productive tillers per plant in rice (Nawaz *et al.*, 2017).

The longest panicle in upland rice was observed by Anu (2001) at 80 kg N ha^{-1} while Ranjini (2002) found longest panicle at 90 kg N ha^{-1}. Mini (2005) observed that length of panicle increased with increase in N level in upland rice and maximum panicle length was recorded at 100 kg N ha^{-1}. Bahmanyar and Mashaee (2010) obtained the longest panicle in rice at 23 kg N ha^{-1}. Awan *et al.* (2011) observed maximum panicle length in rice at 156 kg N ha^{-1}. Kumar (2016) obtained maximum panicle length at 120 kg N ha^{-1} in upland rice. Suman (2017) observed the longest panicle at 90 kg N ha^{-1} in upland rice. Sikuku *et al.* (2016)

stated that, in upland rice, higher rates of N application resulted in longer panicles. Gewaily *et al.* (2018) obtained the longest panicle at 220 kg N ha^{-1}.

Sudhakar *et al.* (1986) obtained increased grain weight with N application and maximum grain weight was observed at 80 kg N ha^{-1} in rice. Anu (2001) observed an increase in grain weight per panicle upto application of 80 kg N ha^{-1}. Ranjini (2002) observed maximum grain weight per panicle upto application of nitrogen at 90 kg ha^{-1}. Mini (2005) obtained maximum grain weight per panicle at 100 kg N ha^{-1}. However, Kumar (2016) observed maximum grain weight at 120 kg N ha^{-1}.

Islam *et al.* (1997) recorded maximum number of filled grains per panicle in aus rice at 80 kg N ha^{-1}. Geethadevi *et al.* (2000) obtained maximum filled grains per panicle in hybrid rice at 150 kg N ha^{-1}. Mini (2005) obtained maximum number of filled grains at 100 kg N ha^{-1}. Bahmanyar and Mashaee (2010) obtained maximum number of filled grains per panicle in rice at 23 kg N ha^{-1}. Awan *et al.* (2011) observed maximum number of filled grains per panicle in rice at 156 kg N ha^{-1}. Akanda *et al.* (2012) obtained maximum number of filled grains per panicle in aromatic rice at 50 kg N ha^{-1}. Hasanuzzaman *et al.* (2012) observed maximum number of filled grains per panicle in hybrid rice at 120 kg N ha^{-1}. Kumar (2016) reported maximum number of filled grains at 120 kg N ha^{-1}. Gewaily *et al.* (2018) obtained maximum number of filled grains at 220 kg N ha^{-1}.

Anil *et al.* (1989) reported that the grain yield of rice significantly increased with increasing N levels upto 120 kg N ha^{-1}. Pandey and Tripathi (1994) found significant influence of grain and straw yield on N level upto 120 kg N ha^{-1} than at lower levels owing to significant increase in panicles m^{-2} and panicle weight. According to Krishnan *et al.* (1994), a linear response in grain yield with increasing N levels was obtained upto 240 kg N ha^{-1}. Islam *et al.* (1997) recorded the highest grain and straw yields in aus rice at 80 kg N ha^{-1}. Mhasker and Thorat (2005) obtained significantly higher grain and straw yields by the application of 120 kg N ha^{-1}. Awan *et al.* (2011) observed maximum grain and straw yield in rice at 156 kg N ha^{-1}. Amin *et al.* (2012) obtained the highest grain and straw yields at 150 kg N ha^{-1}. Salam *et al.* (2004) opined that N level had significant effect on grain yield and the highest grain yield was recorded with 80 kg N ha^{-1}. Mini (2005) reported the highest grain and straw yields at 100 kg N ha^{-1} in upland rice. Shaun *et al.* (2007) obtained maximum grain yield at 120 kg N ha^{-1}. Wang-Dan Ying *et al.* (2008) observed significant increase in rice yield with increase in N level from 150 to 225 kg ha^{-1}. Sana *et al.* (2008) reported the highest grain yield at 90 kg N ha^{-1}. Maximum grain and straw yields in rice were observed at 140 kg N ha^{-1} (Kabir *et al.*, 2011). Akanda *et al.* (2012) obtained maximum grain yield in aromatic rice at 50 kg N ha^{-1}. Alim (2012) reported the highest grain and straw yields in rice at 100 kg N ha^{-1} in boro rice. Hasanuzzaman *et al.* (2012) obtained maximum grain yield in hybrid rice at 120 kg N ha^{-1}. Malik *et al.* (2012) obtained maximum grain yield in aerobic rice at 120 kg N ha^{-1}. Jahan *et al.* (2014) recorded highest grain and straw yield in aromatic rice at 60 kg N ha^{-1}. Yield of rice increased with increase in the level of N and maximum grain yield was obtained at 120 kg N ha^{-1} (Djaman *et al.*, 2015). Nayak *et al.* (2015) observed that higher grain and straw yields in rice were recorded when N was applied @ 80 kg ha^{-1}. Swaroopa and Lakshmi (2015) obtained maximum grain and straw yields in rice at 135 kg N ha^{-1}. Kumar (2016) obtained the highest grain yield of 2822 kg ha^{-1} and straw yield of 3560 kg ha^{-1}when N was applied @ 120 kg ha^{-1}. El – Hosiny *et al.* (2017) obtained maximum grain and straw yields at 144 kg N ha^{-1}. Javed *et al.* (2017) observed maximum grain and straw yields in fine rice at 60 kg N ha^{-1}. The highest grain yield in scented rice was recorded at 120 kg N ha^{-1} (Kumar and Kureel, 2017). The maximum grain yield, straw yield and biological yield were observed when N was given @ 90 kg ha^{-1} (Adhikari *et al.*, 2018). Gewaily *et al.* (2018) found that there was a linear increase in grain yield with increase in N rate from 0 to 220 kg N ha^{-1}.

Anu (2001) obtained maximum harvest index (HI) of upland rice under shaded conditions at 80 kg N ha^{-1}. Ranjini (2002) observed significant increase in HI with incremental levels of N and maximum was obtained at 90 kg N ha^{-1} in upland rice. Mini (2005) obtained maximum HI at 120 kg N ha^{-1}. Malik *et al.* (2012) observed maximum HI in aerobic rice at 120 kg N ha^{-1}. Jahan *et al.* (2014)

recorded the highest HI in aromatic rice at 60 kg N ha^{-1}. Murthy *et al.* (2014) obtained the highest HI in rabi rice at 180 kg N ha^{-1}. Kumar (2016) reported that application of 120 kg N ha^{-1} registered maximum HI in upland rice. Nath *et al.* (2016) obtained the highest HI in hybrid rice at 180 kg N ha^{-1}.

2.1.2.2 Potassium

Mondal *et al.* (1987) obtained higher number of panicles, percentage of filled grains per panicle and 1000 grain weight in rice at 160 kg K_2O ha^{-1}. Velayudham and Velayudham(1991) reported that application of 45 kg K_2O ha^{-1} produced more number of grains per panicle in rice. Anu (2001) found that, in upland rice, maximum number of productive tillers and filled grains per panicle were obtained at 45 kg K_2O ha^{-1}. The maximum productive tillers per hill and filled grains per panicle in upland rice were obtained at 45 kg K_2O ha^{-1} (Ranjini, 2002). Mini (2005) revealed that application of 50 kg K_2O ha^{-1} produced maximum panicle length, weight of panicle, number of spikelets per panicle, number of filled grains per panicle and 1000 grain weight in upland rice. The maximum number of productive tillers and filled grains per panicle in hybrid rice were recorded at 80 kg K_2O ha^{-1} (Yajjala, 2011) Akanda *et al.* (2012) obtained the highest number of productive tillers and filled grains per panicle in aromatic rice at 25 kg K_2O ha^{-1}. Islam *et al.*(2015) obtained maximum number of productive tillers m^{-2}, filled grains per panicle and the longest panicle in aman rice at 80 kg K_2O ha^{-1} .The highest panicle length and number of filled grains per panicle in rice were observed at 60 kg K_2O ha^{-1} (Huda *et al.*,2016). Kumar (2016) obtained higher number of productive tillers per hill, longer panicles, higher weight of panicle, more number of spikelets per panicle, more number of filled grains and 1000 grain weight with 60 kg K_2O ha^{-1}. Birla (2017) obtained the longest panicle at 96 kg K_2O ha^{-1}. Suman (2017) recorded the highest values of productive tillers m^{-2} and panicle length in upland rice at 45 kg K_2O ha^{-1}.

Brohi *et al.* (1997) obtained the highest grain yield in rice at 40 kg K_2O ha^{-1}. Potassium has an important influence in grain yield, duration of crops and harvest index (Raju *et al.*, 1999). They also mentioned that rice yield and other characters responded well to higher K levels upto 60 kg K_2O ha^{-1}. Anu (2001) found that, in upland rice, yield increased with increase in the level of K and maximum grain and straw yields were obtained at 45 kg K_2O ha^{-1}. The maximum grain and straw yields in upland rice were obtained at 45 kg K_2O ha^{-1} (Ranjini, 2002). Mini (2005) recorded maximum grain and straw yields at 50 kg K_2O ha^{-1}. Bahmanyar and Mashaee (2010) obtained maximum grain and straw yields in rice at 30 kg K_2O ha^{-1}. The maximum grain and straw yields in rice were observed at 80 kg K_2O ha^{-1} (Kabir *et al.*, 2011). The maximum grain yield in hybrid rice was recorded at 80 kg K_2O ha^{-1} (Yajjala, 2011). Islam *et al.* (2015) obtained the highest grain and straw yields of rice at 80 kg K_2O ha^{-1}. However, Kumar (2016) and Huda *et al.* (2016) observed maximum grain and straw yields at 60 kg K_2O ha^{-1}. Birla (2017) obtained maximum grain and straw yields at 96 kg K_2O ha^{-1}. Kalala *et al.* (2017) reported maximum grain yield in rice at 50 kg K_2O ha^{-1}. Suman (2017) recorded the highest grain and straw yields in upland rice at 45 kg K_2O ha^{-1}.

Akanda *et al.* (2012) obtained maximum HI in aromatic rice at 25 kg K ha^{-1}. Murthy *et al.* (2014) obtained the highest HI in rabi rice at 50 kg K_2O ha^{-1}. The highest HI in aman rice was recorded at 80 kg K_2O ha^{-1} (Islam *et al.*,2015). Kumar (2016) observed the highest HI (0.45) at 60 kg K_2O ha^{-1}. Nath *et al.* (2016) obtained the highest HI in hybrid rice at 90 kg K_2O ha^{-1}.

2.1.2.3 Combined Effect of Nitrogen and Potassium

The maximum values of yield attributing characters and yield were recorded at combined application of NK at 80:45 kg ha^{-1} (Anu, 2001). Similar findings were recorded by Ranjini (2002) at NK level of 90:45 kg ha^{-1}(2:1 ratio). Mini (2005) obtained maximum grain and straw yields at 100:50 kg NK ha^{-1} (2:1 ratio) in upland rice. Bahmanyar and Mashaee (2010) obtained the longest panicle, maximum number of filled grains per panicle and grain and straw yields in rice at 23 kg N ha^{-1} and 30 kg K_2O ha^{-1}. The maximum grain and straw yields in rice were observed at 140:80 kg NK ha^{-1} (Kabir *et al.*, 2011). Akanda *et al.* (2012) repoted maximum grain and straw yields in rice with NK applied @ 50:25 kg NK ha^{-1} (2:1 ratio). The highest grain and straw yields in rice were obtained at 120:70 kg NK ha^{-1} (Kumar and Dawson, 2012). Murthy *et al.* (2014) observed that combined application of NK at 180:50 kg ha^{-1} resulted in higher grain yield of rabi rice. Patel and Mishra (2015) obtained maximum grain and straw yields in rice with application at 90:40 kg NK ha^{-1}. Kumar (2016) obtained maximum grain and straw yields at 120:60 kg NK ha^{-1} (2:1 ratio) in upland rice. Nath *et al.* (2016) obtained maximum grain and straw yields at 180:90 kg NK ha^{-1} (2:1 ratio) in hybrid rice. Kumar *et al.* (2017) obtained the highest grain and straw yield in aerobic rice at 150:37.5 kg NK ha^{-1}. Suman (2017) obtained the highest grain and straw yields at 90:45 kg NK ha^{-1} (2:1 ratio) in upland rice.

2.1.3. Physiological and Chemical estimation

2.1.3.1 Nitrogen

The highest chlorophyll content in upland rice was registered at 100 kg N ha^{-1} (Mini, 2005). According to Maheshwari (2006), total chlorophyll and its fractions (chlorophyll a and chlorophyll b) were affected by N levels and 175 kg N ha^{-1} gave the highest chlorophyll content in rice. Lee *et al.* (2011) obtained the highest chlorophyll content at 180 kg N ha^{-1} in rice. Akanda *et al.* (2012) obtained maximum chlorophyll content in aromatic rice at 50 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 (2017) 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} and lower RLWC at lower level of nitrogen of 100 kg ha^{-1}.

According to Uppal and Shidul (1995), there is an increase in grain protein content in rice up to 120 kg N ha^{-1}. Similar finding was reported in upland rice by Anu (2001) upto 80 kg N ha^{-1}, Ranjini (2002) at 90 kg N ha^{-1} and Mini (2005) at 100 kg N ha^{-1}. Murthy (2009) observed that grain quality in rice in terms of protein content progressively increased with incremental doses of N upto 180 kg ha^{-1}. Maqsood *et al.* (2013) observed increase in grain protein content due to N application at 100 kg ha^{-1} in rice. Swaroopa and Lakshmi (2015) obtained maximum value of grain protein content in rice at 135 kg N ha^{-1}. Kumar (2016) observed that there was a significant increase in grain protein content (5.96 per cent) in upland rice at 100 kg N ha^{-1}. The highest grain protein content (8.34 per cent) in scented rice was recorded at 120 kg N ha^{-1}(Kumar and Kureel, 2017).

Brohi *et al.* (1997) found that N fertilization had a significant influence on nutrient uptake by straw and grain and obtained maximum uptake of N, P and K at 240 kg N ha^{-1}. Anu (2001) obtained the highest NPK uptake in upland rice at 80 kg N ha^{-1}. Similar findings were reported in upland rice by Ranjini (2002) and Mini (2005) at 90 kg N ha^{-1} and 100 kg N ha^{-1} respectively. Mhasker and Thorat (2005) found that application of 120 kg N ha^{-1} recorded significantly higher N, P and K uptake in scented rice. Nutrient uptake was higher in rice when N was given at 200 kg ha^{-1} (Artacho *et al.*, 2009). The maximum uptake of N, P and K in rice was observed at 140 kg N ha^{-1} (Kabir *et al.*, 2011). Tayefe *et al.* (2011) concluded that, in rice, total N uptake increased with increase in N and maximum nutrient uptake was obtained at 90 kg N ha^{-1}. Uwanyirigira (2013) recorded higher N uptake in upland rice at 109 kg N ha^{-1}. Qiao – gang *et al.* (2013) stated that uptake of N, P and K in rice showed an increasing trend with N application from 0 to 270 kg N ha^{-1}, but decreased at N levels beyond 270 kg N ha^{-1}. Murthy *et al.* (2014) observed that N applied @ 180 kg ha^{-1} resulted in the higher uptake of nutrients in rabi rice. Nayak *et al.* (2015) observed the higher N uptake in rice at 80 kg N ha^{-1}. Nath *et al.* (2016) found that N levels had significant effect on nutrient uptake in hybrid rice and the uptake was the maximum at 180 kg N ha^{-1}.

Kumar (2016) revealed that application of 120 kg N ha^{-1} registered the highest NPK uptake by grain and straw in upland rice. Kumar *et al.* (2017) obtained maximum nutrient uptake in aerobic rice at 150 kg N ha^{-1}.

2.1.3.2 Potassium

The highest chlorophyll content in upland rice was registered at 50 kg K_2O ha^{-1}(Mini,2005) . Akanda *et al.* (2012) obtained maximum chlorophyll content in aromatic rice at 25 kg K_2O ha^{-1}. Wakeel *et al.* (2017) observed maximum chlorophyll content in aerobic basmati rice at 180 kg K_2O ha^{-1}.

Anu (2001) observed maximum grain protein content in upland rice when K was given at 45 kg K_2O ha^{-1}. Mini (2005) obtained the highest grain protein content at 50 kg K_2O ha^{-1}. Kumar (2016) recorded the highest grain protein content in upland rice at 50 kg K_2O ha^{-1}.

Zaina and Ismail (2016) observed the highest proline content in rice at 160 kg K_2O ha^{-1}.

Brohi *et al.* (1997) found that K fertilization had significant influence on P and K uptake by rice but it did not influence N uptake. Similar trends were observed in upland rice by Ranjini (2002) at 45 kg K_2O ha^{-1} and Mini (2005) at 50 kg K_2O ha^{-1}. The maximum uptake of N, P and K in rice was observed at 80 kg K_2O ha^{-1} (Kabir *et al.*, 2011). The maximum uptake of K in hybrid rice was recorded at 80 kg K_2O ha^{-1} (Yajjala, 2011). Murthy *et al.* (2014) observed that K application @ 50 kg K_2O ha^{-1} resulted in higher uptake of nutrients in rabi rice. Filho *et al.* (2016) observed that K levels increased N, P and K uptake in upland rice. Maximum uptake of K by rice was obtained at 60 kg K_2O ha^{-1} (Huda *et al.*, 2016). Nath *et al.* (2016) found that K levels had significant effect on nutrient uptake in hybrid rice and the uptake was maximum at 90 kg K_2O ha^{-1}. Zaina and Ismail (2016) observed higher uptake of nutrients in rice at 160 kg K_2O ha^{-1}. Birla (2017) found that application of increased level of K in soil (96 kg K_2O ha^{-1}) resulted in higher uptake of N, P and K in rice. Kalala *et al.* (2017) found that K application increased K uptake in rice from low to adequate range. Kumar *et al.* (2017) reported maximum nutrient uptake in aerobic rice at 37.5 kg K_2O ha^{-1}.

2.1.3.3 Combined effect of Nitrogen and Potassium

The maximum grain protein content in upland rice was recorded at 80:45 kg NK ha^{-1} (Anu, 2001). Mini (2005) observed that chlorophyll content and RLWC were significantly influenced by NK level of 100 kg N : 50 kg K_2O ha^{-1}. The maximum chlorophyll content in leaves was obtained at 120:60 kg NK ha^{-1} and protein content in grain at 70:45 kg NK ha^{-1} in upland rice (Suman, 2017).

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) application for upland rice. She also obtained higher P status of soil at 80 kg N and 40 kg K_2O ha^{-1}.

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 N at 200 kg ha^{-1} resulted in maximum incidence of green leaf hoppers and white ears in rice (Kulagod *et al.*, 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 and 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).

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}.

2.2. INFLUENCE OF SPACING

2.2.1. Growth characters

Das *et al.* (1988) opined that closer spacing compensated yield loss by greater number of plants and tiller population per unit area. Spacing of 25cm x 25cm recorded taller plants, more number of tillers per hill and higher LAI and DMP than the other two spacings of 30 cm x 30 cm and 20 cm x 20 cm in rice (Jain, 2006). Ogbodo *et al.* (2010) found significantly higher plant height and tiller number were obtained at 30 cm x 30 cm spacing compared to 10 cm x 10 cm and 20 cm x 20 cm in rice. Awan *et al.* (2011) observed maximum plant height and tillers m^{-2} in rice at 156 kg N ha^{-1} and at a spacing of 22.5 cm × 22.5 cm. According to Faizul *et al.* (2013), closer spacing of 15 cm x 15 cm gave higher values of plant height, tillers m^{-2}, LAI and DMP in rice. Barua *et al.*(2014) obtained the highest number tillers m^{-2} at 25 cm × 15 cm spacing in boro rice. Khatun *et al.* (2015) obtained maximum number of tillers m^{-2} at the spacing of 25 cm ×15 cm. Moro (2016) opined that spacing had a definite role in tiller production and observed reduced number of tillers m^{-2} under closer spacing. Plant geometry of 15 cm x 10 cm recorded the tallest plant and the highest LAI, but DMP was higher with the spacing of 20 cm x 15 cm (Mahato and Adhikari, 2017). The tallest plants in aus rice were found at 20 cm x 10 cm spacing and maximum number of tillers m^{-2} was observed at 20 cm x 25 cm spacing (Ninad *et al.*, 2017).

2.2.2 Yield and Yield attributing characters

Geethadevi *et al.* (2000) obtained maximum grain yield in rice at 20 cm × 10 cm spacing. Baloch *et al.* (2002) opined that an increase in spacing induced vigorous plant growth as well as increased the number of panicles per hill, grain yield per hill, filled grains per panicle and 1000 grain weight and a spacing of 22.5 cm x 22.5 cm was found to be more appropriate in rice. According to Omina EL-Shayieb (2003), a narrow spacing of 20 cm × 10 cm resulted in higher grain yield and yield components of rice compared with 20 cm × 20 cm or 30 cm× 20 cm. Higher values of panicle length, panicle weight, number of spikelets per panicle, grain per panicle were observed by Nadeem *et al.* (2004) in rice at 20 cm×20 cm spacing when compared to 20 cm × 15 cm and 15 cm × 15 cm spacings. Awan *et al.* (2011) observed maximum number of filled grains per panicle and grain and straw yields in rice at a spacing of 22.5 cm ×22.5 cm. Amin *et al.* (2012) obtained the highest grain and straw yields at a spacing of 10 cm ×10 cm in rice. Sulthana *et al.* (2012) revealed that rice crop sown at 25 cm ×15 cm produced the highest grain yield of 5.69 t ha^{-1}. Faizul *et al.*(2013) opined that closer spacing intercepted maximum photosynthetically active radiation than wider spacing and also resulted in higher grain yield. Barua *et al* (2014) obtained the highest number of productive tillers m^{-2}, grains per panicle and grain yield at 25 cm × 15 cm spacing in boro rice. According to Uddin *et al.*(2015), 20 cm ×15 cm spacing was found better for higher grain yield (3.66 t ha^{-1}), number of productive tillers per hill (5.13), number of total grains per panicle (91.80), number of filled grains per panicle (84.40) and harvest index (0.45) in transplanted boro rice. Meena *et al.*(2015) found that a spacing of 25 cm ×15 cm was good for getting maximum productivity in rice and the grain yield was on par with the spacing of 20 cm ×10 cm. Khatun *et al.*(2015) obtained maximum grain yield at 25 cm ×15 cm spacing. The maximum number of productive tillers m^{-2} and grains per panicle in aus rice were observed at 25 cm x 20 cm spacing but grain yield was the highest at 20 cm x 10 cm spacing (Ninad *et al* ., 2017). The highest number of grains per panicle was obtained in aman rice at 40 cm x 40 cm spacing but grain yield was higher at 30 cm x 30 cm spacing (Sarkar and Nahar, 2017).

Awan *et al.* (2011) observed maximum number of filled grains per panicle and grain and straw yields in rice at 156 kg N ha^{-1} and at a spacing of 22.5 cm ×22.5 cm. Amin *et al.* (2012) obtained the highest grain and straw yields at 150 kg N ha^{-1} and at a spacing of 10 cm ×10 cm in rice.

2.2.3 Physiological and chemical estimations

The P uptake in rice was higher at 20 cm×20 cm spacing while K uptake was higher at 10 cm×10 cm spacing (Meas *et al*., 2011). A spacing of 30 cm × 30 cm favoured higher nutrient uptake (Singh *et al.*, 2013). An increase of 8.5 to 9.8 per cent in total nutrient uptake in rice was obtained with 25 cm × 25 cm spacing compared to 30 cm × 30 cm spacing (Ram *et al.*, 2014). The highest nutrient uptake in rice was obtained at 15 cm × 10 cm spacing (Sampath *et al.*, 2017).

2.2.4 Major weeds

The highest weed density was noticed at wider spacing of 25 cm × 35 cm compared to closer spacing of 10 cm × 15 cm in rice (Hossein *et al.*, 2003). A closer spacing of 20 cm × 10 cm resulted in the lowest weed dry weight (Salma *et al.*, 2017).

2.2.5 Pest and disease incidence

The highest incidence of disease and disease severity were observed for 20 cm x15 cm spaing compared to 25cm x25 cm spacing (Kaing *et al*., 2015).

2.2.6 Economics of cultivation

A spacing of 30 cm × 30 cm resulted in higher BCR (Singh *et al.*, 2013). Closer spacing of 25 cm × 25 cm resulted in higher net returns and BCR in rice than wider spacing of 30 cm × 30 cm (Ram *et al.*, 2014). The highest BCR in direct seeded rice was observed at a spacing of 20 cm × 10 cm (Dongarwar *et al.*, 2017). A spacing of 20 cm x 10 cm recorded maximum gross returns, net returns and BCR in rice (Kumar, 2017).

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Materials and Methods

3. MATERIALS AND METHODS

A field experiment on 'Productivity of upland rice (*Oryza sativa* L.) at different NK ratios and spacings' was conducted at Instructional Farm, College of Agriculture, Vellayani during *Kharif*, 2018. The objective of the research was to study the effect of NK ratios and spacings on growth and yield of upland rice and to work out the economics of cultivation. The materials and methods used are presented in this chapter.

3.1 GENERAL DETAILS

3.1.1 Experimental Site

The experiment was conducted at Instructional Farm of the 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 texture of the soil is sandy clay loam. The physico – chemical characteristics of the soil of the experimental field are presented in Table 1.

3.1.3 Climate

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

The daily weather parameters like mean temperature, relative humidity (RH) and rainfall were recorded for the standard weeks during the cropping period. The rainfall received during the crop season extending from 29/6/2018 to 14/09/2018 was 940.70 mm in 51 rainy days. The mean maximum and minimum temperature recorded during the crop season were 33 and 23 °C respectively. The maximum and minimum relative humidity of 96.43 and 70.90 per cent were recorded respectively during the crop season.

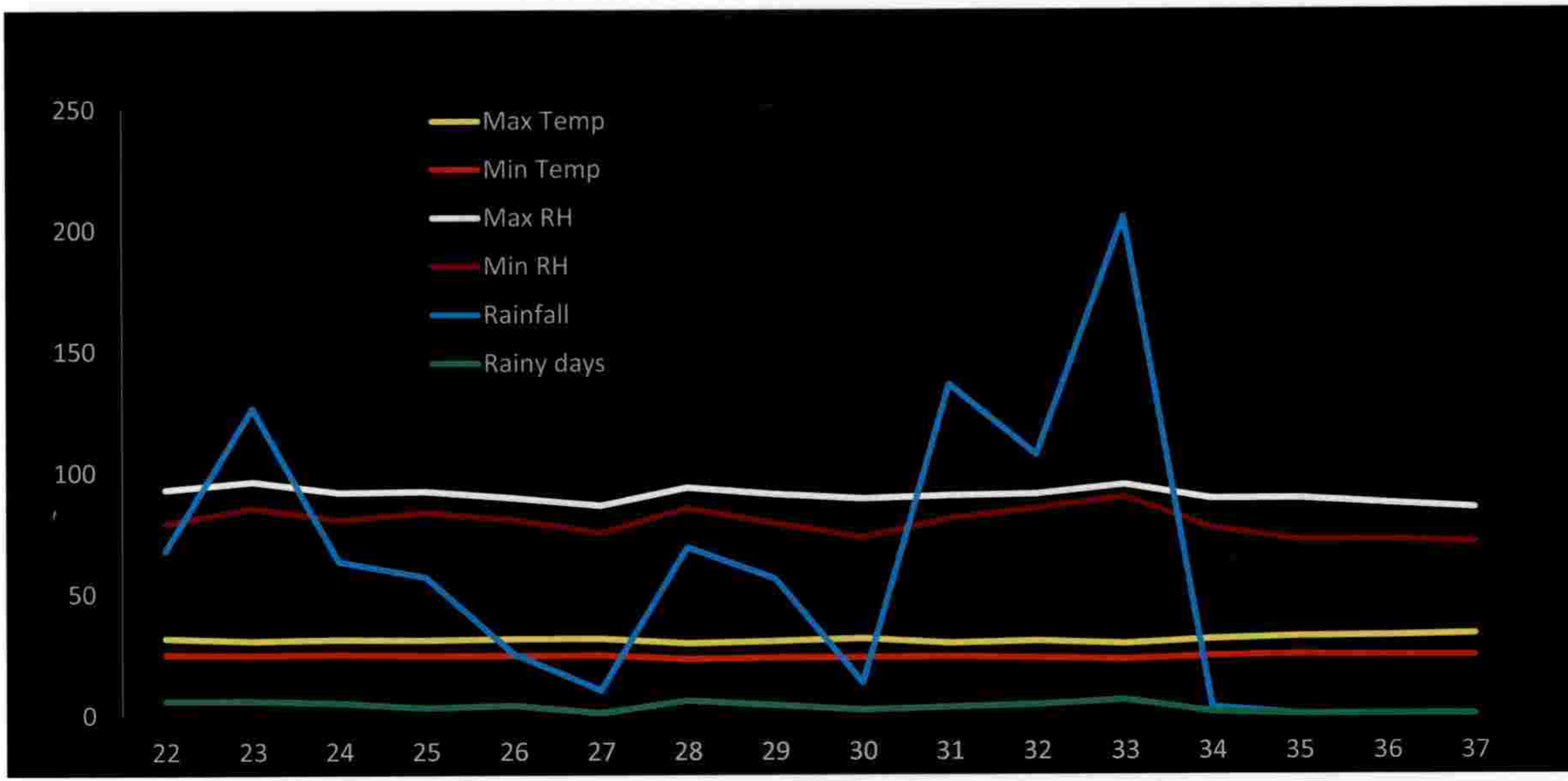

Fig. 1 Weather parameters during the cropping period (May – September 2018)

3.1.4 Cropping Season

The field experiment was conducted during *Kharif*, 2018 (May to September 2018). The crop was sown on 29th May, 2018 and harvested on 14th September, 2018.

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

Particulars	Value	Method used
A. Particle size composition		
Coarse Sand (%)	16.92	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine Sand (%)	30.52	
Silt (%)	23.85	
Clay (%)	27.81	
Texture	Sandy clay loam	
B. Physical properties		
Bulk density (Mg m^{-3})	1.59	Core method (Blake, 1965)
Porosity (%)	40.05	
Water holding capacity (%)	19.03	
C. Chemical properties		
pH	4.8 (Very strongly acidic)	pH meter with glass electrode (Jackson, 1973)
Organic carbon (%)	0.71 (Medium)	Walkley and Black rapid titration method (Walkey and Black, 1934)

Available N (kg ha^{-1})	250 (Low)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	31.50 (High)	Bray extraction and photoelectric colorimetry (Jackson, 1973)
Available K (kg ha^{-1})	224 (Medium)	Neutral normal ammonium acetate extract using flame photometry (Jackson, 1973)

3.2 MATERIALS

3.2.1 Crop and Variety

Rice variety Prathyasa (MO 21) released from Rice Research station, Moncompu was used for the study. It is a photo insensitive, semi tall and non lodging variety with 105-110 days duration. It is moderately resistant to gall midge, sheath rot and sheath blight.

3.2.2 Source of seed

Prathyasa (MO-21) seeds were collected from Rice Research station, Moncompu, Kerala Agricultural University.

3.2.3 Manures and Fertilizers

Dried cowdung (0.5 per cent N, 0.3 per cent P_2O_5 and 0.4 per cent K_2O content) was used as source of organic manure. Source of NPK for the experiment were urea (46 per cent N), rajphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O).

3.3 METHODS

3.3.1 Design and Lay Out

Design	: Factorial RBD
Treatments	: 12
Replication	: 3
Season	: *Kharif,* 2018
Gross Plot Size	: 5 m x 4 m
Net Plot Size	: 4.6 m x 3.8 m

3.3.2 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)

l_2 : 90 kg N : 45 kg K_2O

l_3 : 120 kg N : 60 kg K_2O

l_4 : 60 kg N : 45 kg K_2O

l_5 : 90 kg N : 67.5 kg K_2O

l_6 : 120 kg N : 90 kg K_2O

2) Spacing (S)

s_1 : 20 cm x 15 cm

s_2 : 20 cm x 10 cm

Treatment combinations = 6 x 2 = 12

3.3.3 Field Preparation and Lay Out

The experimental area was ploughed and brought to a fine tilth. It was laid into plots as per the layout plan.

RI	RII	RIII
l_1s_1	l_1s_2	l_2s_1
l_1s_2	l_1s_1	l_2s_2
l_2s_1	l_2s_2	l_1s_2
l_2s_2	l_2s_1	l_2s_2
l_3s_1	l_3s_2	l_3s_1
l_3s_2	l_3s_1	l_3s_2
l_4s_1	l_4s_2	l_4s_1
l_4s_2	l_4s_1	l_4s_2
l_5s_1	l_5s_2	l_5s_1
l_5s_2	l_5s_1	l_5s_2
l_6s_1	l_6s_2	l_6s_1
l_6s_2	l_6s_1	l_6s_2

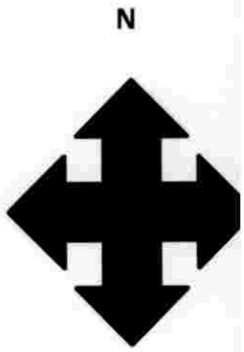

Fig. 2 Layout plan of the experiment

3.3.4 Application of Lime

Recommended dose of lime (600 kg ha^{-1}) was uniformly applied to all plots in two splits, 350 kg ha^{-1} at one week before sowing and 250 kg ha^{-1} at one month after sowing.

3.3.5 Seeds and Sowing

The pre - germinated paddy seeds were dibbled at a spacing of 20 cm x 10 cm and 20 cm x 15 cm as per treatments on 29/05/2018.

3.3.6 Application of Manures and Fertilizers

Dried cowdung was applied uniformly to all the plots @ 5 t ha^{-1} before sowing the seeds. Entire dose of P (30 kg P_2O_5 ha^{-1}) was applied uniformly to all plots just before sowing the seeds, incorporated well into the soil and levelled uniformly. Nitrogen and potassium fertilizers were applied as per the treatments.

3.3.7 Water Management

Life saving irrigation was given when there was no rain.

3.3.8 Weed Management

Hand weedings were done at 15, 30 and 45 DAS.

3.3.9 Plant Protection

During panicle initiation stage Thiamethoxam 5g / 15 L was sprayed twice during consecutive weeks for rice bug attack. Thiamethoxam+ Chlorantraniliprole 4 ml /10 L was applied against rice bug and stem borer.

3.3.10 Harvest

The crop was harvested on 14/09/2018. The crop was harvested, threshed, winnowed and grain and straw weight were recorded separately and expressed in kg ha^{-1} on dry weight basis.

Plate 1.General view of the experimental plot

3.4 GROWTH CHARACTERS

3.4.1 Plant Height at 30 DAS, 60 DAS and at harvest

Plant height was measured from 5 randomly selected plants at 30, 60 DAS and at harvest and expressed in cm. The plant height was measured from the base to the tip of the top most leaf at 30 and 60 DAS. At harvest, the height was recorded from the base to the tip of the longest panicle.

3.4.2 Number of Tillers m^{-2} at 60 DAS

Number of tillers was counted from the net plot area.

3.4.3 Leaf Area Index at 60 DAS

Five observation plants were tagged and maximum length and breadth of the 3rd leaf from the top were taken. The LAI was worked out using the formula suggested by Yoshida *et al.*, 1976.

$$\text{LAI} = \frac{k(l \times w) \times \text{Number of leaves per hill}}{\text{Land area occupied by the plant}}$$

Where k - Constant factor (0.75)
l - Maximum length of the 3rd leaf blade from the top(cm)
w - Maximum width of leaf blade (cm)

3.4.4 Dry Matter Production at 30 DAS, 60 DAS and at harvest

At 30 and 60 DAS, five hills were randomly selected and uprooted from the net plot area. At harvest, five hills were randomly selected and uprooted from the net plot area and the grain and straw were separated. The samples were initially air dried for a day and later oven dried at 75 ± 5 °C to constant weight. The DMP was computed and was expressed in kg ha^{-1}.

Seedling stage

Tillering stage

Maturity stage

Plate 2. Different growth stages

3.5 YIELD ATTRIBUTES

3.5.1 Productive Tillers m^{-2}

At harvest, productive tillers were counted by using a quadrant of size 0.5 m x 0.5 m and the mean number was worked out and expressed as panicle m^{-2}.

3.5.2 Length of Panicle

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

3.5.3 Grain Weight per Panicle

Five panicles were randomly selected from each treatment plot, grains were separated from each panicle and the weight was recorded on dry weight basis. The mean value was computed and expressed in g.

3.5.4 Number of Spikelets per Panicle

The spikelets were separated from each panicle, counted and the average number was worked out.

3.5.5 Percentage of Filled Grains per Panicle

From the five randomly selected panicles, the total number of filled and unfilled grains were counted separately for each panicle and the percentage of filled grains per panicle was worked out.

3.5.6 1000 Grain Weight

1000 grains from each plot were counted, dried, weighed and expressed in g.

3.5.7 Grain Yield ha^{-1}

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

3.5.8 Straw Yield ha^{-1}

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

3.5.9 Harvest Index

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

$$\text{Harvest index} = \frac{\text{Economic Yield}}{\text{Biological Yield}}$$

3.6 PHYSIOLOGICAL AND CHEMICAL ESTIMATIONS

3.6.1 Chlorophyll Content at panicle emergence stage

Total chlorophyll content of the leaves was analyzed by DMSO (dimethyl sulphoxide) method suggested by Yoshida *et al*. (1976).

3.6.2 Relative Leaf Water Content (RLWC) at flowering stage

The method described by Slayter and Baars (1965) was used to determine RLWC. It was calculated as

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

3.6.3 Proline Content at Panicle Initiation stage

Proline content of leaves was estimated by the method described by Bates *et al.* (1973).

3.6.4 Protein Content of Grain

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

3.6.5 Nutrient Uptake

The plant samples at harvest stage were analyzed for the total N, P and K content. The plant samples were separated in to grain and straw and initially sun dried for a day and then dried in hot air oven at 75 ± 5 °C to constant weight, ground and used for analysis. The required quantities of grain and straw were weighed out accurately, subjected to acid extraction and N, P and K content were determined separately. Total nitrogen content was estimated by modified microkjheldal method (Jackson, 1973), phosphorus content by vanadomolybdate phosphoric yellow colour method (Jackson, 1973) and potassium content using flame photometer (Jackson, 1973).

Uptake of N, P and K at harvest were worked out as the product of dry weight of plant samples and the respective nutrient content in the plant sample and expressed in kg ha^{-1}

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

3.6.6 Nutrient Use Efficiency

Nutrient use efficiency was determined using partial factor productivity of nutrient suggested by Cassman *et al.* (1996).

$$\text{Partial factor productivity} = \frac{Yf}{Na}$$

Yf = Yield from fertilized plot

Na= Nutrient applied in kg ha^{-1}

3.6.7 Soil Analysis

For initial soil sample analysis, soil samples were drawn to a depth of 15 cm from four different spots in the experiment plot, shade dried, ground and composite samples were prepared by quartering. After the harvest of crop also, composite soil samples were drawn from each treatment plot for the analysis of available N, P and K and organic carbon (OC).

3.7 MAJOR WEEDS OF UPLAND RICE

3.7.1 Observations on weed composition

3.7.2 Weed Dry Weight

Observations on important upland weed species and weed dry weight were recorded by the quadrant method. The weeds uprooted from the quadrant, were cleaned, air dried and then oven dried at 75 ± 5 °C.

3.8 PEST AND DISEASE INCIDENCE

The incidence of pest and diseases never reached the threshold level. So uniform score was given to all plots.

3.9 ECONOMIC ANALYSIS

The economics was worked out based on the cost of cultivation and the prevailing market price of the produce.

3.9.1 Gross Income

3.9.2 Net Income

Net income was computed using the formula

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

3.9.3 Benefit Cost Ratio

Benefit cost ratio was computed using the formula

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

3.10 STATISTICAL ANALYSIS

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

Results

4. RESULTS

The field experiment entitled 'Productivity of upland rice (*Oryza sativa* L.) at different NK ratios and spacings' was conducted during *Kharif*, 2018 at the Instructional Farm, College of Agriculture, Vellayani to study the response of upland rice to NK ratios and spacings. The observations on growth and yield parameters, physiological parameters, soil physical and chemical properties, weed dry weight and economics of cultivation were recorded, statistically analysed and presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Plant height

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

The data revealed that NK ratios did not significantly influence plant height at early stages of growth(30 DAS) but significantly influenced plant height at later stages of growth(60 DAS and harvest). Spacings did not significantly influence plant height at 30 DAS.

At 60 DAS, the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) produced the tallest plants of 96.71 cm and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording a plant height of 91.15 cm and significantly superior to other treatments. The treatment l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio) produced the shortest plants of 81.80 cm and was on par with rest of the treatments. Spacing did not have any significant influence on plant height at 60 DAS.

At harvest, the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest plant height of 104.53 cm and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) and was significantly superior to other treatments. The shortest plants of 93.76 cm were produced by the treatment l_2

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

Treatments	Plant height		
	30 DAS	60 DAS	At harvest
NK levels and ratios (L)			
l_1 (60 :30)	46.95	83.25	94.41
l_2 (90 :45)	52.70	87.10	93.76
l_3 (120 : 60)	52.01	96.71	104.53
l_4 (60 :45)	48.93	81.80	93.93
l_5 (90 : 67.5)	50.86	82.46	94.61
l_6 (120 :90)	50.03	91.15	102.60
SEm(±)	2.12	3.25	2.43
CD (0.05)	NS	9.609	7.193
Spacing(S)			
s_1 (20 cm × 15 cm)	51.03	86.60	97.12
s_2 (20 cm × 10 cm)	49.46	87.56	97.49
SEm(±)	1.22	1.88	1.40
CD (0.05)	NS	NS	NS

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

Treatments	Plant height		
(l × s interaction)	30 DAS	60 DAS	At harvest
l_1s_1	47.66	81.23	94.26
l_1s_2	46.95	85.26	94.56
l_2s_1	51.20	84.93	92.23
l_2s_2	54.20	89.26	95.30
l_3s_1	54.80	96.40	105.13
l_3s_2	49.23	97.03	103.93
l_4s_1	47.46	82.10	94.13
l_4s_2	50.40	81.80	93.93
l_5s_1	53.23	82.70	94.30
l_5s_2	48.50	82.23	94.93
l_6s_1	51.87	92.23	102.70
l_6s_2	48.20	90.06	102.50
SEm(±)	3.01	4.60	3.44
CD (0.05)	NS	NS	NS

(90:45 kg ha^{-1} of N and K_2O at 2:1 ratio). The spacing had no profound influence on plant height at harvest.

The interaction effect due to NK ratios and spacings was not significant at 30 DAS, 60 DAS and harvest.

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

The number of tillers m^{-2} as influenced by treatments are recorded in Tables 3a and 3b.

The result revealed that NK ratios had significant influence on number of tillers m^{-2} but spacing did not have any significant effect. At 60 DAS, l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) produced maximum number of tillers m^{-2} of 505.13 and it was significantly superior to all other treatments. The lowest number of tillers m^{-2} of 391.90 was observed at l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio).The maximum number of tillers m^{-2} (461) was observed with spacing s_2 (20 cm x 10 cm) and was significantly superior to s_1 (20 cm x 15 cm). The interaction effect was not significant.

4.1.3 Leaf Area Index at 60 DAS

The LAI at 60 DAS as influenced by different treatments is presented in Tables 3a and 3b.

The results revealed that NK ratios had a significant influence on LAI but spacing did not have any significant effect. At 60 DAS, l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) produced significantly higher LAI of 4.11 and was on par with l_3 (2:1 ratio). Spacings and its interaction with NK ratios was not significant.

4.1.4 Dry Matter Production

The DMP at different growth stages as influenced by the treatments and their interactions are summarized in Tables 4a and 4b.

Table 3a. Effect of NK ratios and spacings 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)	391.90	3.41
l_2 (90 :45)	412.75	3.41
l_3 (120 : 60)	431.83	4.00
l_4 (60 :45)	409.52	3.53
l_5 (90 : 67.5)	420.06	3.53
l_6 (120 :90)	505.13	4.11
SEm(±)	17.97	0.17
CD (0.05)	53.059	0.511
Spacing(S)		
s_1 (20 cm × 15 cm)	397	3.64
s_2 (20 cm × 10 cm)	461	3.69
SEm(±)	10.37	0.141
CD (0.05)	30.633	NS

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

Treatments	Number of tillers m^{-2}	Leaf area index
(l × s interaction)		
l_1s_1	361.62	3.23
l_1s_2	376.77	3.59
l_2s_1	337.05	3.32
l_2s_2	448.72	3.50
l_3s_1	422.17	4.02
l_3s_2	482.00	3.98
l_4s_1	393.15	3.70
l_4s_2	470.52	3.36
l_5s_1	392.05	3.36
l_5s_2	449.07	3.70
l_6s_1	490.65	4.09
l_6s_2	519.62	4.13
SEm(±)	25.42	0.23
CD (0.05)	NS	NS

At 30 DAS, there was no significant difference between treatments. Though not significant, the treatment l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recorded maximum DMP of 1646 kg ha^{-1}. The lowest DMP of 1287 kg ha^{-1} was recorded by the treatment l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio). The spacings did not have any significant influence on DMP at 30 DAS. Though not significant, the treatment s_2 (20 cm × 10 cm) recorded higher DMP compared to s_1 (20 cm × 15 cm).

At 60 DAS, the treatment l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recorded maximum DMP of 3596 kg ha^{-1} which was on par with the treatments l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) and l_5 (90: 67.5 kg ha^{-1} of N and K_2O at 2:1.5 ratio) which recorded DMP of 3324 and 3240 kg ha^{-1} respectively. The lowest DMP of 2243 kg ha^{-1} was recorded by the treatment l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio). At 60 DAS s_2 (20 cm × 10 cm) recorded higher DMP of 3164 kg ha^{-1} which was significantly superior to s_1 (20 cm × 15 cm) registering DMP of 2820 kg ha^{-1}.

At harvest, the treatments differed significantly and the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded maximum DMP of 7153 kg ha^{-1} which was on par with the treatment l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio). The lowest DMP of 5682 kg ha^{-1} was recorded by the treatment l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio) which was on par with treatments l_2 (90: 45 kg ha^{-1} of N and K_2O), l_4 (60: 45 kg ha^{-1} of N and K_2O) and l_5 (90: 67.5 kg ha^{-1} of N and K_2O. At harvest, spacings exerted a significant influence on DMP and s_2 (20 cm × 10 cm) registered a higher DMP of 6593 kg ha^{-1} and was significantly superior to s_1 (20 cm × 15 cm) recording DMP of 5982 kg ha^{-1}.

Interaction effect due to NK ratios and spacings did not significantly influence DMP except at 60 DAS and harvest. At 60 DAS, maximum DMP of 3979 kg ha^{-1} was obtained in the treatment interaction l_3s_2 (120 :60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) and was on par with l_5s_1 (90 :67.5 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm) and l_6s_2 (120 :90 kg ha^{-1} of N

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

Treatments	Dry matter production		
	30 DAS	60 DAS	Harvest
NK levels and ratios (L)			
l_1 (60 :30)	1287	2718	5682
l_2 (90 :45)	1482	2830	6256
l_3 (120 : 60)	1541	3324	7153
l_4 (60 :45)	1566	2243	5721
l_5 (90 : 67.5)	1473	3240	5978
l_6 (120 :90)	1646	3596	6936
SEm(±)	114	135	159
CD (0.05)	NS	399.1	471.2
Spacing(S)			
s_1 (20 cm × 15 cm)	1438	2820	5982
s_2 (20 cm × 10 cm)	1560	3164	6593
SEm(±)	65	78	92
CD (0.05)	NS	230.4	272.9

Table 4b. Interaction effect of NK ratios and spacings on dry matter production at 60 days after sowing and harvest, kg ha^{-1}

Treatments	Dry matter production		
(l × s interaction)	30 DAS	60 DAS	At harvest
l_1s_1	1351	2291	5261
l_1s_2	1222	3145	6103
l_2s_1	1404	2351	6002
l_2s_2	1559	3309	6510
l_3s_1	1484	2670	6838
l_3s_2	1597	3979	7468
l_4s_1	1494	2400	5510
l_4s_2	1638	2086	5933
l_5s_1	1357	3854	5579
l_5s_2	1589	2626	6377
l_6s_1	1537	3355	6704
l_6s_2	1756	3838	7169
SEm(±)	161	191	225
CD (0.05)	NS	564.4	665.3

and K_2O and spacing of 20 cm × 10 cm) with DMP 3854 and 3838 kg ha^{-1} respectively. The lowest DMP of 2086 kg ha^{-1} was recorded by l_4s_2 (60:45 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm. At harvest, the maximum DMP of 7468 kg ha^{-1} was obtained in the treatment interaction l_3s_2 (120 :60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) and was on par with l_3s_1 (120 :60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm) and l_6s_2 (120 :90 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) with DMP of 6838 and 7169 kg ha^{-1} respectively.

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Number of Productive Tillers m^{-2}

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

The results revealed significant influence of NK ratios on number of productive tillers m^{-2}. The treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded maximum number of productive tillers m^{-2} of 323.12 and it was significantly superior to all other treatments except l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) which produced 292.75 productive tillers m^{-2}. The lowest number of productive tillers m^{-2} of 210.12 was recorded by l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio) and it was on par with l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio).

In the case of spacing, s_2 (20 cm × 10 cm) recorded significantly higher productive tillers m^{-2} of 281.25.

Interaction effect did not significantly influence number of productive tillers m^{-2} but the highest number of productive tillers m^{-2} was recorded in the treatment l_5s_2 (120:60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) and the lowest in the treatment l_4s_1 (60:45 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm).

4.2.2 Length of Panicle

The length of panicle (cm) as influenced by various treatments are presented in Tables 5a and 5b.

NK ratio influenced length of panicle significantly. The treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded significantly higher panicle length of 24.95 cm which was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording a panicle length of 23.30cm. The shortest panicle length of 20.78 was recorded at l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio). Spacing did not significantly influence length of panicle.

Interaction of NK ratios and spacings was also found not significant. Though not significant, the longest panicle was observed in the treatment combination l_3s_1 (120:60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm) and shortest panicle was observed in the treatment l_4s_2 (60:45 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm).

4.2.3 Grain Weight per Panicle

The mean weight of panicle (g) as influenced by various treatments and their interactions is presented in Tables 5a and 5b.

NK ratios significantly influenced grain weight per panicle. The treatment l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recorded significantly higher grain weight per panicle of 2.70 g and was on par with l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recording 2.61 g. The lowest grain weight per panicle of 2.03 was recorded by l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio). Spacing did not significantly influence grain weight per panicle.

The interaction effect of NK ratios and spacings did not significantly influence grain weight per panicle.

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

Treatments	Productive tillers m^{-2}	Length of panicle (cm)	Grain weight per panicle (g)
l_1 (60 :30)	218.62	20.78	2.03
l_2 (90 :45)	265.62	21.93	2.10
l_3 (120 : 60)	323.12	24.95	2.61
l_4 (60 :45)	210.12	20.90	2.25
l_5 (90 : 67.5)	258.00	22.25	2.53
l_6 (120 :90)	292.75	23.30	2.70
SEm(±)	11.63	0.86	0.11
CD (0.05)	34.355	2.556	0.326
s_1 (20 cm × 15 cm)	241.50	22.43	2.60
s_2 (20 cm × 10 cm)	281.25	22.27	2.47
SEm(±)	6.72	0.50	0.06
CD (0.05)	19.835	NS	NS

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

Treatments (l × s interaction)	Productive tillers m^{-2}	Length of panicle (cm)	Grain weight per panicle (g)
l_1s_1	194.25	19.56	2.20
l_1s_2	243.00	22.00	1.87
l_2s_1	254.00	21.53	2.00
l_2s_2	277.25	22.33	2.20
l_3s_1	291.50	25.40	2.60
l_3s_2	354.75	24.50	2.63
l_4s_1	188.75	22.40	2.73
l_4s_2	231.50	19.40	1.76
l_5s_1	253.50	22.50	2.50
l_5s_2	262.50	22.00	2.56
l_6s_1	267.00	23.20	2.60
l_6s_2	318.50	23.40	2.80
SEm(±)	16.46	1.22	0.156
CD (0.05)	NS	NS	NS

4.2.4 Number of Spikelets per Panicle

The mean data of number of spikelets per panicle as influenced by different treatments are given in the Tables 6a and 6b.

NK ratios and spacings did not significantly influence number of spikelets per panicle. The maximum number of spikelets per panicle (96.98) was recorded at l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio) and minimum number of spikelets per panicle (81.65) was recorded at l_5 (90:67.5 kg ha^{-1} of N and K_2O at 2:1.5 ratio).

The interaction of treatments did not significantly influence number of spikelets per panicle significantly.

4.2.5 Percentage of Filled Grains per Panicle

The mean data of percentage of filled grains per panicle as influenced by different treatments and their interactions are given in the Tables 6a and 6b.

The NK ratios and spacings did not significantly influence percentage of filled grains per panicle. The interaction effect due to NK ratios and spacings also did not significantly influence percentage of filled grains per panicle.

4.2.6 1000 Grain Weight

The mean data of 1000 grain weight as influenced by different treatments and their interactions are shown in the Tables 6a and 6b.

The NK ratios and spacings did not significantly influence 1000 grain weight. The interaction effect due to NK ratios and spacings also did not significantly influence 1000 grain weight.

Table 6a. Effect of NK ratios and spacings on number of spikelets per panicle, percentage of filled grains per panicle and 1000 grain weight

Treatments	Number of spikelets per panicle	Percentage of filled grains per panicle	1000 grain weight (g)
NK levels and ratios(L)			
l_1 (60 :30)	85.06	85	25.85
l_2 (90 :45)	90.90	86	25.55
l_3 (120 : 60)	85.86	84	25.10
l_4 (60 :45)	95.98	84	24.53
l_5 (90 : 67.5)	81.65	89	25.85
l_6 (120 :90)	84.56	86	25.55
SEm(±)	3.51	2.70	0.78
CD (0.05)	NS	NS	NS
Spacings(S)			
s_1 (20 cm × 15 cm)	85.97	85	25.19
s_2 (20 cm × 10 cm)	88.70	85	25.61
SEm(±)	2.02	1.56	0.451
CD (0.05)	NS	NS	NS

Table 6b. Interaction effect of NK ratios and spacings on number of spikelets per panicle, percentage of filled grains per panicle and 1000 grain weight

Treatments (l × s interaction)	Number of spikelets per panicle	Percentage of filled grains per panicle	1000 grain weight (g)
l_1s_1	90.70	84.33	25.07
l_1s_2	79.43	85.66	26.63
l_2s_1	92.33	87.66	25.47
l_2s_2	89.46	84.33	25.63
l_3s_1	76.00	84.00	25.66
l_3s_2	95.73	84.33	24.53
l_4s_1	101.90	83.33	24.43
l_4s_2	90.06	85.33	24.63
l_5s_1	75.66	89.67	25.06
l_5s_2	87.63	88.67	26.63
l_6s_1	79.23	86.67	25.47
l_6s_2	89.90	86.00	25.63
SEm(±)	4.96	3.83	1.10
CD (0.05)	NS	NS	NS

4.2.7 Grain Yield

The mean data of grain yield as influenced by different treatments and their interactions are presented in the Tables 7a and 7b.

The NK ratios showed significant variation in grain yield and the treatment l_3 (120 :60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded significantly higher grain yield of 3123 kg ha^{-1} and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) which recorded a grain yield of 2994 kg ha^{-1} . The lowest grain yield of 2348 kg ha^{-1} was recorded by l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio) which was on par with l_1 and l_5. Spacing exerted a significant influence on grain yield and s_2 (20 cm × 10 cm) recorded significantly higher grain yield of 2816 kg ha^{-1} compared to s_1 (20 cm × 15 cm) which produced a grain yield of 2609 kg ha^{-1}.

The interaction effect of NK ratios and spacings on grain yield differed significantly. The treatment combination l_3s_2 (120:60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) recorded the highest grain yield of 3256 kg ha^{-1} and it was on par with l_2s_2 (90:45 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm), l_3s_1(120 : 60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm), l_6s_1(120:90 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm) and l_6s_2 (120:90 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) . The lowest grain yield of 2265 kg ha^{-1} was recorded by the treatment combination l_4s_1 (60:45 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm).

4.2.8 Straw Yield

The mean data of straw yield as influenced by different treatments and their interaction are presented in Tables 7a and 7b.

The NK ratios significantly influenced the straw yields and the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest straw yield of 4030 kg ha^{-1} and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording 3942 kg ha^{-1}. The lowest straw yield of 3217 kg ha^{-1} was recorded by l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio) which was on par with l_4 and l_5. Spacing

Table 7a. Effect of NK ratios and spacings 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)	2464	3217	0.43
l_2 (90 :45)	2762	3494	0.44
l_3 (120 : 60)	3123	4030	0.43
l_4 (60 :45)	2348	3372	0.40
l_5 (90 : 67.5)	2583	3394	0.43
l_6 (120 :90)	2994	3942	0.43
SEm(±)	117	87	0.01
CD (0.05)	347.8	258.5	NS
Spacing(S)			
s_1 (20 cm × 15 cm)	2609	3373	0.44
s_2 (20 cm × 10 cm)	2816	3778	0.43
SEm(±)	68	50	0.06
CD (0.05)	200.8	149.3	NS

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

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
(l × s interaction)			
l_1s_1	2346	2914	0.44
l_1s_2	2583	3520	0.42
l_2s_1	2668	3334	0.44
l_2s_2	2856	3654	0.43
l_3s_1	2989	3848	0.43
l_3s_2	3256	4212	0.43
l_4s_1	2265	3244	0.41
l_4s_2	2432	3501	0.40
l_5s_1	2458	3121	0.44
l_5s_2	2709	3667	0.42
l_6s_1	2929	3774	0.43
l_6s_2	3059	4109	0.42
SEm(±)	166.6	169.9	0.01
CD (0.05)	488	493	NS

also exerted a significant influence on straw yield and s_2 (20 cm × 10 cm) produced a straw yield of 3778 kg ha^{-1} which was significantly superior to s_1 (20 cm × 15 cm).

The interaction effect of NK ratios and spacings on straw yield differed significantly. The interaction l_3s_2 (120:60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) recorded the highest straw yield of 4212 kg ha^{-1} and was on par with l_3s_1 (120:60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm), l_6s_1 (120:90 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm) and l_6s_2 (120 : 60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) respectively. The lowest straw yield of 2914 kg ha^{-1} was recorded by the treatment combination l_1s_1 (60: 30 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm).

4.2.9 Harvest Index

The mean data of HI as influenced by different treatments and their interactions are given in the Tables 7a and 7b.

Neither NK ratios, spacings, nor their interactions significantly influenced HI.

4.3 PHYSIOLOGICAL AND CHEMICAL PARAMETERS

4.3.1 Chlorophyll Content at Panicle Emergence Stage

The mean data of chlorophyll content as influenced by different treatments and their interactions are given in the Tables 8a and 8b.

Neither NK ratios, spacings nor their interactions significantly influenced chlorophyll content.

4.3.2 RLWC at Flowering Stage

Neither NK ratios, spacings, nor their interactions significantly influenced RLWC content (Tables 8a and 8b).

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

Treatments	Chlorophyll content (mg g^{-1} FW)	Relative leaf water content (%)	Proline content (μmol g^{-1} FW)
NK levels and ratios (L)			
l_1 (60 :30)	0.96	78.48	0.48
l_2 (90 :45)	1.00	79.56	0.45
l_3 (120 : 60)	1.01	80.38	0.43
l_4 (60 :45)	1.01	80.15	0.45
l_5 (90 : 67.5)	1.01	80.93	0.40
l_6 (120 :90)	0.96	81.01	0.45
SEm(±)	0.04	3.35	0.02
CD (0.05)	NS	NS	NS
Spacing(S)			
s_1 (20 cm × 15 cm)	1.01	80.08	0.45
s_2 (20 cm × 10 cm)	0.97	80.08	0.43
SEm(±)	0.02	1.93	0.01
CD (0.05)	NS	NS	NS

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

Treatments	Chlorophyll content (mg g^{-1} FW)	Relative leaf water content (%)	Proline content (μmol g^{-1} FW)
(l × s interaction)			
l_1s_1	0.96	78.93	0.46
l_1s_2	0.96	78.03	0.50
l_2s_1	1.00	78.96	0.46
l_2s_2	1.00	80.16	0.43
l_3s_1	1.01	81.06	0.43
l_3s_2	1.02	79.70	0.43
l_4s_1	1.00	78.30	0.46
l_4s_2	1.03	82.00	0.43
l_5s_1	1.06	82.06	0.40
l_5s_2	0.96	79.80	0.40
l_6s_1	1.00	81.20	0.46
l_6s_2	0.93	80.83	0.43
SEm(±)	0.06	4.47	0.02
CD (0.05)	NS	NS	NS

4.3.3 Proline Content at Panicle Initiation

It can be seen from Tables 8a and 8b that neither NK ratios, spacings, nor their interactions significantly influenced proline content.

4.3.4 Protein Content of Grains

The mean data of protein content of grain as influenced by different treatments are given in Tables 9a and 9b.

The NK ratios significantly influenced the protein content of grain and the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest value of 5.51 per cent and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) which registered a value of 5.39 per cent. The lowest value of 4.32 per cent was recorded by l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio).

No significant variation in protein content of grain was observed either due to spacing or its interaction with NK ratios.

4.3.5 NPK Uptake by Crop at Harvest

4.3.5.1 Uptake of Nitrogen

The mean data on N uptake at harvest as influenced by different treatments are given in Tables 10a and 10b.

The NK ratios significantly influenced N uptake and the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest N uptake of 89.20 kg ha^{-1} and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording a value of 86.44 kg ha^{-1}. The lowest N uptake of 44.83 kg $ha^{-1}$was registered by l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio).

Neither spacings nor its interaction with NK ratios significantly influenced N uptake.

Table 9a. Effect of NK ratios and spacings on grain protein content, %

Treatments	Grain protein content
NK levels and ratios (L)	
l_1 (60 :30)	4.32
l_2 (90 :45)	4.65
l_3 (120 : 60)	5.51
l_4 (60 :45)	4.54
l_5 (90 : 67.5)	4.93
l_6 (120 :90)	5.39
SEm(±)	0.12
CD (0.05)	0.372
Spacing(S)	
s_1 (20 cm × 15 cm)	4.81
s_2 (20 cm × 10 cm)	4.96
SEm(±)	0.07
CD (0.05)	NS

Table 9b. Interaction effect of NK ratios and spacings on grain protein content, %

Treatments	Grain protein content
(l × s interaction)	
l_1s_1	4.14
l_1s_2	4.50
l_2s_1	4.83
l_2s_2	4.47
l_3s_1	5.64
l_3s_2	5.37
l_4s_1	4.32
l_4s_2	4.77
l_5s_1	4.72
l_5s_2	4.14
l_6s_1	4.72
l_6s_2	5.14
SEm(±)	0.17
CD (0.05)	NS

4.3.5.2 Uptake of Phosphorous

The mean data on P uptake at harvest as influenced by different treatments are given in Tables 10a and 10b.

The NK ratios significantly influenced P uptake and the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest value of 16.55 kg ha^{-1} and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording 14.93 kg ha^{-1}. The lowest P uptake of 10.40 kg ha^{-1} was registered by l_2 (90:45 kg ha^{-1} of N and K_2O at 2:1 ratio).

Neither spacings nor its interaction with NK ratios significantly influenced P uptake

4.3.5.3 Uptake of Potassium

The mean data on K uptake at harvest as influenced by different treatments are given in Tables 10a and 10b.

The NK ratios significantly influenced the K uptake and the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest value of 45.71 kg ha^{-1} and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording 44.61 kg ha^{-1} respectively. The lowest K uptake was registered by l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio).

Neither spacings nor its interaction with NK ratios significantly influenced K uptake.

4.3.6 Nutrient Use Efficiency

4.3.6.1 Nitrogen Use Efficiency

The mean data of NUE as influenced by different treatments are given in Tables 11a and 11b.

The data revealed significant difference due to treatments. The treatment l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest value of 41.08 kg

Table 10a. Effect of NK ratios and spacings on N, P and K uptake at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
NK levels and ratios (L)			
l_1 (60 :30)	44.83	11.80	25.53
l_2 (90 :45)	66.01	10.73	34.43
l_3 (120 : 60)	89.20	16.55	45.71
l_4 (60 :45)	54.50	10.40	29.33
l_5 (90 : 67.5)	63.55	11.89	37.10
l_6 (120 :90)	86.44	14.93	44.61
SEm(±)	1.89	1.29	1.47
CD (0.05)	5.594	3.812	4.361
Spacing(S)			
s_1 (20 cm × 15 cm)	67.92	12.72	35.97
s_2 (20 cm × 10 cm)	66.92	12.71	36.27
SEm(±)	1.45	0.74	0.85
CD (0.05)	NS	NS	NS

Table 10b. Interaction effect of NK ratios and spacings on N, P and K uptake at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
(l × s interaction)			
l_1s_1	43.87	12.06	24.65
l_1s_2	45.79	11.53	26.42
l_2s_1	64.61	10.70	35.44
l_2s_2	67.42	10.75	33.42
l_3s_1	89.34	17.25	44.63
l_3s_2	89.06	15.86	46.79
l_4s_1	55.83	10.64	30.42
l_4s_2	53.17	10.16	28.25
l_5s_1	64.08	11.59	36.96
l_5s_2	63.02	12.20	37.24
l_6s_1	89.81	11.59	43.70
l_6s_2	83.08	12.20	45.51
SEm(±)	2.68	1.82	2.08
CD (0.05)	NS	NS	NS

grain kg^{-1} N and was on par with l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording 39.14 kg grain kg^{-1} N. The lowest value of 24.95 kg grain kg^{-1} N was recorded by l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio).

Among spacings, s_2 (20 cm × 10 cm) obtained significantly higher NUE (33.01 kg grain kg^{-1} N) while s_1 (20 cm × 15 cm) recorded a NUE of 30.52 kg grain kg^{-1} N.

The interaction effect of NK ratios and spacings did not significantly influence NUE.

4.3.6.2 Phosphorous Use Efficiency

The mean data of PUE as influenced by different treatments are given in Tables 11a and 11b.

Among the treatments, l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded significantly higher PUE of 104.10 kg grain kg^{-1} P_2O_5 and was on par with l_6 (120 :90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording 99.82 kg grain kg^{-1} P_2O_5. The lowest value of 78.29 kg grain kg^{-1} P_2O_5 was recorded by l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio).

Among spacings, s_2 (20 cm × 10 cm) obtained significantly higher PUE (93.87 kg grain kg^{-1} P_2O_5) while s_1 (20 cm × 15 cm) recorded a PUE of 86.98kg grain kg^{-1} P_2O_5).

The interaction effect of NK ratios and spacings did not significantly influence PUE.

4.3.6.3 Potassium Use Efficeincy

The mean data of KUE as influenced by different treatments are given in Tables 11a and 11b.

Table 11a. Effect of NK ratios and spacings on nitrogen use efficiency, phosphorous use efficiency and potassium use efficiency

Treatments	Nitrogen use efficiency (kg of grain kg^{-1} N)	Phosphorous use efficiency (kg of grain kg^{-1} P_2O_5)	Potassium use efficiency (kg of grain kg^{-1} K_2O)
NK levels and ratios (L)			
l_1 (60 :30)	41.08	82.16	82.16
l_2 (90 :45)	30.69	92.07	61.38
l_3 (120 : 60)	26.02	104.10	52.05
l_4 (60 :45)	39.14	78.29	52.19
l_5 (90 : 67.5)	28.70	86.12	38.27
l_6 (120 :90)	24.95	99.82	33.27
SEm(±)	1.30	3.92	2.16
CD (0.05)	3.846	11.595	6.389
Spacing(S)			
s_1 (20 cm × 15cm)	30.52	86.98	51.10
s_2 (20 cm × 10cm)	33.01	93.87	55.33
SEm(±)	0.75	2.26	1.25
CD (0.05)	2.221	6.694	3.689

Table 11b. Interaction effect of NK ratios and spacings on nitrogen use efficiency, phosphorous use efficiency and potassium use efficiency

Treatments	Nitrogen use efficiency (kg of grain kg^{-1} N)	Phosphorous use efficiency (kg of grain kg^{-1} P_2O_5)	Potassium use efficiency (kg of grain kg^{-1} K_2O)
(l × s interaction)			
l_1s_1	39.11	78.22	78.22
l_1s_2	43.05	86.10	86.10
l_2s_1	29.64	88.93	59.28
l_2s_2	31.73	95.21	63.47
l_3s_1	24.91	99.65	49.82
l_3s_2	27.13	108.55	54.27
l_4s_1	37.76	75.52	50.34
l_4s_2	40.53	81.06	54.04
l_5s_1	27.31	81.93	36.41
l_5s_2	30.10	90.32	40.14
l_6s_1	24.41	97.65	32.55
l_6s_2	25.49	101.98	33.99
SEm(±)	1.84	5.55	3.06
CD (0.05)	NS	NS	NS

Among the treatments, l_1 (60: 30 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest KUE of 82.16 kg grain kg^{-1} K_2O and was significantly superior to all other treatments.

Among spacings, s_2 (20 cm × 10 cm) obtained significantly higher KUE (55.33 kg grain kg^{-1} K_2O) while s_1 (20 cm × 15 cm) recorded a KUE of 51.10 kg grain kg^{-1} K_2O.

The interaction effect of NK ratios and spacings did not exert significant influence on KUE.

4.3.7 Soil Analysis after the Experiment

4.3.7.1 Available Nitrogen in Soil

The mean data on post harvest available N in soil as influenced by different treatments are given in Tables 12a and 12b.

The treatments differed significantly and the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the highest value of 312.65 kg ha^{-1} and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording 297.39 kg ha^{-1}. The lowest value of 241.78 kg ha^{-1} was recorded at l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio).

Among the spacing treatments, s_1 (20 cm × 15 cm) recorded the highest available N content of 285.28 kg ha^{-1} and was significantly superior to s_2 (20 cm × 10 cm) which recorded 266.56 kg ha^{-1} .

The interaction effect of NK ratios and spacings did not significantly influence the available N status of soil after the experiment.

4.3.7.2 Available Phosphorous in Soil

Tables 12a and 12b show the mean data of available P in soil as influenced by different treatments.

Among the treatments, l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded significantly higher available P status of soil (37.44 kg ha^{-1}) and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording 36.74 kg ha^{-1}. The treatment l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the lowest value of 34.05 kg ha^{-1}

Neither spacings nor its interaction with NK ratios significantly influenced the available P content in soil.

4.3.7.3 Available Potassium in Soil

The mean data of available K in soil as influenced by different treatments are presented in the Tables 12a and 12b.

Among the treatments, l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recorded significantly higher available K in soil (310.05 kg ha^{-1}) and was on par with l_5 (90:67.5 kg ha^{-1} of N and K_2O at 2:1.5 ratio) and l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio). The treatment l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the lowest value of 203.55 kg ha^{-1}.

Neither spacings nor its interaction with NK ratios significantly influenced the available K content of soil.

4.3.7.4 Organic Carbon Content in Soil

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

Neither NK ratios, spacings nor their interaction significantly influenced OC content of the soil. Though not significant, the treatment l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recorded maximum value 0.78 per cent and l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1ratio) recorded the lowest value of 0.75 per cent.

Table 12a. Effect of NK ratios and spacings on available NPK and organic carbon status of the soil after the experiment

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)	241.78	34.05	203.55	0.76
l_2 (90 :45)	269.43	34.24	207.20	0.76
l_3 (120 : 60)	312.65	37.44	282.52	0.75
l_4 (60 :45)	264.51	35.06	222.88	0.77
l_5 (90 : 67.5)	269.77	35.36	307.62	0.77
l_6 (120 :90)	297.39	36.74	310.05	0.78
SEm(±)	8.66	0.36	9.59	0.014
CD (0.05)	25.587	1.085	28.325	NS
Spacing(S)				
s_1 (20 cm × 15cm)	285.28	35.51	261.84	0.76
s_2 (20 cm × 10cm)	266.56	35.45	249.43	0.78
SEm(±)	5.00	0.21	5.54	0.008
CD (0.05)	14.771	NS	NS	NS

Table 12b. Interaction effect of NK ratios and spacings on available NPK and organic carbon status of the soil after the experiment

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic Carbon content (%)
(l × s interaction)				
l_1s_1	250.93	34.54	205.88	0.74
l_1s_2	232.63	33.55	201.22	0.77
l_2s_1	276.95	34.55	209.81	0.80
l_2s_2	261.91	33.94	204.58	0.72
l_3s_1	315.56	36.93	281.38	0.72
l_3s_2	309.73	37.94	283.65	0.78
l_4s_1	302.46	35.74	215.78	0.76
l_4s_2	226.55	34.37	229.97	0.77
l_5s_1	263.52	35.18	320.69	0.74
l_5s_2	276.02	35.53	294.56	0.80
l_6s_1	302.25	36.09	337.49	0.76
l_6s_2	292.52	37.39	282.61	0.79
SEm(±)	12.15	0.520	13.57	0.02
CD (0.05)	NS	NS	NS	NS

4.4 MAJOR WEEDS OF UPLAND RICE

4.4.1 Major Weed Species

The major weeds observed in the field were grasses: Bermuda grass (*Cynodon dactylion*), sedges: purple nut sedge (*Cyperrus rotundus*) *and* broad leaved weeds: seed under leaf (*Phyllanthus niruri*), wild mustard (*Cleome viscosa*) and touch me not (*Mimosa pudica*).

4.4.2 Weed Dry Weight

The data on weed dry weight as influenced by the treatments are presented in Tables 13a and 13b.

The data revealed no significant influence of treatments or their interactions on weed dry weight at the three stages of weeding *viz* 15 DAS, 30 DAS and 45 DAS.

4.5 PESTS AND DISEASE INCIDENCE

The major pests observed in the field were rice bug (*Leptocorisa oratorius)* and stem borer (*Scirpophaga incertulus*). No disease incidence was observed in the plot. The pest incidence never reached threshold level.

4.6 ECONOMIC ANALYSIS

The mean data on net income and BCR as influenced by different treatments are given in the Tables 14a and 14b.

The NK ratio significantly influenced net income and BCR. The treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) registered the highest net income (₹ 47176 ha^{-1}) and was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) recording ₹ 42033 ha^{-1}. The treatment l_1 (60:30 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded the lowest net income of ₹ 25250 ha^{-1}. Spacings also influenced net income significantly.

Table 13a. Effect of NK ratios and spacings on weed dry weight, g m^{-2}

Treatments	15 DAS	30 DAS	45 DAS
NK levels and ratios (L)			
l_1 (60 :30)	6.50	22.81	21.26
l_2 (90 :45)	6.73	22.84	20.16
l_3 (120 : 60)	8.33	23.04	25.83
l_4 (60 :45)	4.02	22.50	23.40
l_5 (90 : 67.5)	4.20	22.52	25.50
l_6 (120 :90)	7.20	22.90	23.00
SEm(±)	2.22	0.27	3.45
CD (0.05)	NS	NS	NS
Spacing(S)			
s_1 (20 cm × 15cm)	6.50	22.81	22.37
s_2 (20 cm × 10cm)	5.82	22.72	24.01
SEm(±)	1.28	0.16	1.99
CD (0.05)	NS	NS	NS

Table 13a. Interaction effect of NK ratios and spacings on weed dry weight, g m^{-2}

Treatments	15 DAS	30 DAS	45 DAS
(l × s interaction)			
l_1s_1	6.90	23.62	20.56
l_1s_2	6.10	22.01	21.96
l_2s_1	7.23	24.32	21.06
l_2s_2	6.23	21.36	19.26
l_3s_1	7.99	21.10	27.27
l_3s_2	8.67	24.98	24.39
l_4s_1	4.36	21.68	22.44
l_4s_2	3.68	23.32	24.36
l_5s_1	4.08	23.01	26.02
l_5s_2	3.96	22.03	24.98
l_6s_1	6.58	22.71	21.9
l_6s_2	7.82	23.13	24.1
SEm(±)	3.84	5.78	5.06
CD (0.05)	NS	NS	NS

Among the spacing treatments, s_2 (20 cm × 10 cm) obtained significantly higher net income of ₹ 36505 ha^{-1} while s_1 (20 cm × 15 cm) recorded a net income of ₹ 29937 ha^{-1}.

The interaction effect of NK ratios and spacings differed significantly on net income. The interaction l_3s_2 (120: 60 kg ha^{-1} of N and K_2O and spacing of 20 cm × 10 cm) recorded the highest net income of ₹ 51262 ha^{-1} and it was on par with l_2s_2, l_3s_1, l_6s_1 and l_6s_2. The lowest net income of ₹ 21017 ha^{-1} was recorded by the treatment combination l_1s_1 (60:30 kg ha^{-1} of N and K_2O and spacing of 20 cm × 15 cm)

Among the treatments, the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded significantly higher BCR of 1.70 and it was on par with l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) which obtained a BCR of 1.62. The lowest value for BCR of 1.33 was recorded at l_4 (60:45 kg ha^{-1} of N and K_2O at 2:1.5 ratio). Spacings and its interaction with NK ratios did not significantly influence BCR.

Table 14a. Effect of NK ratios and spacings on net income and benefit cost ratio

Treatments	Net income (₹ ha^{-1})	Benefit cost ratio
NK levels and ratios (L)		
l_1 (60 :30)	25250	1.38
l_2 (90 :45)	34612	1.52
l_3 (120 : 60)	47176	1.70
l_4 (60 :45)	22125	1.33
l_5 (90 : 67.5)	28127	1.42
l_6 (120 :90)	42033	1.62
SEm(±)	3644	0.05
CD (0.05)	10756.5	0.164
Spacing(S)		
s_1 (20 cm × 15cm)	29937	1.52
s_2 (20 cm × 10cm)	36505	1.62
SEm(±)	2103	0.032
CD (0.05)	6210.3	NS

Table 14b. Interaction effect of NK ratios and spacings on net income and benefit cost ratio

Treatments	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	BCR
(l × s interaction)			
l_1s_1	84971	21017	1.33
l_1s_2	95091	29484	1.45
l_2s_1	96713	31814	1.49
l_2s_2	103962	37410	1.56
l_3s_1	108933	43089	1.65
l_3s_2	118760	51262	1.75
l_4s_1	84193	19815	1.30
l_4s_2	90465	24435	1.37
l_5s_1	89348	23813	1.36
l_5s_2	99627	32440	1.48
l_6s_1	106762	40071	1.60
l_6s_2	112338	43995	1.64
SEm(±)		5153	0.078
CD (0.05)		14672.4	NS

Discussion

5. DISCUSSION

The results of the experiment entitled 'Productivity of upland rice (*Oryza sativa* L.) at different NK ratios and spacings' are discussed in this chapter.

5.1 GROWTH CHARACTERS

As evident from Tables 2a, 3a and 4a, height at 60 DAS and at harvest, tiller number and LAI at 60 DAS, DMP at 60 DAS and at harvest were significantly influenced by treatments.

The NK levels did not significantly influence plant height at 30 DAS, but the levels significantly influenced the plant height at 60 DAS and at harvest. The treatment l_3 (120:60 kg ha^{-1} of N and K at 2:1 ratio) registered maximum plant height at 60 DAS and at harvest (Fig. 3). Increasing N levels increased plant height at different stages of growth. Nitrogen is an important constituent of physiologically active compounds like proteins, enzymes, nucleic acids and other body building constituents. Nitrogen is associated with protoplasm synthesis and vegetative growth due to increased cell division and cell elongation. Application of N at 240 kg ha^{-1} resulted in the significant increase in plant height of aerobic rice (Anil, 2013). Similar results were reported by Anu (2001), Ranjini (2002), Mini (2005) and Kumar (2016) in upland rice. Higher plant height due to K application was noticed at 60 DAS and at harvest. Potassium favoured growth of meristematic tissue, induced drought tolerance and thereby higher plant height. Mini (2005) reported taller plants in upland rice at NK applied at 100:50 kg ha^{-1}(2:1 ratio). Similar effect of NK levels on plant height was reported by Anu (2002) in upland rice who obtained higher plant height at NK applied at 80:45 kg ha^{-1}.

Spacing did not exert any significant influence on plant height at any growth stages. But taller plants were observed at closer spacings. This might be due to higher competition in case of closer spacing for sunlight which made them taller. This was in conformity with the findings of Shah *et al.* (1991), Om *et al.* (1993) and Das (2016). The interaction effect was also not significant.

Higher levels of N and K influenced number of tillers m^{-2} (Table 3a). Among the NK levels, l_3 (120:60 kg $ha^{-1}$of N and K_2O) at the ratio 2:1 produced maximum number of tillers m^{-2} (Fig. 4). Tillering was favourably influenced by incremental dose of N and K. This was mainly due to more N and K availability that provided proper crop nutrition and thereby promoted tillering. Anu (2001) obtained higher tiller number at 80 kg N and 45 kg K_2O ha^{-1}respectively in upland rice. Mini (2005) obtained higher tiller number at NK level of 100 and 50 kg ha^{-1}(2:1 ratio) in upland rice. Kumar (2016) reported higher tiller number at NK dose of 120:60 kg ha^{-1}(2:1 ratio) in upland rice. Higher N and K availability due to increased application of N and K might have promoted plant height and resulted in increased uptake of NPK at tillering stage. Potassium favoured protein synthesis and positively influenced tiller production.

The spacings significantly influenced number of tillers m^{-2}. At 60 DAS, closer spacing registered higher number of tillers m^{-2}. This might be due to the fact that at closer spacing plant population was more and hence more number of tillers. This was in conformity with the findings of Das (2016) and Meena *et al.* (2010) who got the maximum number of tillers m^{-2} at closer spacing.The interaction effect due to NK ratios and spacing did not influence number of tillers m^{-2} significantly (Table3b).

The LAI was significantly influenced by NK levels as depicted in the Table 3a. The treatment l_6 (120:90 kg ha^{-1} of N and K_2O at 2:1.5 ratio) registered maximum LAI. The favourable influence of N on tiller number and leaf area resulted in higher LAI. The higher value of LAI at higher levels of N and K might be due to more production of tillers. Similar findings were reported by Anu (2001), Mini (2005) and Kumar (2016) in upland rice.

The spacing did not have any significant influence on LAI even though higher LAI was obtained at closer spacing. The interaction effect due to NK ratios and spacing did not significantly influence LAI (Table 3b).

The DMP was also influenced by higher levels of N and K but it was significant only at 60 DAS and at harvest (Table 4a and 4b). The DMP increased significantly with successive increments of N and K. Maximum DMP was

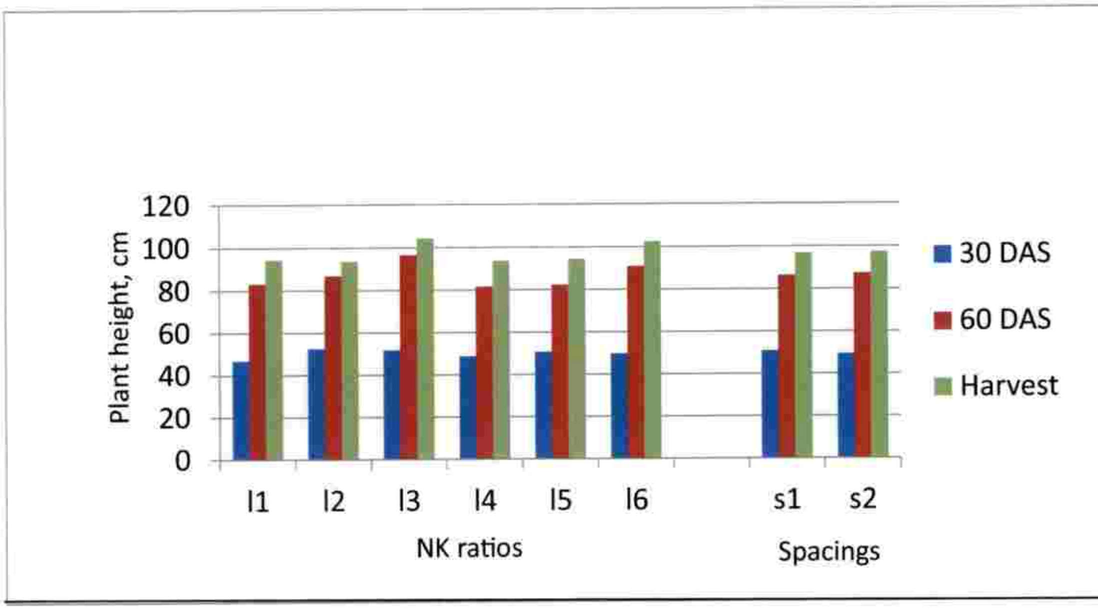

Fig. 3 Effect of NK rat ios and spacings on plant height,cm

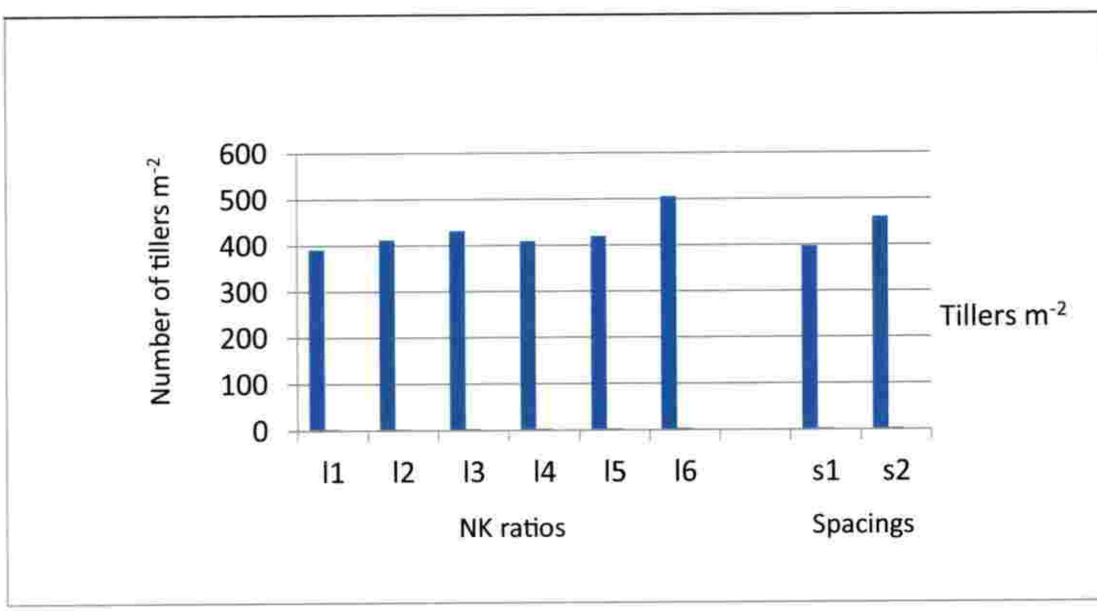

Fig. 4 Effect of NK ratios and spacing s on number of tillers m^{-2}

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obtained at 120:60 kg NK ha^{-1} (l_3, 2:1 ratio) (Fig. 5). Higher doses of N and K might have induced more vegetative growth leading to better interception of photosynthetically active radiation, greater photosynthesis by the crop and higher translocation of photosynthates. Anu (2001) got higher DMP at 80:45 kg ha^{-1} of NK. Mini (2005) obtained higher DMP at NK dose of 100:50 kg ha^{-1} (2:1 ratio). Kumar (2016) reported higher DMP at NK dose of 120:60 kg ha^{-1}(2:1 ratio) in upland rice. Similar results were obtained by Hebbal (2014) who got the highest DMP at 125 kg N ha^{-1}. Higher availability of N for plants resulted in higher uptake of nutrients and translocation of the same to different parts. Potassium has the ability to enhance the plant growth which finally resulted in higher DMP. The involvement of K in the uptake and translocation of nutrients resulted in higher DMP.

Spacing significantly influenced DMP. A closer spacing of 20 cm × 10 cm resulted in higher DMP. This might be due to more number of plants per unit area compared to wider spacing. Similar results were obtained by Dhal and Mishra (1994), Padmaja and Reddy (1998) and Das (2016). The interaction effect due to NK ratios and spacings were also found significant at 60 DAS and at harvest from Table 4b. The interaction l_3s_2 (120:60 kg $ha^{-1}$of N and K_2O and spacing of 20 cm × 10 cm) recorded the maximum value of DMP (Fig 6).

5.2 YIELD ATTRIBUTES AND YIELD

The result revealed (Tables 5a, 6a and 7a) the favourable influence of NK ratios on yield attributing characters like length of panicle, grain weight of panicle, productive tillers m^{-2} and yield. The above characters were significantly improved by the application of NK at 120:60 (2:1 ratio) which might be due to increased nutrient uptake and higher DMP at different growth stages. The higher LAI at 60 DAS promoted photosynthesis, translocation of photosynthates from source to sink and contributed to higher panicle weight. Higher values of yield attributes might be due to enhanced cell expansion since N is an inevitable constituent of different enzymes and proteins. Anu (2001) got higher yield attributes at 80:45 kg ha^{-1} of N and K_2O. Mini (2005) obtained higher yield attributes at NK dose of 100:50 kg ha^{-1} (2:1 ratio) in upland rice. This was in conformity with the findings of Kumar (2016) who obtained higher yield attributes at NK dose of 120:60 kg ha^{-1}(2:1 ratio) in upland rice. Optimum application of NPK resulted in maximum number of productive tillers (Ahmad *et al.*,2005). Anil (2016) registered higher values for yield attributes and substantiated that increased application of N at tillering stage resulted in more number of productive tillers. Similar results were reported by Kumar and Kureel (2017) and Adhikari *et al.* (2018) in rice.

The spacing did not have significant influence on yield attributing characters except for productive tillers m^{-2}. The productive tillers were higher at closer spacing than wider spacing. This might be due to more number of plants m^{-2} .Similar results were reported by Faizul *et al.* (2013), who obtained maximum number of effective tillers at closer spacings. Lacerda and Nascento (2016) obtained more number of panicles at closer spacing than wider spacing. The interaction effect of NK ratios and spacings did not influence yield attributing parameters. Though not significant the interaction l_3s_1 (120:60 kg ha^{-1}of N and K_2O and spacing of 20 cm × 15 cm) produced the highest value of productive tillers(Table 5b).

The results revealed (Table 7a and 7b) the profound influence of NK levels on grain and straw yields. Application of 120:60 kg ha^{-1}of NK (2:1 ratio, l_3) produced maximum grain and straw yields (Fig. 7). The treatment l_3 produced 3123 and 4030 kg ha^{-1} of grain and straw yields respectively, while l_1 (60:30 kg ha^{-1} of NK at 2:1 ratio) recorded 2464 and 3217 kg ha^{-1} of grain and straw yields respectively. Higher grain and straw yields in l_3 might be due to beneficial effect of N and K on productive tillers, length of panicle and weight of panicle. Yield is the ultimate manifestation of yield attributes and favourable influence of N and K (120:60 kg NK ha^{-1} at 2:1 ratio) on LAI, photosynthetic rate, translocation of assimilates from leaves to grain, high DMP and nutrient uptake might have led to higher grain and straw yields. The steady supply of nutrients due to higher levels of N and K resulted in higher yield attributing parameters and finally higher grain

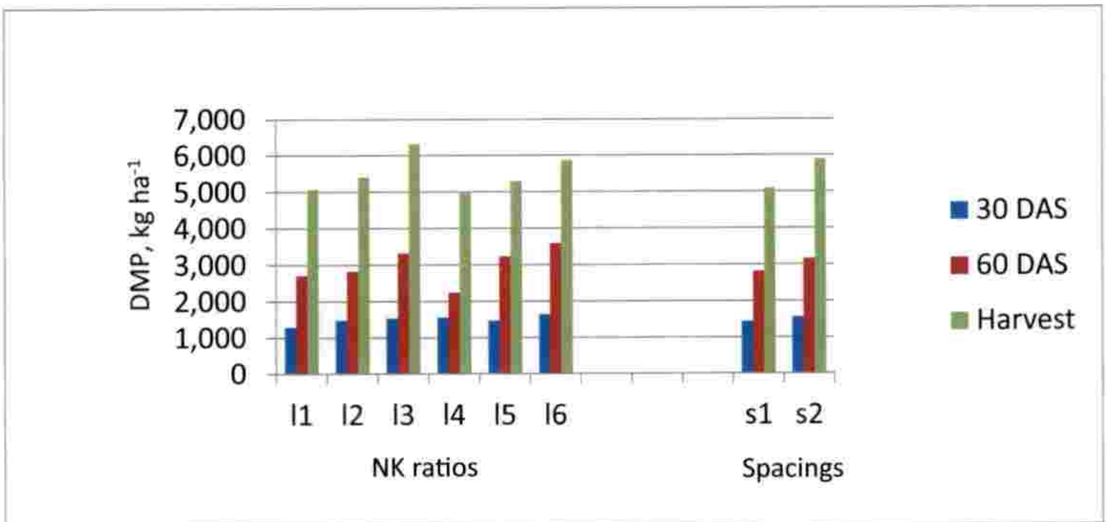

Fig. 5 Effect of NK ratios and spacings on DMP at different growth stages, kg ha^{-1}

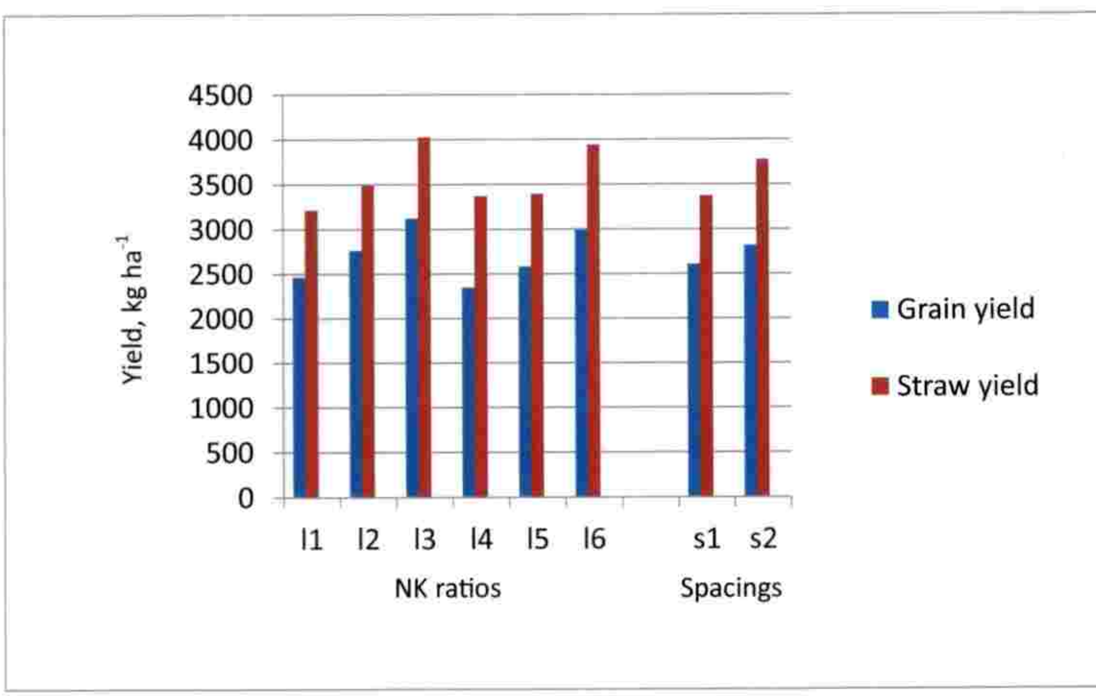

Fig. 7 Effect of NK ratios and spacings on grain yield and straw yield, kg ha^{-1}

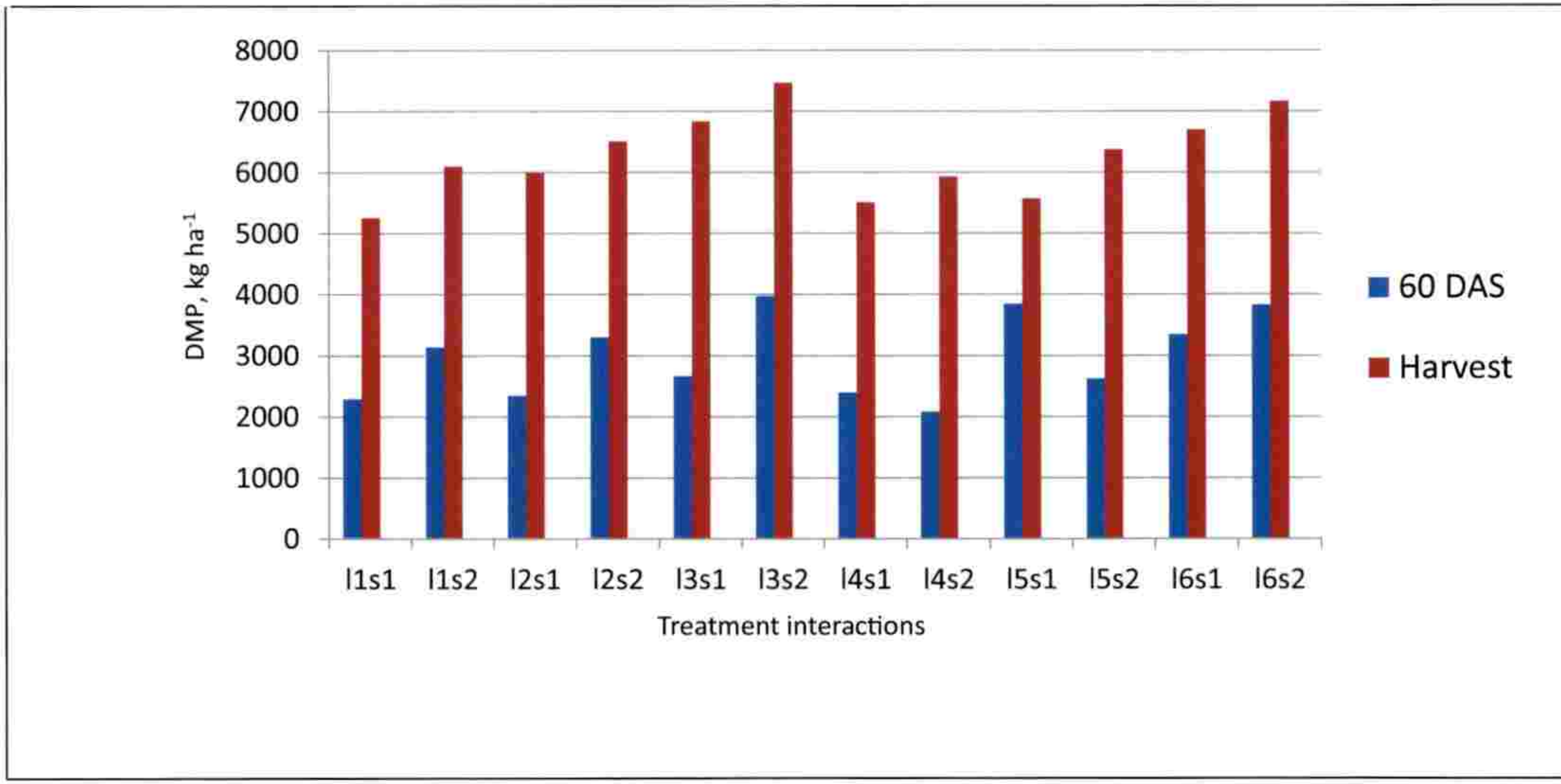

Fig. 6 Interaction effect of NK ratios and spacing s on DMP at 60 DAS and harvest, kg ha^{-1}

and straw yields. Anu (2001) got higher grain and straw yields at 80:45 kg ha^{-1} of N and K_2O. Mini (2005) obtained higher grain and straw yields at NK dose of 100:50 kg ha^{-1} of N and K_2O (2:1 ratio) in upland rice. Similar findings were reported by Kumar (2016) who obtained higher grain and straw yields at NK dose of 120:60 kg ha^{-1} (2:1 ratio) in upland rice.

A closer spacing of 20 cm × 10 cm resulted in higher grain and straw yields. This might be due to more number of plants per unit area. At closer spacing, there was equidistant distribution of plants and better exploitation of the resources (Jadoski *et al.*, 2000). This corroborates with the findings of Hossain *et al.* (2003), Uddin *et al.* (2015) and Lacerda and Nascento (2016) in rice. The interaction effect due to NK ratios and spacings were significant in both grain and straw yields and the highest values were obtained by l_3s_2 (120:60 kg $ha^{-1}$of N and K_2O and spacing of 20 cm × 10 cm) (Fig. 8).

Neither NK ratios, spacings nor their interaction significantly influenced the harvest index.

5.3 PHYSIOLOGICAL PARAMETERS

The chlorophyll content of leaves at panicle emergence stage was not significantly influenced by NK ratios, spacings or their interaction (Table 8a and 8b). Though not significant, the treatment l_3 (120: 60 kg $ha^{-1}$of N and K_2O at 2:1 ratio) recorded the maximum chlorophyll content of 1.01mg g^{-1} FW.

Relative leaf water content in leaves at flowering stage was not significantly influenced by NK ratios, spacings or their interaction (Table 8a). Though not significant, the treatment l_6 (120:90 kg $ha^{-1}$of N and K_2O at 2:1.5 ratio) recorded maximum RLWC 81.01 per cent. Higher levels of N and K induced drought tolerance, improved moisture availability of the crop and there by available water content in the crop was improved. This was in conformity with finding of Ranjini (2002) and Kumar (2016) in upland rice. Spacing or its interaction with NK levels did not significantly influence RLWC.

It was found that neither the NK ratios, spacings nor their interaction significantly influenced proline content (Table 8a).

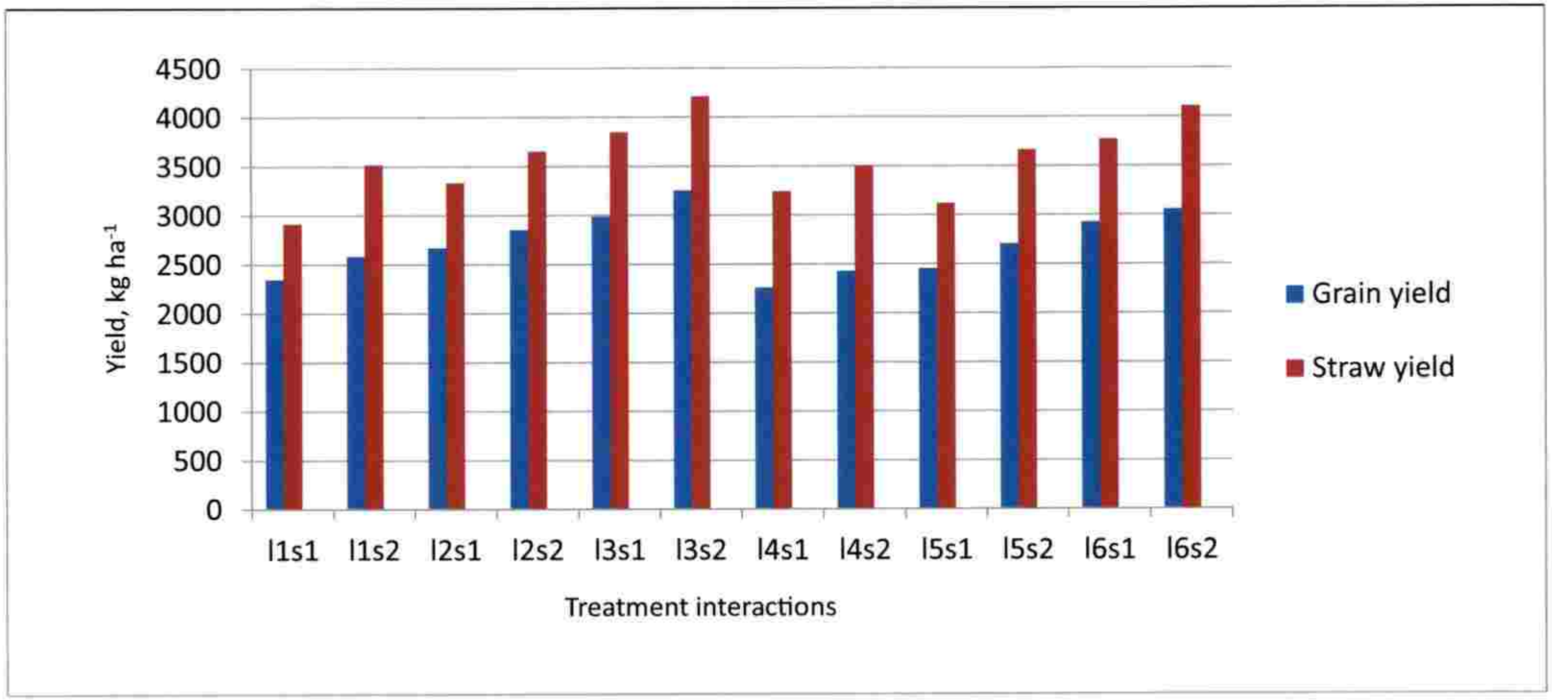

Fig. 8 Interaction effect of NK ratios and spacing on grain and straw yields, kg ha^{-1}

The NK levels significantly influenced protein content of grain (Table 9a). The maximum grain protein content was recorded by l_3 (120:60 kg $ha^{-1}$of N and K_2O at 2:1 ratio). Anu(2001) got higher grain protein content at 80:45 kg ha^{-1} of N and K_2O. Similar results were reported by Mini (2005) and Kumar (2016) in upland rice. Higher application of N and K increased the grain protein content through their effect on amino acid polymerization. Neither spacing nor its interaction with NK levels had significant influence on protein content of grain.

5.4 UPTAKE OF NUTRIENTS

The results (Table 10a) revealed that uptake of N, P and K was significantly influenced by NK levels. Among the treatments, the treatment l_3 (120:60 kg ha^{-1} of N and K_2O at 2:1 ratio) recorded maximum uptake of nutrients (Fig. 9). Higher DMP coupled with greater nutrient availability especially during critical growth stages helped the crop for better absorption of nutrients and hence higher NPK uptake. Higher nutrient availability led to greater root development, LAI and increased CO_2 assimilation and all these might have promoted nutrient uptake (Mahajan *et al.*, 2012). Higher root volume and root weight might have helped the plants to absorb more nutrients from the soil and hence higher nutrient uptake. Further higher concentration of NPK in grain and straw led to higher uptake of nutrients. Increased uptake of nutrients at higher levels of N and K was reported by Anu(2001), Ranjini (2002) and Mini (2005) in upland rice. Similar findings were reported by Kumar (2016) in upland rice who obtained the highest nutrient uptake at NK applied at 120 and 60 kg ha^{-1}. Higher availability of nutrients promoted vegetative growth in terms of taller plants, more leaves, tiller number, higher yield attributes, DMP and yield and all these might have contributed to higher nutrient uptake in l_3. Neither spacing nor its interaction with NK levels significantly influenced nutrient uptake.

5.5 NUTRIENT USE EFFICIENCY

The results presented in Table 11a revealed that NK ratios and spacing significantly influenced NUE, PUE and KUE. At higher NK ratios both NUE and KUE decreased and this might be due to higher losses of N and K when applied in higher quantities or inefficiency of the plant in utilizing the nutrients. PUE increased with increase in NK ratios since 30 kg P_2O_5 ha^{-1} was applied uniformly to all treatments. This is in accordance with the findings of Anu (2001) and Mini (2005) who reported higher NUE at 80:45 $kgha^{-1}$ of N and K and at 100:50 kg ha^{-1} of N and K respectively.

The spacing also influenced the nutrient use efficiency significantly. The spacing s_2 (20 cm × 10 cm) recorded significantly higher nutrient use efficiency. The interaction due to NK levels and spacing did not significantly influence the nutrient use efficiency (Table 11b).

5.6 SOIL ANALYSIS AFTER THE EXPERIMENT

The data on the available NPK and organic carbon status of the soil after the experiment are presented in the Table 12a. From that data it is evident that the NK ratio significantly influenced available nutrients in the soil. The treatment l_3 (120:60 kg ha^{-1} of N and K_2O) recorded maximum soil available N and P, but the treatment l_6 (120:90 kg ha^{-1} of N and K_2O) recorded maximum soil available K (Fig. 10). Mini (2005) obtained higher soil available nutrients at 120:90 kg NK ha^{-1}. The available nutrient status of the soil increased at higher NK levels because of the abundance of nutrients in the soil solution. The NK ratio did not have any significant influence on soil organic carbon content. The spacing influenced available nitrogen content in the soil significantly and a spacing of 20 cm × 15 cm recorded higher soil available nitrogen. Available P and K were not significantly influenced by spacing. Neither spacing nor its interaction with NK levels significantly influenced the available nutrients.

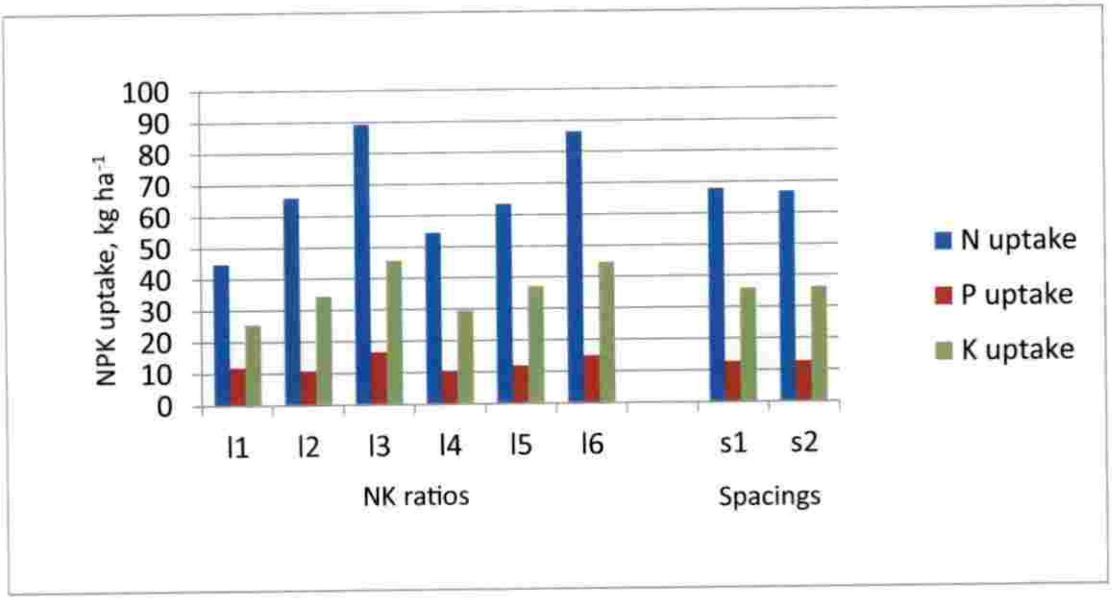

Fig. 9 Effect of NK ratios and spacings on N, P and K uptake by crop at harvest, kg ha $^{-1}$

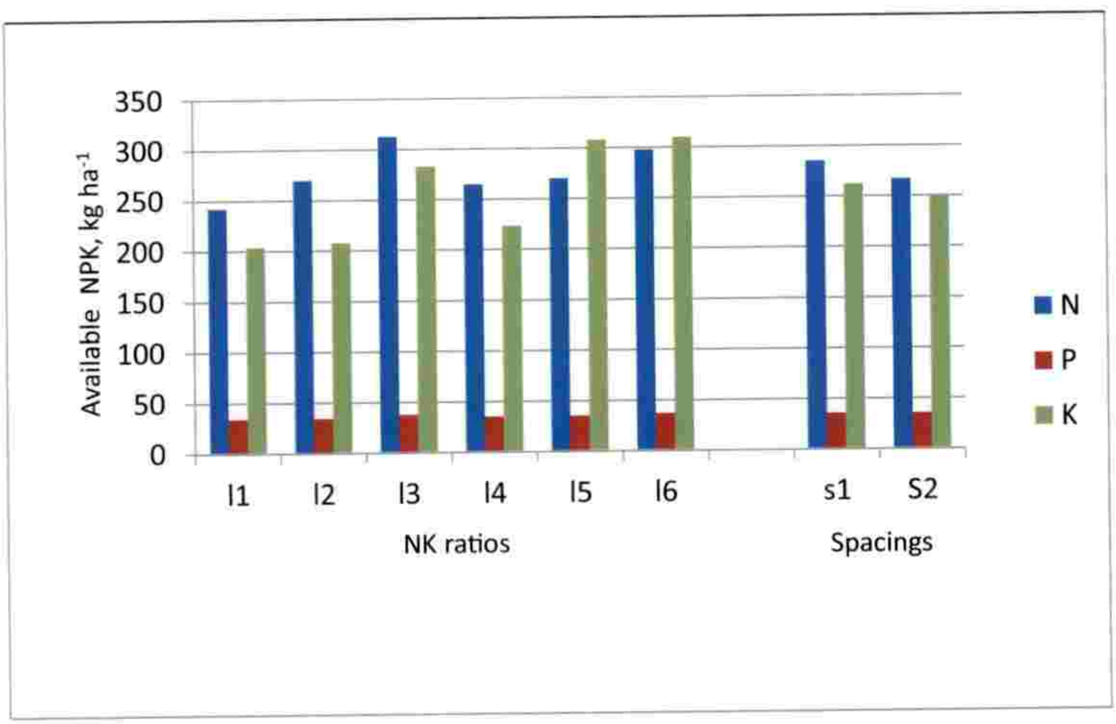

Fig. 10 Effect of NK ratios and spacings on available NPK status of soil, kg ha $^{-1}$

5.7 MAJOR WEEDS

The major weed species observed were *Cynodon dactylion, Cyperus rotundus, Phyllanthus niruri, Cleome viscosa and Mimosa pudica.* The weed dry weight was not significantly influenced by either NK ratios, spacing or their interaction.

5.8 PEST AND DISEASE INCIDENCE

The major pests observed in the field were rice bug (*Leptocorisa oratorius)* and stem borer (*Scirpophaga incertulus*). No disease incidence was observed in the plot. The pest incidence never reached threshold level and the pests and disease incidence did not adversely affect the performance of upland rice.

5.9 ECONOMIC ANALYSIS

The NK ratio influenced the net income and BCR significantly as evident from the Table 14a. The treatment l_3 (120:60 kg ha^{-1} of N and K at 2:1 ratio) recorded maximum net income and BCR (Fig. 11). Higher grain and straw yields recorded by l_3 resulted in higher net income and BCR. This is in conformity with the findings of Mini (2005) in upland rice. The spacing also influenced the net income significantly. BCR was not influenced by spacing. A closer spacing of 20 cm × 10 cm resulted in significantly higher net income. The treatment interaction l_3s_2 (120:60 kg ha^{-1} of N and K and 20 cm × 10 cm) produced the maximum net income.

The results of the study revealed that the treatment combination l_3s_2 (120:60 kg ha^{-1} of N and K_2O and 20 cm × 10 cm) recorded the highest value for grain yield, straw yield and yield attributes, indicating that sowing seeds at a spacing of 20 cm × 10 cm in conjunction with 120 kg N and 60 kg K_2O favourably influenced the yield attributes and yield of upland rice and thereby higher net income and BCR.

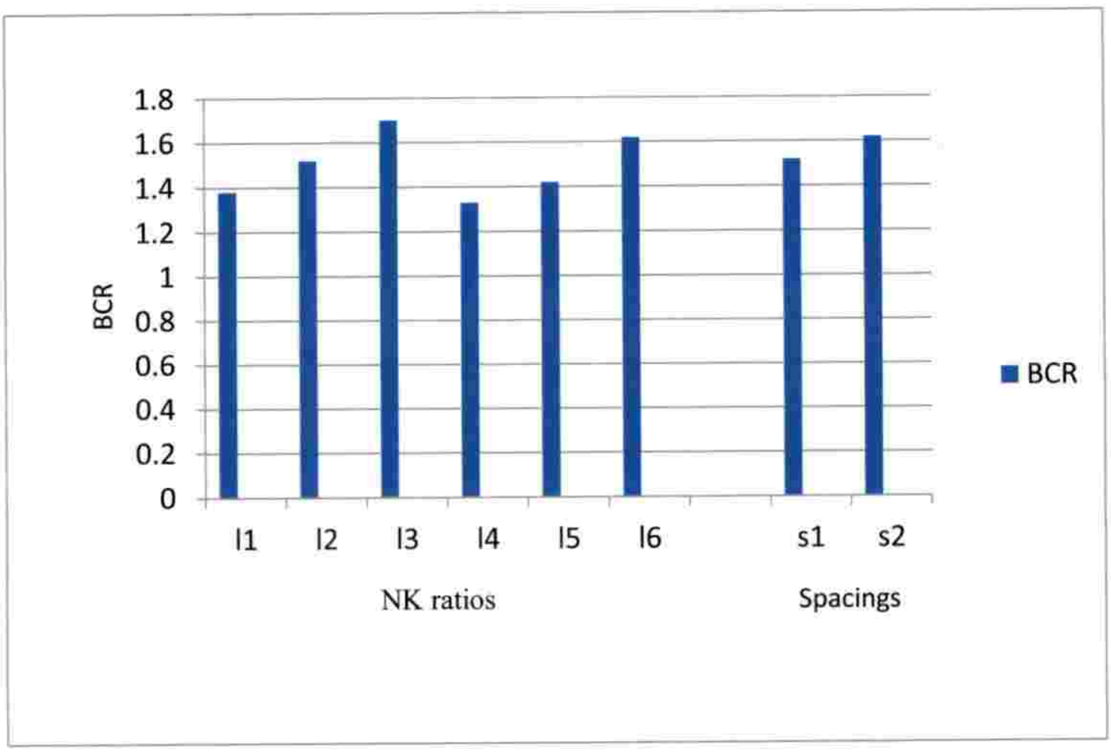

Fig. 11 Effect of NK ratios and spacing s on benefit cost ratio

Summary

6. SUMMARY

A field experiment was conducted in the Instructional Farm, College of Agriculture, Vellayani to study the productivity of upland rice at different NK ratios and spacings during *Kharif*, 2018. The soil of the experimental site was sandy clay loam in texture, acidic in reaction and low in available N, high in available P and medium in available K. The treatments comprised of six levels of N and K in 2:1 and 2:1.5 ratios (l_1: 60:30 kg , l_2 : 90 : 45 kg , l_3 : 120 : 60 kg, l_4 : 60 : 45 kg , l_5 : 90 : 67.5 kg , l_6 : 120 : 90 kg) and two spacings (s_1 : 20 cm x 15 cm and s_2 : 20 cm x 10 cm). FYM @ 5 t ha^{-1} and P at 30 kg P_2O_5 ha^{-1} were applied uniformly to all the plots. The experiment was laid out as 6×2 factorial randomized block design with three replications. Observations on growth characters, yield attributes, yield, physiological parameters, nutrient uptake, nutrient use efficiency, soil available nutrients and economics of cultivation as influenced by different treatment were tabulated, statistically analysed and presented in this chapter.

There was a significant influence of treatments on plant height at 60 DAS and at harvest. The treatment l_3 (120:60 kg $ha^{-1}$of N and K) (2:1 ratio) produced the tallest plants. Neither spacing nor its interaction with NK levels significantly influenced the plant height at any stage. Tillers number m^{-2} was maximum at NK level of 120:90 kg ha^{-1} (2:1.5 ratio). A spacing of 20 cm x 10 cm recorded maximum tiller number m^{-2}. The interaction effect of NK levels and spacing did not significantly influence the tiller number m^{-2}. LAI at 60 DAS was maximum at an NK ratio of 120: 90 kg ha^{-1} (l_6) (2:1.5 ratio). Though not significant, 20 cm x 10 cm spacing recorded higher LAI. Neither spacing nor its interaction with NK levels significantly influenced the LAI. The total DMP increased with increase in plant growth. The maximum DMP was recorded at NK level of 120: 90 kg ha^{-1}(2:1.5 ratio) at 60 DAS and at 120: 60 kg ha^{-1} (2:1 ratio) at harvest. A spacing of 20 cm x 10 cm recorded maximum DMP. Treatment interactions also significantly influenced DMP. Application of 120 kg N and 60 kg K_2O along with 30 kg P_2O_5 ha^{-1} and a spacing of 20 cm x 10 cm significantly increased DMP.

The length of panicle increased with increase in N and K levels. The NK level at 120: 60 kg ha^{-1} (2:1 ratio) recorded maximum panicle length. Though not significant, 20 cm x 15 cm spacing recorded higher panicle length. The interaction due to NK ratios and spacing on length of panicle was not significant. The weight of panicle also increased with increased levels of N and K. The NK level at 120: 90 kg ha^{-1} (2:1.5 ratio) recorded the maximum panicle weight. Neither spacing nor its interaction with NK levels significantly influenced the panicle weight. The maximum number of productive tillers m^{-2} was obtained at 120: 60 kg ha^{-1} (2:1 ratio). The spacing significantly influenced number of productive tillers m^{-2} and 20 cm x 10 cm recorded maximum value. The interaction effect due to NK ratios and spacing was not significant.

The grain and straw yields were significantly influenced by NK levels. The maximum grain and straw yields were recorded at the NK level of 120: 60 kg ha^{-1}(2:1 ratio). Grain and straw yields were significantly influenced by spacing. A spacing of 20 cm x 10 cm recorded maximum grain and straw yields. Treatment interactions also significantly influenced both grain and straw yields. Application of 120 kg N and 60 kg K_2O ha^{-1}(2:1 ratio) and a spacing of 20 cm x 10 cm produced maximum grain and straw yields. Harvest index was not influenced by either NK ratios, spacing or their interaction.

The grain protein content was also influenced by NK levels. Maximum grain protein content was recorded by the treatment l_3 (120 kg N: 60 kg K_2O ha^{-1}, 2:1 ratio). Neither spacing nor its interaction with NK levels significantly influenced grain protein content.

Uptake of N, P and K was significantly influenced by NK levels. Application of 120 kg N and 60 kg K_2O ha^{-1} (2:1 ratio) recorded maximum N, P and K uptake. Neither spacing nor its interaction with NK levels significantly influenced N, P and K uptake.

Nutrient use efficiency was significantly influenced by NK levels. Nitrogen use efficiency and potassium use efficiency were maximum at l_1 (60:30

kg NK ha^{-1}). Phosphorous use efficiency was maximum at l_3 (120:60 kg NK ha^{-1}). Among spacing, 20 cm x 10 cm recorded maximum, NUE, PUE and KUE. Interaction due to NK ratios and spacing did not influence nutrient use efficiency.

The NK levels significantly influenced soil available N, P and K status after the experiment. Available N and P were maximum at plots applied with 120 kg N and 60 kg K_2O ha^{-1} (2:1 ratio) along with 30 kg P_2O_5 ha^{-1}. Available K was maximum in plots applied with 120 kg N and 90 kg K_2O ha^{-1} (2:1.5 ratio) along with 30 kg P_2O_5 ha^{-1}. Spacing significantly influenced soil available N and a spacing of 20 cm x 10 cm registered higher available N in the soil. Available P and K were not influenced by either spacing or its interaction with NK levels.

It was observed that NK levels significantly influenced BCR and net income. The treatment l_3 (120:60 kg NK ha^{-1}, 2:1 ratio) recorded maximum net income and BCR. A spacing of 20 cm x 10 cm recorded maximum net income. Spacing did not have a significant influence on BCR. The interaction due to NK ratios and spacing significantly influenced net income and application of 120 kg N ha^{-1} and 60 kg K_2O ha^{-1} and a spacing of 20 cm x 10 cm recorded maximum net income.

Future line of work

Studies on NK levels and spacing on upland rice under varying levels of shade are to be explored. The possibility of foliar application of N and K at different growth stages are to be studied. The results of this study may be tested in farmers' fields and after getting confirmation, may be popularized as a package.

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APPENDIX 1

Weather parameters during the cropping period -29th May to 14th September, 2018

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

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Abstract

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PRODUCTIVITY OF UPLAND RICE (*Oryza sativa* L.) AT DIFFERENT NK RATIOS AND SPACINGS

by

GREESHMA S.
(2017-11-059)

ABSTRACT

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2019

ABSTRACT

A field experiment on 'Productivity of upland rice (*Oryza sativa* L.) at different NK ratios and spacings' was conducted during *Kharif*, 2018 at the Instructional Farm, College of Agriculture, Vellayani to study the influence of different levels of N and K, their ratios and spacing on growth and yield of upland rice and to work out the economics of cultivation. The variety used for the experiment was Prathyasha (MO 21). The technical programme consisted of 12 treatment combinations with six NK levels and two spacings laid out in 6 x 2 factorial RBD. The treatments were NK levels (L) (kg ha^{-1} at 2:1 and 2:1.5 ratios) **l_1**: 60 kg N : 30 kg K_2O (Control), **l_2** : 90 kg N : 45 kg K_2O , **l_3** : 120 kg N : 60 kg K_2O, **l_4**: 60 kg N : 45 kg K_2O, **l_5** : 90 kg N : 67.5 kg K_2O, **l_6** : 120 kg N : 90 kg K_2O. There were two spacings (S) *viz* **s_1** : 20 cm x 15 cm and **s_2** : 20 cm x 10 cm. Uniform dose of 30 kg ha^{-1} P_2O_5 was given to all plots. The crop was sown on 29 -05-2018 and harvested on 14-09-2019. The soil of the site was sandy clay loam with available NPK content of 250, 31.5 and 244 kg ha^{-1}respectively.

The treatment l_3 (120 kg N: 60 kg K_2O) produced the tallest plants and maximum DMP at harvest. The spacing s_2 (20 cm x 10 cm) recorded maximum DMP at harvest.Tillers m^{-2} and LAI were significantly influenced by treatments and l_6 (120 kg N: 90 kg K_2O) produced maximum tillers m^{-2} and LAI. Among the spacings, s_2 (20 cm x 10 cm) recorded maximum tillers m^{-2}. Spacing did not significantly influence LAI.

The yield attributes *viz.*, number of productive tillers m^{-2} , length of panicle , grain yield and straw yield were favourably influenced by treatment l_3 (120 kg N: 60 kg K_2O) except weight of panicle for l_6. The treatment l_3 recorded maximum grain and straw yields of 3123 and 4030 kg ha^{-1} respectively and was on par with l_6. Among spacing, s_2 (20 cm x 10 cm) recorded maximum number of productive tillers m^{-2}, grain and straw yields. Grain and straw yields were significantly influenced by the interaction and l_3s_2 recorded the highest grain yield and was on par with l_2s_2, l_3s_1, l_6s_1 and l_6s_2. With regard to straw yield, l_3s_2 recorded the highest straw yield and was on par with l_3s_1, l_6s_1 and l_6s_2.

The results showed favourable influence of treatments on protein content of grain. The treatment l_3 recorded maximum grain protein content of 5.51 per cent and was on par with treatment l_6 (5.39 per cent). The lowest grain protein content was recorded by l_1

The uptake of nutrients was profoundly influenced by the treatments. Increased uptake of nutrients was recorded at an NK level of 120 kg N: 60 kg K_2O. The spacings did not significantly influence nutrient uptake. Increasing the levels of N, P and K increased the soil available nutrients. Application of NK at 120 kg N: 60 kg K_2O significantly improved nutrient status of soil.

The results of the economic analysis revealed that net income and BCR were maximum in plots supplied with 120 kg N: 60 kg K_2O ha^{-1}. Spacing (20 cm x 10 cm) significantly influenced net income.

Based on this investigation, it can be concluded that application of 120 kg N: 60 kg K_2O along with 30 kg P_2O_5 ha^{-1} and sowing in a spacing of 20 cm x 10 cm was found to favourably influence growth characters, yield attributing characters, yields and economics of upland rice and it was further noted that increasing N dose from 60 to 120 kg ha^{-1} significantly influenced the growth,yield attributes, yield and net income irrespective of K dose.

സംഗ്രഹം

കരനെല്കൃഷിയിലെ നൈട്രജൻ പൊട്ടാസ്യം അനുപാതവും ഇടയകലവും എന്ന വിഷയത്തിൽ ഒരു പഠനം കാർഷിക കോളേജ് ഇൻസ്ട്രക്ഷണൽ ഫാർമിൽ നടത്തുകയുണ്ടായി. കരനെല്കൃഷിക് അനുയോജ്യമായ അളവിലും അനുപാതത്തിലും ഉള്ള നൈട്രജനും പൊട്ടാസിയവും ശരിയായ ഇടയകലവും കണ്ടുപിടിക്കുക ആയിരുന്നു ഈ പഠനത്തിന്റെ ലക്ഷ്യം. മൻകൊമ്പ് നെല്ലുഗവേഷണ കേന്ദ്രത്തിൽ നിന്നും വികസിപ്പിച്ചെടുത്ത പ്രത്യാശ എന്ന കരനെല്ലിനം ആണ് പഠനത്തിന് ഉപയോഗിച്ചത്.

പരീക്ഷണത്തിൽ ഉപയോഗിച്ച വിവിധ അളവുകൾ താഴെ കൊടുത്തിരിക്കുന്ന രീതിയിൽ ക്രമീകരിച്ചു.

നൈട്രജൻ പൊട്ടാസ്യം അനുപാതം

l_1 : 60 kg N : 30 kg K_2O

l_2 : 90 kg N : 45 kg K_2O

l_3 : 120 kg N : 60 kg K_2O

l_4 : 60 kg N : 45 kg K_2O

l_5 : 90 kg N : 67.5 kg K_2O

l_6 : 120 kg N : 90 kg K_2O

ഇടയകലം

s_1 : 20 cm x 15 cm

s_2: 20 cm x 10 cm

മൊത്തം പന്ത്രണ്ടു ട്രീട്മെന്റുകളായി മൂന്നു പ്രാവിശ്യം ആവർത്തിച്ചു റാൻഡൊമിസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പഠന രീതി അവലംബിച്ചു പരീക്ഷണം നടത്തി. 30 കിലോ P_2O_5 ഫോസ്ഫറസ് എല്ലാ ട്രീട്മെന്റുകളിലും ഒരുപോലെ അടിവളമായി നൽകി.

പഠനത്തിന്റെ പ്രധാന കണ്ടത്തെലുകൾ ഇവയാണ്. 120 : 60 kg NK ha^{-1} (l_3) എന്ന അളവിൽ നൈട്രജനും പൊട്ടാസിയവും കൊടുക്കുന്നതും 20 cm × 10 cm (s_2) അകലത്തിൽ വിത്ത് ഇടുന്നതും കരനെല്ലിന്റെ വളർച്ചയ്ക്കും കൂടുതൽ നെല്മണികൾ ഉണ്ടാകുന്നതിനും നല്ലതാണെന്നു കണ്ടെത്തി. കൂടാതെ കൂടുതൽ വിളവിനും, വൈക്കോൽ ഉത്പാദനത്തിനും 120 : 60 kg NK ha^{-1}. അനുപാതത്തിൽ നൽകുന്നത് നല്ലതാണെന്നു തെളിഞ്ഞു. ഈ അനുപാതത്തിൽ മൂലകങ്ങൾ നൽകുന്ന വഴി കർഷകന്റെ ലാഭവും ഗണ്യമായി വർധിക്കുന്നതായി കണ്ടു.

ഈ പരീക്ഷണത്തിൽ നിന്നും വ്യക്തമാകുന്നത് 120 കിലോ നൈട്രജനും 60 കിലോ പൊട്ടാഷും 30 കിലോ ഫോസ്ഫോറസും എന്ന തോതിൽ മൂലകങ്ങൾ നൽകുകയും 20 cm × 10 cm ഇടയകലത്തിൽ വിത്ത് നടുകയും ചെയ്യുക വഴി കരനെൽച്ചെടിയുടെ വളർച്ചയും ഉല്പാദനഘടകങ്ങളും അനുകൂലമാക്കാനും അതുവഴി കൂടുതൽ വിളവ് ലഭിക്കാനും കർഷകന്റെ ആദായം വർധിപ്പിക്കാനും സാധിക്കുന്നതായി തെളിഞ്ഞിരിക്കുന്നു.