PERFORMANCE OF UPLAND RICE (*Oryza sativa* L.) AS INFLUENCED BY NK LEVELS AND FYM SUBSTITUTION

by

SARAVANA KUMAR. M

(2014 - 11 - 209)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
PADANNAKKAD, KASARAGOAD – 671 314
KERALA, INDIA

2016

DECLARATION

I, hereby declare that this thesis entitled **"PERFORMANCE OF UPLAND RICE (*Oryza sativa* L.) AS INFLUENCED BY NK LEVELS AND FYM SUBSTITUTION"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society

Place Padannakkad

Date 28 06 2016

Saravana Kumar M

(2014 - 11 - 209)

CERTIFICATE

Certified that this thesis entitled **"PERFORMANCE OF UPLAND RICE (*Oryza sativa* L.) AS INFLUENCED BY NK LEVELS AND FYM SUBSTITUTION"** is a record of research work done independently by Mr Saravana Kumar M under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him

Place Padannakkad

Date 28 06 2016

Sri. V. Jayakrishnakumar
(Major Advisor, Advisory Committee)
Associate Professor
Department of Agronomy (Instructional Farm)
College of Agriculture, Vellayam
Thiruvananthapuram

CERTIFICATE

We, the undersigned members of the advisory committee of Mr Saravana Kumar M ,a candidate for the degree of **Master of Science in Agriculture** with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled **"PERFORMANCE OF UPLAND RICE(*Oryza sativa* L.) AS INFLUENCED BY NK LEVELS AND FYM SUBSTITUTION"** may be submitted by Mr Saravana Kumar M ,in partial fulfilment of the requirement for the degree

Sri V. Jayakrishnakumar
(Chairman, Advisory Committee)
Associate Professor
Department of Agronomy
College of Agriculture, Vellayam,
Thiruvananthapuram

Dr. A. S. Anilkumar
(Member, Advisory Committee)
Professor and Head
Department of Agronomy
College of Agriculture,
Padannakkad

Dr Jacob John
(Member, Advisory Committee)
Associate Professor (Agronomy)
CSRC, Karamana,
Thiruvananthapuram

Dr M. Govindan
(Member, Advisory Committee)
Associate Dean
College of Agriculture,
Padannakkad

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

I extend my sincere gratitude and reverence to ***Sri. V. Jayakrishnakumar,*** *Associate Professor Department of Agronomy and the Chairman of my Advisory Committee for his unstinted support, inspiring guidance and constant encouragement throughout the course of investigation and preparation of thesis This work would not have been possible without his valuable help and support*

I wish to express my sincere gratitude to ***Dr. A. S. Anilkumar,*** *Professor and Head, Department of Agronomy, College of Agriculture, Padannakkad and Member Advisory Committee for her constant encouragement, support, critical suggestions and timely help throughout the research work and course of study*

I express my heartfelt gratitude to ***Dr. Jacob john,*** *Associate Professor (Agronomy), College of Agriculture, Padannakkad and Member Advisory Committee for her timely suggestions and kind guidance throughout the course programme*

I express my heartfelt gratitude to ***Dr. R. Ilangovan*** *Associate Professor Department of Agronomy for his valuable and positive advices and instructions which were always informative and helpful to me throughout the course of investigation*

I am grateful to ***Dr. M. Govindan*** *Associate Dean College of Agriculture Padannakkad, for his critical suggestions and instructions throughout the post graduate programe*

I extend my sincere respect and gratitude to ***Mr. Surendren, Dr. P.R. Suresh, Dr. K.M. Sreekumar, Dr. Namboodiri Raji Vasudevan, Dr. G. V. Sudarsana Rao, Dr. P.K. Retheesh*** *and* ***Dr. Binitha, N.K.*** *who have always given encouragement and support Their personal involvement at times of need was highly valuable*

I express my deepest and sincere thanks to ***Mr. Ambu*** *for timely providing all necessary requirements for the conduct of research work.*

I thank Abhimannue, Aloka, Arun, Abbas, Anjana, Kokila, Nimisha, Sowmiya, Premalatha and my seniors and juniors for every help extended to me

I wish to acknowledge with gratitude the award of fellowship by the Kerala Agricultural University during the tenure of the M Sc (Ag) programme

I am most indebted to my Mother and Father for their affection, constant encouragement and support without which I would not have completed this work Above all, for the attention focused and facilities arranged to carry forward my studies

I bow before the God almighty for all the bountiful blessings showered on me at each and every moment without which this study would never have seen light

Saravana Kumar. M

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

LIST OF ABBREVIATIONS

%	-	Per cent
^{0}C	-	Degree Celsius
° E	-	Degree East
° N	-	Degree North
AF	-	Aqua Flowable
BCR	-	Benefit cost ratio
BSS	-	Bright sunshine
CD	-	Critical difference
CF	-	Chemical fertilizer
cm	-	Centimetre
cc	-	Cubic centimetre
CO_2	-	Carbon dioxide
DAS	-	Days after sowing
D_b		Bulk density
DMP	-	Dry matter production
et al	-	And others
ETL	-	Economic Threshold Level
$FeSO_4$	-	Iron sulphate
Fig	-	Figure
FYM	-	Farmyard manure
g cc^{1}	-	Gram per cubic centimetre
g		Gram
ha^{1}	-	Per hectare
HI	-	Harvest Index

INM	-	Integrated Nutrient Management
K	-	Potassium
K_2O	-	Potash
kg	-	Kilogram
kg ha ^{1}	-	Kilogram per hectare
l	-	Litre
LAI	-	Leaf Area Index
m	-	Metre
mm	-	Milli metre
mm day ^{1}	-	Milli metre per day
m^2	-	Square metre
m^3	-	Cubic metre
ml	-	Millilitre
M mol m ^{2} s ^{1}	-	Milli mole per metre square per second
MSL	-	Mean sea level
N	-	Nitrogen
NS	-	Not significant
P	-	Phosphorus
P_2O_5		Phosphate
PTB	-	Pattambi
RARS	-	Regional Agricultural Research Station
RLWC	-	Relative Leaf Water Content
SE	-	Standard error
Rs	-	Rupees
t ha ^{1}	-	Tonnes per hectare

INTRODUCTION

1. INTRODUCTION

Rice (*Oryza sativa* L) is the most essential cereal food crop and feeds more than half of the world's population The slogan "Rice is life" is most suitable for India, as rice plays a major role in our national food security The area under rice cultivation in India is 42 4 million hectares with a production of 104 3 million tonnes and a productivity of 2 46 tonnes per hectare (GOK, 2015) In 2050, there is an urgent need to raise the rice production to 137 3 million tonnes to feed the population of 1824 million people in India

With respect to Kerala, the rice production was 6 89 lakh tonnes from an area of 3 11 lakh hectares during 2002-03 and after 10 years (2012-13) the production declined to 5 08 lakh tonnes from an area of 1 97 lakh hectares (GOK, 2015) The state has witnessed 35 per cent reduction in lowland rice area and 28 per cent reduction in production during the last ten years It is observed that the present production of rice is only less than one fourth of requirement of 40 lakh tonnes The drastic reduction in rice production is mainly attributable to decrease in area under rice cultivation, conversion of wetlands to non agricultural purposes like industrial and infrastructure development, replacement with other cash crops like rubber, pepper and cardamom, shortage of labour, high wage rate and non remunerative prices The scope for expansion of area under sole crop of rice is limited In this context, the best alternative is to increase cultivation of upland rice Upland rice can be grown in backyards of homesteads, as an intercrop in coconut gardens, as an intercrop in pulses, oilseeds, vegetables and even in grow bags in terrace gardens

Upland rice is grown in about 13 per cent of the area under rice in India, but contributes to only 4 per cent of the rice production In Kerala, upland rice is cultivated in 0 11 million hectares and constitutes about 13 4 % of total rice area (Singh *et al* , 2011) The present level of productivity of upland rice in Kerala is less than 1 t ha^{1} The major constraints in upland rice are moisture stress, nutrient imbalance, high weed infestation and poor soil fertility. High productivity can be achieved through proper nutrient management practices.

Nutrient management is one of the important factors which influence upland rice production. Studies on nutrient management on upland rice indicated that it will respond to higher levels of nitrogen and potassium. Nitrogen is one of the most important essential nutrients for plant growth and development of rice. Nitrogen is a major constituent of amino acids, enzymes, etc. and plays a vital role in many plant functions (such as photosynthesis). It increases plant biomass and yield through efficient use of water. An incremental dose of nitrogen tends to increase the yield of cereals (Khan *et al.*, 1994). In rice, potassium is the second important nutrient after nitrogen and K uptake was comparatively higher than N uptake in rice. Potassium promotes growth, yield attributes, yield, increases resistance to pests, regulates water utilization by plant and strengthens plant tissues. Potassium increases strength of rice stalk and thus prevents lodging and sterility.

The excessive use of chemical fertilizers has not only polluted the soil, water and environment but also affected the life of human beings. Thus, in present day agriculture the importance of organic manures is increasing, because it plays a vital role in improving and maintaining good soil fertility. So, to stimulate sustainability for long term basis measures have to be adopted. Integrated use of organic manures and chemical fertilizer would quiet promising not only in providing greater stability in production, but also maintaining higher soil fertility status. Here comes the significance of combined use of organic manures and chemical fertilizer in a sustained way. INM is the adoption of appropriate and managerially efficient technologies for the judicious use of plant nutrients in an integrated manner so as to attain optimum economic yield from a specific cropping system (Sarkar, 2000). It can be applied by organic, inorganic and biological sources in an integrated manner to maintain sustainable production. Organic manure application increases the water holding capacity, lowers bulk density and increases the infiltration rate (Sharma and Sharma, 1994).

FYM is one of the commonly available organic manures with a nutrient content of 0 5 0 2 0 3 per cent NPK respectively It improves the physical properties of soil especially the structure, aggregation, water holding capacity, porosity, cation exchange capacity and enhances enzymatic activities and influences the yield of crops

The suitable combination of organic and inorganic nutrient sources were found to increase the growth and yield attributes of rice (Maragatham, 1996, Battacharya and Nain, 2001) There is a possibility of increasing upland rice production by increasing N and K levels with different levels of FYM substitution Hence the present study entitled "Performance of upland rice (*Oryza sativa* L) as influenced by NK levels and FYM substitution" was undertaken with the objectives of studying the influence of different levels of N and K on growth and yield of upland rice, to assess the possibility of substitution of inorganic N by FYM and to work out the economics of cultivation

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Upland rice can be grown under aerobic conditions as any other crop and moisture has to be maintained at field capacity unlike lowland rice It is reported to have high water productivity, drought and shade tolerance The present level of productivity of upland rice in Kerala is less than 1 t ha^{-1} The major constraints in upland rice cultivation are water stress, nutrient imbalance, high weed infestation and poor soil fertility Integrated use of inorganic and organic source of nutrients has a tremendous potential in not only sustaining agricultural productivity and soil health but also substituting a part of fertilizer requirement by organics for different crops and cropping system The relevant literature on the effect of N, K and FYM 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

Thomas (2000) noted that plant height increased with incremental doses of nitrogen Mini (2005) observed that plant height in rice was favourably influenced by N upto 100 kg ha^{-1} In upland basmati rice, the plant height increased significantly with increasing levels of nitrogen upto 120 kg ha^{-1} (Sharma *et al*, 2007) The tallest plants were observed in plots applied with 100 kg N ha^{-1} (Islam *et al*, 2008) Maheswari *et al* (2008) obtained the maximum plant height (91 cm) at 175 kg N ha^{-1} in aerobic rice, which was significantly higher than lower levels of 150, 125 and 100 kg N ha^{-1} respectively Kumar and Shivay (2009) found that increase in levels of N positively influenced the plant height and N applied at 150 kg ha^{-1} produced the tallest plant Kumar *et al* (2014) observed that 150 kg N ha^{-1} was found better in obtaining tallest plant different rice genotypes and above this, it did not increase significantly Rao *et al* (2014) opined that plant height increased progressively with incremental levels of N upto 120 kg N ha^{-1}. Application of 150 kg N ha^{-1} produced the tallest plants in rice (Ajaykumar, 2015).

Anu (2001) stated that tiller number increased with incremental dose of N upto 80 kg ha^{-1}. In upland rice, the maximum tiller production was obtained by nitrogen applied at 90 kg ha^{-1} (Ranjini, 2002). Kumar and Shivay (2009) opined that N applied at 150 kg ha^{-1} produced more number of tillers. Similarly, higher number of tillers was obtained at higher levels of nitrogen upto 100 kg ha^{-1} (Mannan *et al.* 2012). Pramanik and Bera (2013) reported that N applied at 200 kg ha^{-1} recorded the maximum tiller numbers $hill^{-1}$ in rice. Rao *et al.* (2014) stated that the highest tiller numbers m^{-2} was obtained by addition of 120 kg N ha^{-1}.

Mini (2005) obtained maximum LAI at 100 kg N ha^{-1}. Mhaskar *et al.* (2006) reported higher leaf area and LAI throughout the growth period were noticed at 120 kg N ha^{-1}. Higher levels of nitrogen significantly increased the LAI values upto 175 kg N ha^{-1} (Maheswari *et al.*, 2008). At all the growth stages of rice, a fertilizer level of 150 kg N ha^{-1} recorded the highest LAI (Kumar and Shivay, 2009). Akanda *et al.* (2012) observed the highest leaf area at 75 kg N ha^{-1}.

Ranjini (2002) found that upto 90 kg N ha^{-1} there was an increase in DMP of upland rice. Saito *et al.* (2006) observed that 90 kg N ha^{-1} was found better in obtaining higher dry matter production of 7.9 t ha^{-1}. Maheswari *et al.* (2008) obtained the maximum dry matter production (15.38 t ha^{-1}) at 175 kg N ha^{-1}. Kumar and Shivay (2009) obtained the highest DMP of rice by addition of N at 150 kg ha^{-1}. Luka *et al.* (2013) obtained higher DMP in rice at fertilizer level of N_{65}. Due to beneficial effect of vegetative growth, there was accumulation of dry matter at all the stages with increase in N level upto 100 kg ha^{-1} (Seema *et al.*, 2014).

2.1.1.2. Potassium

Potassium is a macronutrient involved in many plant processes critical for optimum growth, yield and quality of crops. K plays a wide range of functions like enzyme activation, photosynthesis, protein synthesis and osmotic potential. Potassium is involved in sugar translocation and helps to resist drought, lodging and pest and disease incidence. It helps in minimizing the losses of applied nutrients and increases the availability throughout the growth period thereby results in the higher yield of rice.

Mini (2005) found that application of potassium at 50 kg ha^{-1} produced the tallest plant at harvest. Surendran (2005) opined addition of potassium @ 50 kg ha^{-1} recorded the tallest plant of 95.5 cm. Fertilizer level of 25 kg K_2O ha^{-1} produced the tallest plant in rice (Akanda *et al.*, 2012). Dutta *et al.* (2013) suggested that plant height increased with incremental doses of potassium and maximum height was recorded at 50 kg K_2O ha^{-1}. Similarly, Uddin *et al.* (2013) reported that taller plants were obtained by the application of 60 kg K_2O ha^{-1}. Potassium provided @ 50 kg ha^{-1} produced the tallest plants in rice (Ajaykumar, 2015).

Thakur *et al.* (1993) opined that total number of tillers m^{-2} was increased with increase in the K level up to 66 kg K_2O ha^{-1}. Application of potassium at 45 kg ha^{-1} produced the highest number of tillers (Thomas, 2000; Anu, 2001; Ranjini, 2002). Meena *et al.* (2003) recorded higher tiller number at 62.5 kg K_2O ha^{-1}. Manzoor *et al.* (2008) found that the maximum number of tillers m^{-2} (20.22) was obtained by potassium applied at 62 kg ha^{-1}. Nath (2012) stated that applied potassium fertilizer at 72 kg ha^{-1} produced higher tiller number closely followed by 54 and 90 kg K_2O ha^{-1} respectively. The maximum tiller number was produced at 50 kg K_2O ha^{-1} (Ajaykumar, 2015).

Mini (2005) obtained the highest LAI at 75 kg K_2O ha^{-1}. Mukherjee and Sen (2005) stated that the application of potassium significantly increased the leaf area index. The highest leaf area was obtained at 35 kg K_2O ha^{-1} (Akanda *et al.*, 2012). Ajaykumar (2015) reported that application of 50 kg K_2O ha^{-1} produced the highest LAI in rice.

Kale and Chavan (1998) reported that application of potassium at 50 kg ha^{-1} increased the dry matter of rice. The DMP in upland rice increases with increased levels of K upto 45 kg ha^{-1} (Thomas, 2000; Anu, 2001; Ranjini, 2002). Meena *et al.* (2003) obtained highest dry matter accumulation at 62.5 kg K_2O ha^{-1}. Ajaykumar (2015) reported maximum DMP at 50 kg K_2O ha^{-1} in rice.

2.1.1.3. FYM

FYM is traditionally applied to rice soils in order to maintain the soil organic matter, plant nutrients status and improve the physical, chemical and biological soil properties that directly or indirectly affect soil fertility and productivity. Apart from these, enzymatic activities that encourage root development and rice yield were enhanced. Increased availability and uptake of micronutrients due to application of organic manure favourably influenced growth, yield attributes and yield (Bhattacharya and Chakraborty, 2005).

Ramasamy (1990) found that FYM increased plant height, LAI and DMP over other organic sources. Tripathi *et al.* (1990) reported that increasing dose of FYM from upto 20 tonnes from 5 tonnes, increased dry matter production of rice at various stages. However, maximum DMP was produced by FYM applied at 15 t ha^{-1}. Rajput and Warsi (1991) stated that application of FYM or straw with and without inorganic N significantly increased tillers per hill. Sharma (1992) reported that FYM applied at 10 t ha^{-1}produced tallest plant, highest tiller number m^{-2} and dry matter production of rice.

Bhattacharya *et al.* (2003) found FYM application @ 9 tonnes per hectare produced tallest plants and highest DMP at 7.0 t FYM ha^{-1}. Similarly, Rao *et al.* (2004) suggested that plant height and dry matter production increased with FYM application which increases the soil organic carbon, holds more moisture in soil and creates suitable condition for better root growth and proliferation enabling extraction of nutrients from larger profile area. Vennila *et al.* (2007) found that growth factors increased significantly due to application of FYM. The tallest plant and maximum dry matter accumulation in rice were obtained by FYM incorporation at 20 tonnes per hectare (Shekara, 2010). Panigrahi *et al.* (2014) concluded that rice supplied with FYM at 15 t ha^{-1} produced taller plants at harvest with more tillers and greater LAI compared to inorganic fertilizers. Pradhan and Moharana (2015) found that organic nutrient management expressed significant effect on dry matter accumulation. In Kharif season, application of Dhanicha + FYM + vermicompost produced highest dry matter accumulation and in summer FYM + vermicompost recorded the maximum DMP.

2.1.1.4. Combined Effects of Nitrogen and Potassium

In upland rice, the highest values of growth characters were produced by application of 60:45 kg ha^{-1} of NK compared to lower levels of NK levels (Thomas, 2000). Ranjini (2002) observed that growth characters were notably increased with increasing levels of NK upto 90:45 kg ha^{-1} than lower levels. Mini (2005) concluded that significant increase in growth characters of upland rice were obtained by fertilizer level of N_{100} K_{50}. Bahmanyar and Mashaee (2010) reported that the tallest plant was recorded by combined application of NK at 23 and 30 kg ha^{-1}. Addition of 30 kg potassium in conjunction with 23 kg nitrogen positively influenced the plant height of rice (Kumar *et al.*, 2013). In dry direct seeded rice the tallest plants were produced by combination of N_{60} K_{60} (Uddin *et al.*, 2013).

Bahmanyar and Mashaee (2010) obtained more tillers due to application of NK level at 46:30 kg ha^{-1} compared to lower NK levels. In aerobic rice, NK level of 240:50 kg ha^{-1} recorded maximum tiller number (Reddy *et al.*, 2012). The combined application of nitrogen and potassium at 80 and 20 kg ha^{-1} produced the highest number of total tillers (164.67), which was found statistically identical to those produced total tillers at NK level of 60:40 kg ha^{-1} (Uddin *et al.*, 2013). Pramanik and Bera (2013) opined maximum tillers were produced at NK levels at 200 and 60 kg ha^{-1}. Addition of NK level of 120:60 kg ha^{-1} produced the maximum tiller number (Rao *et al.*, 2014).

Mini (2005) recorded maximum LAI due to rice crop supplied with 100 kg N ha^{-1} and 75 kg K_2O ha^{-1}. Maheshwari *et al.* (2008) obtained higher LAI at N and K applied at 175 kg ha^{-1} and 50 kg ha^{-1} respectively for aerobic rice. Luka *et al.* (2013) recorded maximum LAI at 130 kg N ha^{-1} and 50 kg K_2O ha^{-1}. Ajaykumar (2015) reported maximum LAI was recorded by united application of N and K at 150 kg ha^{-1} and 50 kg ha^{-1} in rice.

Ranijini (2002) obtained maximum DMP at NK applied at 90 and 45 kg K_2O ha^{-1} respectively. Mini (2005) obtained highest DMP at N and K applied at 100 and 50 kg ha^{-1} in upland rice. The maximum DMP was produced by combined application of N and K at 130 kg ha^{-1} and 50 kg ha^{-1} (Luka *et al.*, 2013). Seema (2014) reported maximum DMP at 125 kg N ha^{-1} and 40 kg K_2O ha^{-1} in aerobic rice. Ajaykumar (2015) revealed that higher NK rates of 150:50 kg ha^{-1} produced higher DMP at different growth stages in rice.

2.1.1.5. Combined Effects of Nitrogen, Potassium and FYM

Ranjini (2002) reported that 60 kg N ha^{-1} with 25 per cent as FYM and 30 kg K_2O ha^{-1} produced the tallest plants in upland rice. In rainy season rice, addition of 75 and 37.5 kg NK ha^{-1} with FYM incorporation at 5 tonnes produced the tallest plants (Maiti *et al.*, 2006). Application of 150 kg N ha^{-1} with 25 per cent substituted as FYM and 60 kg K_2O produced the tallest plant (113.73 cm) and was on par with fertilizer level of NK at 150 and 60 kg ha^{-1} (Kumar *et al.*, 2014). The effect of INM practices on plant height at harvest revealed that FYM application @ 5 tonnes in addition to NK rates of 150:40 kg ha^{-1} had registered taller plants over the other treatments (Revathi *et al.*, 2014).

Ranjini (2002) reported maximum tiller number for 60 kg N applied as 30 kg chemical fertilizer and 30 kg as FYM and 30 kg K_2O together with FYM at 5 tonnes per hectare. Dutta and Yhome (2014) reported that application of NK at 60 kg N ha^{-1} and 40 kg K_2O ha^{-1} along with 10 t FYM ha^{-1} produced the maximum number of tillers. Sekhar *et al.* (2014) opined that integration of nutrients at 125 kg N ha^{-1} with 20 per cent substituted as FYM and 40 kg K_2O ha^{-1} recorded the highest tiller number $hill^{-1}$ in rice.

Maiti *et al.* (2006) found that in rainy season rice, maximum leaf-area index of 5.13 was obtained when the crop received N_{75} $K_{37.5}$ along with 5 tonnes FYM. Fertilizer level of N:K at 120:60 kg ha^{-1} produced maximum LAI and was on par with N:K at 120:60 kg ha^{-1} with 25 per cent N substituted as FYM (Aruna *et al.*, 2012). Sunil and Shankaralingappa (2014) opined that combination of N_{50} K_{50} + FYM (10 t ha^{-1}) + Biofertilizers + $FeSO_4$ + IWM practices recorded highest leaf area index at 90 DAS in aerobic rice.

Senthivelu *et al.* (2009) stated that application of FYM at 12.5 t ha^{-1} in addition with 150:50 kg ha^{-1} of NK recorded higher dry matter production at harvest compared to chemical fertilizers alone. Siddaram *et al.* (2011) found that integrated use of 100: 50 kg NK as chemical fertilizer along with 10 t of FYM ha^{-1} recorded the highest DMP in rice. Revathi *et al.* (2014) observed that among the INM practices, united application of FYM at 5 tonnes along with 150:40 kg NK ha^{-1} has recorded the higher DMP. NK fertilizer at 125:40 kg ha^{-1} with 25 per cent N substituted as FYM produced higher dry matter production of rice (Sekhar *et al.*, 2014).

2.1.2. Yield and Yield Attributes

2.1.2.1. Nitrogen

Thomas (2000) reported that rice crop supplied with N at 60 kg ha^{-1} produced the highest productive tiller number $hill^{-1}$. Addition of N at 120 kg ha^{-1} produced the highest number of effective tillers m^{-2} (Sharma *et al.*, 2007).

Maheshwari *et al.* (2008) noticed highest number of productive tillers of aerobic rice was recorded with N supplied at 175 kg ha^{-1} than N at 150, 125 and 100 kg ha^{-1}. Kumar and Shivay (2009) found that number of productive tillers of rice influenced by increasing levels of nitrogen. Similiar findings were reported by Onaga *et al.* (2012), Pasha *et al.* (2013) and Reddy *et al.* (2012). Pramanik and Bera (2013) found that increasing level of nitrogen application upto 150 kg ha^{-1} gradually increased the number of effective tillers $hill^{-1}$. Upto nitrogen level at 120 kg ha^{-1} there was substantial increment in productive tillers in rice (Ali *et al.*, 2014).

Anu (2001) obtained the longest panicle in upland rice at nitrogen applied at 80 kg ha^{-1}. In rice, length of panicle was positively influenced by nitrogen application and the longest panicle was obtained by application of 150 kg N ha^{-1} (Islam *et al.*, 2008). Pasha *et al.* (2012) reported that application of nitrogen at 180 kg ha^{-1} produced longest panicle compared with lower dose of nitrogen in aerobic rice. Sharma *et al.* (2014) stated that addition of 40 to 160 kg N ha^{-1} produced considerably similar panicle length and all were significantly superior over control.

Sharma *et al.* (2007) obtained the maximum number of grains per panicle at N level of 120 kg ha^{-1} which was compared to lower levels of N at 80 and 40 kg ha^{-1}. N level of 175 kg ha^{-1} produced the maximum grains per panicle (Maheswari *et al.*, 2008). Devi *et al.* (2012) revealed that the higher number of grains per panicle was obtained by N @ 150 kg ha^{-1} comparable to 125 kg N ha^{-1} under aerobic condition. Onaga *et al.* (2012) opined that the highest number of spikelets m^{-2} was recorded at 120 kg N ha^{-1} and which contributes to the increased grain yield of rice.

Lawal and Lawal (2002) reported the maximum percent filled grains at 80 kg N ha^{-1}. The highest number of filled grains $panicle^{-1}$ of rice was obtained by nitrogen supplied at 100 kg ha^{-1} (Kumar and Shivay, 2009). According to Pramanik and Bera (2013), the highest number of filled grains $panicle^{-1}$ was obtained at 150 kg N ha^{-1} and was followed by 200 kg N ha^{-1}. Sandyarani *et al.* (2013) opined that N at 240 kg ha^{-1} produced more number of filled grains per panicle and was higher than lower levels.

Devi *et al.* (2012) reported the maximum thousand grain weight by N applied at 150 kg ha^{-1}. The highest test weight was obtained by application of nitrogen at 120 kg ha^{-1} compared to lower levels (Onaga *et al.*, 2012). The maximum test weight of rice grain was recorded with 240 kg N ha^{-1} was considerably higher than 120 kg N ha^{-1} (Reddy *et al.*, 2012). The nitrogen level of 150 kg N ha^{-1} registered the highest test weight as compared to other nitrogen levels (Pramanik and Bera, 2013).

N level of 125 kg ha^{-1} gave highest grain yield compared to N applied at 100 kg ha^{-1} (Sudhakar *et al.*, 2003). Maheswari *et al.* (2008) revealed that N applied at 150 kg ha^{-1} gave the maximum productivity compared to lower levels under aerobic rice cultivation. Application of nitrogen at 40 kg ha^{-1} gave 66.18 and 71.63% increase in grain yield over control without nitrogen (Singh and Tripathi, 2007). The maximum grain yield of rice was produced by N applied at 100 kg ha^{-1}(Kumar and Shivay, 2009). Under aerobic condition, scented rice recorded the highest grain yield of 1636 kg ha^{-1} at 150 kg N ha^{-1} compared to 100 and 125 kg N ha^{-1} (Devi *et al.*, 2012). Application of 120 kg N ha^{-1} recorded the highest grain yield in upland rice of 4842 kg ha^{-1} (Onaga *et al.*, 2012). According to Pasha *et al.* (2012), N level of 180 kg ha^{-1} recorded the highest grain yield compared to lower levels of 120 and 150 kg N ha^{-1}. Reddy *et al.* (2012) stated that application of nitrogen at 240 kg ha^{-1} recorded the maximum grain yield of rice which was considerably higher than other the lower levels of 180 and 120 N kg ha^{-1}. Seema *et al.* (2014) reported the addition of 100 kg N ha^{-1} produced more grain yield under direct seeded aerobic rice. Application of 120 kg N ha^{-1} gave the highest grain yield in rice as observed by Rao *et al.* (2014). Sharma *et al.* (2014) reported higher grain yield at 160 kg N ha^{-1} compared to lower N levels.

Prasad *et al.* (2003) stated that highest straw yield was obtained by nitrogen supplied at 80 kg ha^{-1} compared to lower doses of 40 and 60 kg N ha^{-1}. Sharma *et al.* (2007) obtained remarkable increase in straw yield with N 120 kg ha^{-1} produced 3.45 t ha^{-1}. The highest straw yield (6.23 t ha^{-1}) was observed in application of nitrogen at 150 kg ha^{-1}. Upto 75 kg N ha^{-1} there was substantial increase in straw yield (Mannan *et al.,* 2010). Nitrogen applied at 240 kg ha^{-1} produced the highest straw yield and was significantly superior to 180 and 120 kg N ha^{-1} (Reddy *et al.* 2012). Similarly, the maximum straw yield (4.20 t ha^{-1}) was obtained by nitrogen applied at 240 kg ha^{-1} which was on par with 180 kg N ha^{-1}(Sandyarani *et al.*, 2013). The maximum straw yield was recorded at 150 kg N ha^{-1} (Singh *et al.,* 2014). At N rates of 200 kg ha^{-1} obtained the maximum straw yield of 6.12 t ha^{-1} (Chamely *et al.*, 2015).

Kumar and Shivay (2009) found an increase in HI was obtained at higher levels of N upto 100 kg ha^{-1} and followed by N applied at 150 kg ha^{-1}. The highest harvest index was registered by addition of N at 150 kg ha^{-1} (Pramanik and Bera, 2013). The highest harvest index was recorded by the application of 100 kg N ha^{-1} (Singh *et al.,* 2014). Chamely *et al.*, (2015) obtained the highest harvest index at 200 kg N ha^{-1}.

2.1.2.2. Potassium

Mehla (1995) reported that when more potassium fertilizer was applied in rice increased the number of panicles m^{-2}. Surendran (2005) revealed that number of productive tillers of rice were higher in the plots which received 50 kg K_2O ha^{-1}. Kandil *et al.* (2010) opined that increasing potassium rates upto 48 kg ha^{-1} increased the panicle numbers m^{-2} and highest number of panicle m^{-2} was produced by K applied at 48 kg ha^{-1}. Significant increase in panicles m^{-2} was recorded upto K level of 37.5 kg ha^{-1} (Dutta *et al.*, 2013).

Surendran (2005) noticed the longest panicle of rice at 50 kg K_2O ha^{-1}. Similarly, the highest panicle length was observed in plot receiving 72 kg K_2O ha^{-1} (Nath, 2012). Uddin *et al.* (2013) recorded the longest panicle at 60 kg K_2O ha^{-1}. The longest panicles were recorded by 30 kg K_2O ha^{-1}(Tasnin, 2014).

The maximum grains per panicle were observed by application of 62.5 kg K_2O ha^{-1} (Awan *et al.*, 2007). Higher number of grains per panicle in rice plant was obtained with potassium at 62 kg ha^{-1} (Manzoor *et al.*, 2008). Nath (2012) reported that application of 72 kg K_2O ha^{-1} produced that the highest grains per panicle of 130. Dutta *et al.*, (2013) obtained significant increase in grains $panicle^{-1}$ upto K applied at 37.5 Kg ha^{-1}. Uddin *et al.* (2013) opined that application of potassium @ 40 kg ha^{-1} resulted in the highest grains $panicle^{-1}$ (127.99) and closely followed by potassium applied @ 60 kg ha^{-1}.

Surendran (2005) concluded that the maximum number of filled grains per panicle of rice was obtained by potassium applied at 50 kg ha^{-1}. Increasing potassium levels upto 48 kg K_2O ha^{-1} significantly raised the filled grains $panicle^{-1}$(Kandil *et al.*, 2010). The highest grains $panicle^{-1}$ was obtained at 40 kg K_2O ha^{-1} and was statistically on par with 60 kg K_2O ha^{-1} (Uddin *et al.*, 2013).

Arivazhagan and Ravichandran (2005) reported that application of 75 kg K_2O ha^{-1} recorded the maximum 1000 grain weight in rice. Nath (2012) found that the application of potassium at 72 kg ha^{-1} produced the maximum 1000-grain weight. Dutta *et al.* (2013) suggested that increasing levels of K, increased the 1000 grain weight of rice and the maximum test weight was obtained at K applied at 37.5 kg ha^{-1}. The maximum 1000 grain weight was obtained by potassium applied at 20 kg ha^{-1} (Tasnin, 2014).

Kaliha *et al.* (1995) found that increase in panicle number and filler grains per panicle which contributes to higher grain yield of rice due to potassium applied at 40 kg ha^{-1}. Pillai and Anasuya (1997) noticed that grain yield increased with increasing K rates upto 75 kg ha^{-1}, above which yield increase was negligible. Dwivedi *et al.* (2006) observed that potassium applied at 80 kg K_2O ha^{-1} produced the higher grain yield in rice. Maximum grain yield of 4.73 t ha^{-1} was obtained at 62.5 kg K_2O ha^{-1} (Awan *et al.*, 2007). The maximum yield was observed at 180 kg K_2O ha^{-1} (Pattanayak *et al.*, 2008). Akanda *et al.* (2012) showed the highest grain yield at 25 kg K_2O ha^{-1}. A jump in grain yield increase of 62% over control was noticed with potassium applied at 75 kg ha^{-1} and further increase in K decreased the yield (Uddin *et al.*, 2012). Significant response of grain yield was observed upto K applied at 37.5 kg ha^{-1}(Dutta *et al.*, 2013).

Zayed *et al.* (2007) showed that increasing potassium rate from 0 to 72 kg K_2O ha^{-1} significantly increased straw yield. Bachkaiya *et al.* (2008) found that application of potassium enhanced the straw yield of rice. Kandil *et al.* (2010) opined that potassium fertilization significantly increased the straw yield and the highest straw yield was recorded by K applied at 48 kg ha^{-1}. The highest straw yield was observed in potassium applied at 35 kg ha^{-1}(Akanda *et al.*, 2012). Dutta *et al.* (2013) found significant response of straw yield to K application upto 37.5 kg ha^{-1}. Tasnin (2014) observed that application of potassium at 30 kg ha^{-1} gave the highest straw yield of 6.46 t ha^{-1}.

Mini (2005) obtained the highest HI at K applied at 90 kg ha^{-1}. Jalali-Moridani and Amiri (2014) reported that the maximum HI at 150 kg K_2O ha^{-1}. The maximum HI was obtained by potassium supplied at 50 kg ha^{-1} in rice (Ajaykumar, 2015).

2.1.2.3. FYM

The number of panicle m^{-2} was significantly increased due to FYM applied at 5.54 t ha^{-1} (Sharma and Sharma, 1994). Verma and Bhagat (1994) found that yield contributing characters were affected positively by the incorporation of FYM resulting in the highest grain and straw yields of rice. In rice, application of 20 t FYM ha^{-1} produced the highest values of yield attributes and yield (Kumar *et al.*, 2003). Shekara *et al.* (2010) found that FYM applied at 20 t ha^{-1} recorded more productive tillers hill^{-1}, filled spikelets, 1,000 grain weight which produced higher grain yield compared to without FYM application. The highest values of panicles m^{-2}, grains panicle^{-1}, grain and straw yields were obtained by application of FYM at 15 t ha^{-1} (Panigrahi *et al.*, 2014).

Incorporation of FYM @ 10 tonnes per hectare shown maximum grain yield of rice (Gupta *et al.*, 1995). Madhav *et al.* (1996) observed higher harvest index with application of 120 kg N ha^{-1} supplied 100 per cent as FYM. FYM addition at 10 tonnes per hectare significantly increased the grain and straw yields of rice and wheat (Singh *et al.*, 1996). Reddy and Shivraj (1999) reported higher grain yield due to FYM applied at 10 t ha^{-1}. Chettri *et al.* (2003) reported that farmer's practice of application of FYM at 7 t ha^{-1} was adequate to produce stable rice yields. Gopakkali *et al.* (2012) concluded that application of 125 kg N ha^{-1} supplied through FYM at 12.5 t ha^{-1} along with cattle urine produced the highest grain and straw yields of rice. Panigrahi *et al.* (2014) suggested that application of organic manure @ 15 tonnes produced the highest grain and straw yields of rice.

2.1.2.4. Combined Effects of Nitrogen and Potassium

Anu (2001) found that yield characters were favourably influenced by N and K applied at 80:45 kg ha^{-1}. Mini (2005) found that upland rice fertilized with NK at 100 and 50 kg ha^{-1} favourably influenced the yield attributes and yield. Arivazhagan and Ravichandran (2005) reported that NK applied at 150:75 kg ha^{-1} recorded the highest number of panicles hill^{-1}, panicle length, 1000-grain weight, grain yield and straw yield of rice. According to Kumar *et al.* (2005) application of 160 kg N and 60 kg K_2O ha^{-1} positively influenced the yield attributes of hybrid rice and produced higher grain and straw yields. Sarker *et al.* (1995) found that fertilizer level of 100:75 kg NK ha^{-1} shown higher values of yield components and yield of rice. Application of 60 kg potassium in conjunction with 90 kg nitrogen significantly increased the yield of rice (Nakashgir *et al.*, 2000). Farinelli *et al.* (2004) found that application of 65 kg N ha^{-1} and 20 kg K_2O ha^{-1} was the best combination to produce maximum grain yield. An interaction effect of nitrogen and potassium revealed that NK at 50:25 kg ha^{-1} produced the highest values of yield components and grain yield (Akanda *et al.*, 2012). The highest grain yield of rice was obtained by united application of NK level at 23 and 30 kg ha^{-1}(Kumar *et al.*, 2013).

Anu (2001) reported the maximum HI recorded by NK applied at 80:30 kg ha^{-1} in upland rice. Highest harvest index with positive N-K interactions can be obtained at 25:15 kg NK ha^{-1} in fine grain aromatic rice (Akanda *et al.*, 2012). Ajaykumar (2015) reported the maximum HI due to combined application of 150 kg N ha^{-1} and 50 kg K_2O ha^{-1} in rice.

2.1.2.5. Combined Effects of Nitrogen, Potassium and FYM

Bharathy (2005) reported that integrated application of 10 t FYM ha^{-1} along with NK level of 100 and 40 kg ha^{-1} as chemical fertilizer recorded highest harvest index. FYM application @ 12.5 t ha^{-1} in combination with NK dose of 150:50 kg ha^{-1} registered the highest grain yield of 5538 kg ha^{-1} (Senthievelu and Prabha, 2007). Mankotia *et al.* (2008) stated that application of FYM at 5 t ha^{-1} with 90 kg N ha^{-1} and 33.3 kg K_2O ha^{-1} produced the higher grain yield (5.03 t ha^{-1}) compared to chemical fertilizers alone. The highest grain (30.85 q ha^{-1}) and straw yield (35.25 q ha^{-1}) of rice were obtained with united application of 120 kg N ha^{-1} and 100 kg K_2O ha^{-1} along with 10 t FYM ha^{-1}(Ahmed *et al.*, 2014). Kumar *et al.* (2014) stated that application of NK at 150 and 60 kg ha^{-1} with 25% nitrogen through FYM produced the maximum panicle length, number of grains $panicle^{-1}$, test weight, grain and straw yield. Among the different INM practices, application of FYM @ 5 t ha^{-1} along with NK at 150:40 kg ha^{-1} registered highest panicle number m^{-2} over the other treatments (Revathi *et al.*, 2014). Application of 75 kg N ha^{-1} with 25 per cent substituted as FYM and 40 kg K_2O produced the highest harvest index of rice (Sekhar. *et al.*, 2014).

2.1.3. Physiological Parameters

2.1.3.1. Nitrogen

Thomas (2000) reported the highest RLWC and protein content of grain (4.91%) in upland rice was obtained by higher level of N at 90 kg ha^{-1}. Fertilizer level of nitrogen at 90 kg ha^{-1} increased the RLWC of upland rice (Ranjini, 2002). The maximum RLWC was registered by application of nitrogen at 100 kg ha^{-1} (Mini, 2005). Protein content of grain was increased with the increasing level of nitrogen from 40 to 80 kg ha^{-1} (Sikdar *et al.,* 2008). The higher protein content of grain was recorded at 160 kg N ha^{-1}(Reddy *et al.*, 2012). Maximum grain protein content was observed for nitrogen applied at 103 kg ha^{-1} (Faraji *et al.*, 2013).

2.1.3.2. Potassium

In upland rice grown under open condition, application of 45 kg K_2O ha^{-1} produced the highest protein content of 4.91 per cent (Ranjni, 2002). Dwivedi *et al.* (2006) reported that application of potassium increased the protein content in rice grains. Rao *et al.* (2014) reported higher crude protein content at K applied at 50 kg ha^{-1}.

2.1.3.3. FYM

The protein content of rice was increased by FYM application at 10 t ha^{-1} (Dixit and Gupta, 2000). In wheat, EL-Lattief (2014) reported increased in grain protein content due to FYM application of 8 t ha^{-1}.

2.1.3.4. Combined Effects of Nitrogen and Potassium

Mini (2005) reported that NK levels significantly influenced the protein content of grains in upland rice. The maximum protein content was recorded by application of NK at 100:50 kg ha^{-1}. Kumar *et al.* (2005) revealed that protein content increased with increasing levels of nitrogen and potassium upto 160 kg ha^{-1} and 90 kg ha^{-1}

2.1.3.5. Combined Effects of Nitrogen, Potassium and FYM

Aruna *et al.* (2012) reported the highest protein content at 120 kg N ha^{-1} with 25 per cent substituted as FYM and 60 kg K_2O ha^{-1}. Sekhar *et al.* (2014) obtained the highest protein content at 100 kg N ha^{-1} with 25 per cent substituted as FYM and 40 kg K_2O ha^{-1}.

2.1.4. Nutrient Content and Uptake

2.1.4.1. Nitrogen

Ranjini (2002) obtained highest N uptake at 90 kg N ha^{-1} in upland rice. Mini (2005) stated N applied at 100 kg ha^{-1} shown maximum uptake of N. Sudhakar *et al.* (2003) reported that N uptake improved with each incremental levels of N and the maximum uptake of N was registered at 125 kg N ha^{-1}. Sikdar *et al.* (2008) reported maximum N uptake at 60 kg N ha^{-1}. Rao *et al.* (2013) stated that in all the growth stages nitrogen application favourably influenced the N uptake in rice. The highest grain, straw and total uptake was recorded by application of nitrogen at 240 kg N ha^{-1} which was comparable with 210 kg N ha^{-1}. The nitrogen uptake by grain, straw and total uptake positively improved with successive increase in N addition upto 80 kg ha^{-1} (Nayak *et al.*, 2015).

2.1.4.2. Potassium

Devendra *et al.* (1999) found that the successive increase in K levels resulted in higher potassium uptake by grain and straw. Similarly, increasing levels of N and K to rice resulted in significantly increased the uptake of N and K (Mitra *et al.*, 2001). The maximum uptake of N and K in grain was recorded at potassium applied at 50 kg ha^{-1}. Similar trends were also observed in straw uptake (Surendran, 2005). Krishnappa *et al.* (2006) reported that increased level of potassium tended to increase the potassium uptake in grain and straw. According to Pattanayak *et al.* (2008) macro and secondary nutrient uptake increased under higher rates of K upto 180 kg ha^{-1}. In dry season rice, total K uptake increased by 15.5 and 18.6 % with the addition of 37.5 and 50 kg K_2O ha^{-1}, compared to 25 kg K_2O ha^{-1} (Dutta *et al.*, 2013).

2.1.4.3. FYM

N uptake was increased in kharif rice due to incorporation of 5 tonnes FYM ha^{-1} (Sharma and Mitra, 1990). Sharma (1992) opined that incorporation of 10 t FYM ha^{-1}, increased nutrient uptake in rice and wheat crops over no FYM application. A consistent increase in the nutrients uptake of rice as well as wheat was observed with increase in application of FYM from 0 to 12 t ha^{-1} (Brar and Sindhu, 1995). Madhav *et al.* (1996) reported that FYM application was found to exert positive effect on NPK uptake at harvest. Shekara *et al.* (2010) opined that addition of FYM at 20 t ha^{-1} recorded considerably higher nutrient uptake over 5 t and no FYM application.

2.1.4.4. Combined Effects of Nitrogen and Potassium

Ranjini (2002) obtained highest uptake of NPK at NK level of 90:45 kg ha^{-1}. Kumar *et al.* (2005) reported that increasing levels of nitrogen and potassium up to 160 kg N and 90 kg K_2O ha^{-1} increased the nitrogen and potassium uptake in grain and straw. The NPK uptake of upland rice was favourably affected by NK levels and the highest nutrient uptake was obtained by NK level at 100:50 kg ha^{-1}(Mini, 2005). Ajaykumar (2015) reported that N and K applied at 150:50 kg ha^{-1} respectively produced the highest NPK uptake.

2.1.4.5. Combined Effects of Nitrogen, Potassium and FYM

Satyanarayana *et al.* (2002) noticed that combined inorganic fertilizers and organic manures such as 120:45 kg NK ha^{-1} as chemical fertilizer and in combination with 10 t FYM ha^{-1} recorded the maximum uptake of nutrients. In rainy season rice, maximum uptake of nutrients was recorded at 75:37.5 kg NK ha^{-1}along with 5 t FYM ha^{-1} (Maiti *et al.*, 2006). Kishor *et al.* (2008) stated highest NPK uptake by addition of NK at 90:30 kg ha^{-1} with 5 tonnes FYM. In rice, highest nutrient uptake at harvest stage was recorded by application of FYM at 12.5 tonnes with 150:50 kg ha^{-1} of NK which was higher than the treatment receiving than inorganic fertilizers alone (Senthivelu *et al.*, 2009). Significant higher nitrogen, phosphorus and potassium uptake were recorded by NK applied at 100 and 50 kg ha^{-1} with FYM at 10 t ha^{-1} (Siddaram *et al.*, 2011).

2.1.5. Soil Physical Properties

Application of 150 kg N ha^{-1} with 50 per cent substituted as FYM reduced the bulk density and improved the other physical properties like porosity and water holding capacity which is essential for achieving sustainability in rice based cropping systems (Tripathy and Singh, 2002). Sepehya *et al.* (2012) revealed that application of 90 kg N with 50% substituted as FYM together with 33 kg K_2O ha^{-1} improved the soil physical properties like porosity and water holding capacity. Tadesse *et al.* (2013) reported that soil organic matter and available water holding capacity were increased and soil bulk density was decreased due to application of FYM at 15 t ha^{-1}, which provides good soil condition for enhancing growth of rice.

2.1.6. Soil Available Nutrients

Maiti *et al.* (2006) reported that the highest organic carbon, available NPK content in soil were obtained by application of 75 kg N ha^{-1} and 42.5 kg K_2O ha^{-1} along with 5 t FYM ha^{-1}. Choudary and Suri (2014) reported that NK applied at 90:45 kg ha^{-1} along with FYM @ 5 t ha^{-1} increased the available nutrient status of the soil after the experiment. In rainfed rice, application of 60 kg N with 50 per cent FYM and 30 kg K_2O recorded a significant increase in soil organic carbon and higher available N, P_2O_5 and K_2O of soil after harvest (Gogoi , 2015).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The field experiment was conducted in the field of Sri. Ambu, Akshaya Koolome road, Madikkai, Kasaragod district during *viruppu* 2015. The aim of the study was to assess the influence of different levels of N and K on growth, yield attributes, yield of upland rice and to assess the possibility of substitution of inorganic N by FYM. The details of the materials employed and methods followed during the course of the investigation are described in this chapter.

3.1. MATERIALS

3.1.1. Experimental Site

The field experiment was conducted in the field of Sri. Ambu, Akshaya Koolome road, Madikkai situated at 12° 20' 13" N latitude, 74° 04' 15" E longitude and an altitude of 20 m above mean sea level.

3.1.2. Soil

The soil of the experimental field is sandy loam belonging to the taxonomical order Inceptisol. The physico-chemical properties of the soil are given in the Table 1.

3.1.3. Climate

Weather parameters prevailed during the experimental period is furnished in Appendix I and depicted in Fig 2.

The weather parameters were recorded for the standard weeks during the crop period. A total rainfall of 2322 mm was received in 81 rainy days. The maximum and minimum temperature ranged from 28.50 °C to 32.07 °C and 20.67 °C to 25.14 °C, respectively. Relative humidity varied from 76 to 93.71 per cent. The evaporation and bright sunshine hours day^{-1} ranged from 1.51 to 4.0 mm and 0.36 to 6.71 hours, respectively.

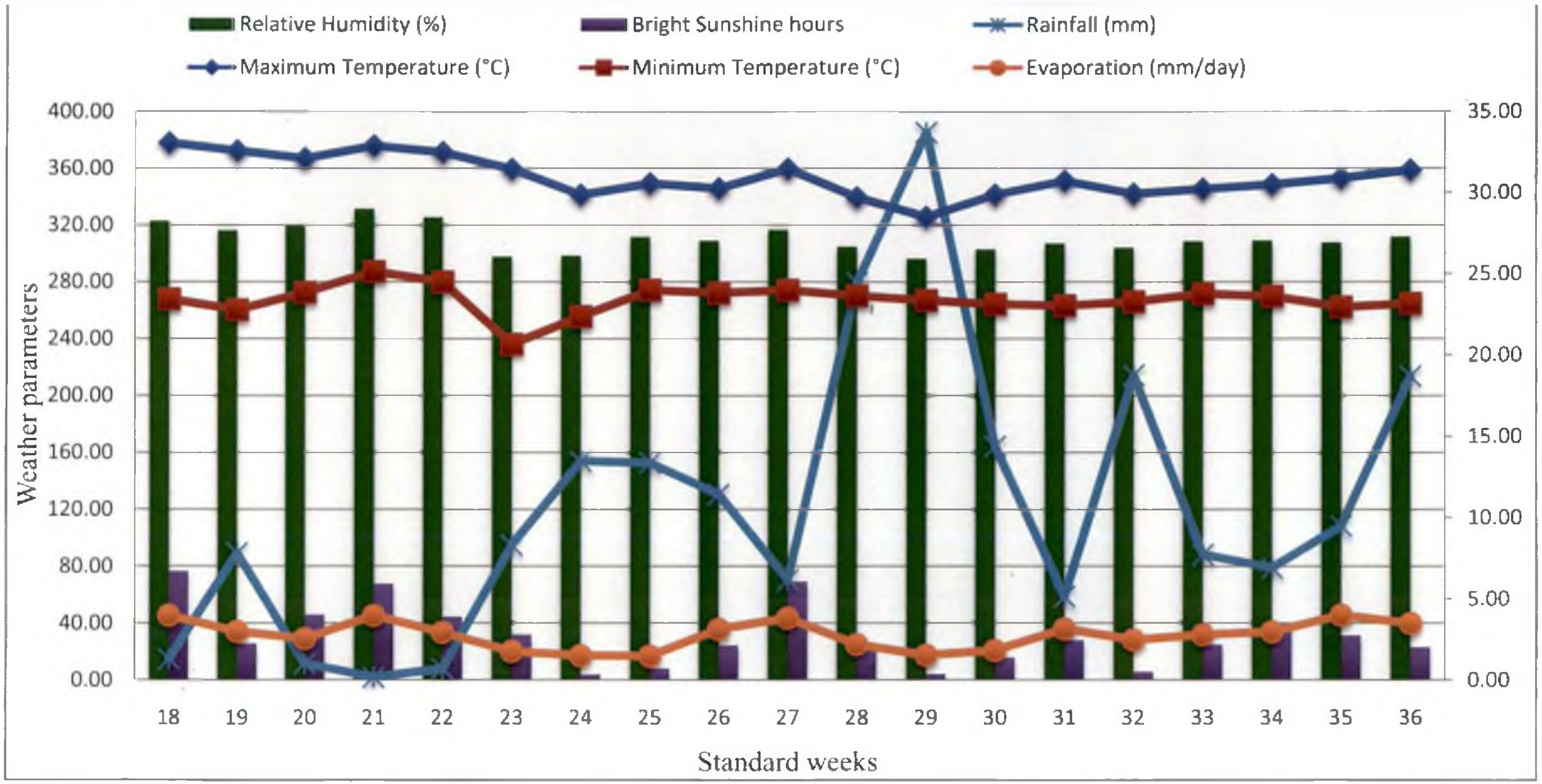

Fig.1. Weather parameters during the cropping period

3.1.4. Season

The field experiment was conducted during the first crop season (*virippu*) of the year 2015. The crop was sown on 4th May, 2015 and harvested on 8th September, 2015.

3.1.5. Crop Variety

The variety used was Aiswarya (PTB 52), which was released from Regional Agricultural Research Station, Pattambi. Aiswarya is a medium duration variety, has duration of 120-125 days. The grains are red, long and bold. It is suitable for *modan*. Aiswarya variety is resistant to blast and blight diseases and also resistant to brown plant hopper. It is suitable to grow in first and second crop season.

3.1.6. Source of Seed Material

Seeds of Aiswarya variety were purchased from RARS, Pattambi.

3.1.7. Manures and Fertilizers

Well decomposed and dried farmyard manure containing 0.5 per cent N, 0.2 percent P_2O_5 and 0.3 percent K_2O was used for the experiment. The fertilizers used for the experiment were urea containing 46 percent N, rockphosphate containing 20 percent P_2O_5 and muriate of potash containing 60 percent K_2O.

3.2. DESIGN AND LAYOUT

Design : RBD

Season : First crop season (*viruppu*), 2015

Treatment : 10

Replication : 3

Plot size

Gross : 5 x 4m

Net : 4.6 x 3.8 m

Spacing : 20 X 15 cm

Two rows of plants were left as border rows to prevent border effect on all the sides on each plot and observations are taken from the plants selected randomly from the net plot area.

3.2.1. Treatments

T_1 : 80:40 kg ha^{-1} NK (100% N as chemical fertilizer)

T_2 : 80:40 kg ha^{-1} NK (75% N as chemical fertilizer, 25% N as FYM)

T_3 : 80:40 kg ha^{-1} NK (50% N as chemical fertilizer, 50% N as FYM)

T_4 : 100:50 kg ha^{-1} NK (100% N as chemical fertilizer)

T_5 : 100:50 kg ha^{-1} NK (75% N as chemical fertilizer, 25% N as FYM)

T_6 : 100:50 kg ha^{-1} NK (50% N as chemical fertilizer, 50% N as FYM)

T_7 : 120:60 kg ha^{-1} NK (100% N as chemical fertilizer)

T_8 : 120:60 kg ha^{-1} NK (75% N as chemical fertilizer, 25% N as FYM)

T_9 : 120:60 kg ha^{-1} NK (50% N as chemical fertilizer, 50% N as FYM)

T_{10} : 60:30 kg ha^{-1} NK (control)

P_2O_5 : Uniform dose of 30 kg ha^{-1} to all treatments

3.3. FIELD CULTURE

3.3.1. Land preparation

The experimental area was uniformly ploughed, levelled and laid out as per the experimental design. Soil samples were taken from the field for analysis

N

R I	R II	R III
T_5	T_{10}	T_2
T_2	T_5	T_{10}
T_9	T_4	T_8
T_3	T_9	T_7
T_4	T_1	T_5
T_1	T_7	T_1
T_8	T_2	T_4
T_6	T_8	T_9
T_{10}	T_3	T_6
T_7	T_6	T_3

Fig.2. Layout plan of the experiment

Plate 1. View of field experiment at Madikkai

before starting the experiment. Before sowing individual plots were levelled uniformly.

3.3.2. Application of Manures

Farmyard manure @ 5 t ha^{-1} was added to all the plots uniformly and additionally calculated amount of farmyard manure was applied as per the treatments and mixed well with the top soil. Nitrogen was applied equally at three split doses first at basal, second at active tillering and third at panicle initiation stage as per the treatments. Full dose of phosphorus were applied at basal at the time of levelling. Potassium was applied in two equal splits, first at basal and remaining at panicle initiation stage as per the treatments.

3.3.3. Seeds and Sowing

Aiswarya seeds were dibbled at 85 kg ha^{-1} at a spacing of 20 X 15 cm.

3.3.4. After Cultivation

Thinning and gap filling were done at fifteen DAS to maintain uniform population. Two hand weeding were carried out one at 15 DAS and another at 30 DAS and post emergence herbicide 2,4 D is applied @ 1 kg ai ha^{-1} of water to control broadleaved weeds.

3.3.5. Irrigation

According to the requirement of crop, the irrigation was scheduled. 8 irrigations were given during early stages of crop due to lack of rainfall.

3.3.6. Plant Protection

Coragen @ 0.2 ml lit^{-1} of water were sprayed to control leaf roller below ETL level during active tillering stage. Malathion @ 1000 ml of EC/AF/ ha of water mixed with Nimbicidine @ 6 ml lit^{-1} of water were sprayed 3 times at a weekly interval from milking stage to grain filling stage for controlling earhead bug damage.

Table 1. Physico-chemical parameters of soil

S.No	Parameter	Content	Rating	Method
A. Mechanical composition				
1.	Sand (%)	76		International pipette method (Robinson, 1922)
2.	Silt (%)	5.5		
3.	Clay (%)	18.5		
4.	Texture	Sandy loam		
B. Physical properties				
1.	Bulk density (g cc^{-1})	1.25		
2.	Porosity (%)	44.68		
3.	Water holding capacity (%)	19.43		
C. Chemical composition				
1.	pH	4.8	Acidic	pH meter (Jackson, 1973)
2.	Organic carbon (%)	0.39		Chromic acid wet digestion method (Walkley and Black, 1934)
3.	Available N (kg ha^{-1})	197	Low	Alkaline Permanganate method (Subbiah and Asija, 1956)
4.	Available P (kg ha^{-1})	4.03	Low	Bray extraction and photoelectric colorimetry (Jackson, 1973)
5.	Available K (kg ha^{-1})	153	Medium	Flame photometry (Stanford and English, 1949)

3.3.7. Plant Sampling

Samples were collected from the net plot area of each plot at 30 DAS, 60 DAS and at harvest. Randomly five sample plants were selected and tagged in net plot area for continuous observations.

3.3.8. Harvest

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

3.4. OBSERVATIONS

3.4.1. Observations on Growth Parameters

3.4.1.1. Height of Plant

From net plot area five plants were randomly selected and mean value of plant height recorded at 30 DAS, 60 DAS and at harvest. From the base of the stem to the tip of the top most leaf were measured as plant height. At harvest, the plant height was measured from the base of the stem to the tip of the longest panicle and expressed in cm.

3.4.1.2. Tiller Number Hill^{-1}

The tiller number hill^{-1} was observed at 30 DAS, 60 DAS and at harvest from the randomly selected five plants of net plot area and the mean values were computed and recorded.

3.4.1.3. Leaf Area Index

The maximum length and breadth of the 3rd leaf from the top of five tagged plants were measured at 60 DAS and the mean value was multiplied with total number of leaves. The LAI was worked out using the formula suggested by Yoshida *et al.* (1976).

$$LAI = \frac{K (L \times W) \times \text{Number of leaves per hill}}{\text{Land area occupied by the plant}}$$

Where, K - Constant factor (0.75)

L - Maximum length of the 3rd leaf blade from the top cm)

W - Maximum width of the leaf blade (cm)

3.4.1.4. Dry Matter Production

Dry mater production was recorded at harvest. The five plants were randomly selected, uprooted, washed, sun dried and oven dried at 80° C to constant weight. Finally DMP is expressed in kg ha^{-1}.

3.4.2. Observations on Yield Attributes and Yield

3.4.2.1. Number of Productive Tillers $Hill^{-1}$

The number of productive tillers was recorded from the randomly selected five plants from net plot at harvest and mean values were calculated accordingly.

3.4.2.2. Length of Panicle

Panicle length was measured from the point of scar to the tip of the panicle obtained from five centre panicles of the tagged hills and mean length of panicle was calculated and expressed in cm.

3.4.2.3. Weight of Panicle

Five centre panicles collected for measuring panicle length were weighed using an electronic balance and the mean weight of the panicle was calculated and expressed in gram.

3.4.2.4. Number of Spikelets Panicle^{-1}

The spikelets from each panicle was removed and counted from the five sample plants in each plot and the mean value was worked out.

3.4.2.5. Number of Filled Grains Panicle^{-1}

From the five sample plants, the number of filled grains per panicle was counted and average value was recorded.

3.4.2.6. Thousand Grain Weight

Thousand grains were separated from clean produce in each plot and record the weight in gram.

3.4.2.7. Grain Yield

The grains were harvested from the each net plot area separately and dried under sun to a constant weight. Grain yield was recorded in kg ha^{-1}.

3.4.2.8. Straw Yield

The harvested straw from each net plot area collected separately and record the constant weight which dried under sun and straw yield was expressed in kg ha^{-1}

3.4.2.9. Harvest Index

The harvest index was calculated using the formula

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

3.4.3. Physiological and Chemical Estimation

3.4.3.1. Protein Content of Grain

The protein content of grain was calculated by multiplying the factor 6.25 with the N content of grain (Simpson *et al.*, 1965).

3.4.3.2. Relative Leaf Water Content (RLWC)

The method was proposed by Weatherly (1950) which was later modified and described in detail by Slatyer and Baars (1965) was used to estimate RLWC. The formula was

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

3.4.3.3. NPK Uptake

Uptake of N, P and K nutrients were estimated by the multiplying nutrient content of the sample and respective dry weight of plant samples and expressed in kg ha^{-1}.

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

3.4.3.4. Leaf Temperature

The Temperature of index leaf (3rd leaf from top) was measured using steady state porometer at flowering stage. It is a non destructive sampling method in which leaf is inserted inside the instrument for recording leaf temperature. It was expressed in °C.

3.4.3.5. Stomatal Conductance

Stomatal Conductance of third leaf from top was measured using steady state porometer at flowering stage by placing the leaf inside the cabin of the instrument. It was expressed in M mol m^{-2} s^{-1}

3.4.3.6. Soil Analysis

Before sowing, soil samples were collected randomly from the experimental field from 0-20 cm depth. Similarly, soil samples after harvest were also collected plot-wise from a depth of 20 cm. Available N, P_2O_5 and K_2O of soil were analyzed before and after the experiment. The available N, P_2O_5 and K_2O were expressed in kg ha^{-1} was expressed in per cent. Methods adopted for analysis of the soil samples are indicated in Table 1.

3.4.4. Observation on Major Weeds of Upland Rice

Observations on important upland weeds were taken.

3.4.5. Major Pest and Disease

Observations on major pest and disease were taken.

3.4.6. Meteorogical Parameters

The data regarding maximum temperature, minimum temperature, relative humidity, rainfall, evaporation and bright sunshine hours during the crop season were recorded in the agromet observatory attached to RARS, Pillicode.

3.4.7. Economic Analysis

3.4.7.1. Benefit Cost Ratio

Cost of cultivation for all the treatments was worked out on the basis of prevailing input cost and market price of grain and straw at the time of experimentation. The net income was calculated by deducting the cost of cultivation from the gross return. The benefit cost ratio (BCR) was worked out as follows.

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

3.5. STATISTICAL ANALYSIS

The data on various characters studied during the course of investigation were subjected to an analysis of variance (F-test) as per the methods suggested by Panse and Sukhatme (1985). Wherever statistical significance was observed, critical difference (CD) at 0.05 level of probability was worked out for comparison. Non significant comparisons were indicated as NS.

RESULTS

4. RESULTS

The data on growth attributes, yield and yield attributes, nutrient uptake, physiological parameters, soil physical and chemical properties, and economics of cultivation are analyzed statistically and results are presented here under.

4.1. GROWTH CHARACTERS

4.1.1. Plant Height

The mean data on plant height recorded at different growth stages viz. 30 DAS, 60 DAS and at harvest are presented in the Table 2.

At 30 DAS, though not significant treatment T_3 (80 kg N applied as CF, 40 kg as FYM and 40 kg as K_2O) produced the tallest plants of 66.33 cm and the shortest plants of 58.13 cm were produced by the treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O).

At 60 DAS, the treatments differed significantly. The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) produced the tallest plants of 98.13 cm and was on par with all the treatments except T_{10}. The treatment T_{10} produced the shortest plants of 80.57 cm.

At harvest, the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the maximum plant height of 148.21 cm, which was on par with T_8 and T_6 and this treatment T_9 was superior to T_4, T_3, T_2, T_5, T_7 and T_{10}. The next best treatment T_4 produced plants of height 138.63 cm and this was found to be on par with T_1, T_3, T_2, T_5, T_7 and superior to T_{10}. The shortest plants of 126.01 cm were produced by T_{10}. The treatment T_9 registered 17.6 per cent increase in plant height over T_{10}.

Table 2. Effect of treatments on plant height at various growth stages

Treatments	Plant height (cm)		
	30 DAS	60 DAS	At harvest
T_1	65.70	94.60	134.67
T_2	64.13	95.27	134.22
T_3	66.33	95.97	134.67
T_4	62.37	93.07	138.63
T_5	60.67	91.00	133.77
T_6	65.87	92.20	140.58
T_7	62.47	93.80	133.28
T_8	61.93	96.33	140.67
T_9	65.20	98.13	148.21
T_{10}	58.13	80.57	126.01
SEm(±)	2.18	2.95	2.84
C.D (0.05)	NS	8.78	8.45

Table 3. Effect of treatments on total number of tillers hill^{-1} at various growth stages

Treatments	Number of tiller hill^{-1}		
	30 DAS	60 DAS	At harvest
T_1	8.37	11.07	11.47
T_2	9.47	11.53	11.13
T_3	9.50	10.83	11.37
T_4	9.93	12.33	12.73
T_5	9.47	12.33	13.20
T_6	9.70	12.00	12.13
T_7	9.90	12.07	13.77
T_8	10.33	12.80	12.53
T_9	9.87	13.27	13.20
T_{10}	7.83	8.20	8.80
SEm(±)	0.57	0.74	0.88
C.D (0.05)	NS	2.19	2.60

4.1.2. Number of Tillers Hill^{-1}

The data on tiller number hill^{-1} at 30 DAS, 60 DAS and at harvest are presented in Table 3.

At 30 DAS, the treatments did not differ significantly. However, treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) registered the maximum tiller number of 10.33 and T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) recorded the lowest value of 7.83, the percentage increase being 31.9.

At 60 DAS, there was significant difference among treatment and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the maximum tiller number of 13.27 with which T_8, T_4, T_5, T_7, T_6 and T_2 were on par. The next best treatment was T_1 and was on par with T_3. The lowest tiller count of 8.20 was registered by the treatment T_{10}. The treatment T_9 registered 61.8 per cent increase in tiller number over T_{10}.

At harvest, the treatments differed significantly and T_7 (120 kg N applied as 100% CF and 60 kg K_2O) produced maximum tiller number of 13.77 and was on par with T_9 , T_5, T_4, T_8, T_6, T_1 and T_3. The treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) produced minimum tillers hill^{-1}of 8.80. Tiller number of T_7 plants was 56.5 per cent more than that of T_{10}.

4.1.3. Leaf Area Index

The data on LAI at 60 DAS are presented in Table 4.

The treatments differed significantly, the maximum LAI of 4.98 was recorded by the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) and was on par with T_8 and T_7. The lowest LAI of 4.02 was recorded by the treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O).

4.1.4. Dry Matter Production (DMP)

The data on dry matter production at harvest are presented in Table 4.

At harvest, there was significant variation among treatments. The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) produced the maximum DMP of 6382 kg ha^{-1}. The treatment T_9 was on par with T_8 and T_7 which gave a DMP of 6242 and 6006 kg ha^{-1}. This was followed by T_6 which registered a DMP of 5867 kg ha^{-1}. The lowest DMP of 4239 kg ha^{-1} was recorded by T_{10}. The treatment T_9 registered a per cent increase of 50.5 over T_{10}.

4.2. YIELD ATTRIBUTES AND YIELD

4.2.1. Number of Productive Tillers Hill^{-1}

The data on number of productive tillers hill^{-1} are presented in Table 5.

The treatments showed significant difference and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) and T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O) registered the maximum number of productive tillers of 12.87 and was on par with other treatment, except T_{10} (60 kg N applied as 100% CF and 30 kg K_2O). The treatment T_{10} recorded the minimum number of productive tillers of 7.67. The percentage increase of productive tillers in T_9 over T_{10} was 67.8.

4.2.2. Length of Panicle

The data on length of panicle are presented in Table 5.

The treatment exhibited significant variation and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) produced the longest panicle of 24.96 cm and was on par with T_6, T_5, T_4, T_8 and T_3. The shortest panicle of 21.20 cm was produced by T_{10} (60 kg N applied as 100% CF and 30 kg K_2O). The treatment T_9 registered 17.7 per cent increase over T_{10}.

Table 4. Effect of treatments on LAI and DMP

Treatments	LAI (60DAS)	DMP (at harvest) ($kg\ ha^{-1}$)
T_1	4.20	4513
T_2	4.22	4994
T_3	4.35	4261
T_4	4.25	5040
T_5	4.39	5410
T_6	4.30	5867
T_7	4.63	6006
T_8	4.77	6242
T_9	4.98	6382
T_{10}	4.02	4239
SEm(±)	0.12	140.36
C.D (0.05)	0.35	384.89

4.2.3. Weight of Panicle

The data on weight of panicle are presented in Table 5.

The weight of panicle was favourably influenced by the treatments and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered maximum panicle weight of 3.11 g which was on par with T_5, T_7 and T_6. The lowest panicle weight of 1.87 g was recorded by T_{10} (60 kg N applied as 100% CF and 30 kg K_2O). The treatment T_9 registered 66.3 per cent increase over T_{10}.

4.2.4. Number of Spikelets Panicle^{-1}

The data on number of spikelets panicle^{-1} are given in Table 6.

The treatments differed significantly and treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) give the highest number of spikelets (166.87) and was on par with treatments T_5, T_4, T_6 and T_3. The lowest spikelet number of 110.20 was recorded by the treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) and was 51.4 per cent lesser than T_9.

4.2.5. Number of Filled Grains panicle^{-1}

The data on number of filled grains panicle^{-1} are given in Table 6.

There was significant difference between the treatments and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered maximum number of filled grains panicle of 147.33, which was on par with T_5, T_6, T_4, T_3 and T_1. The lowest number of filled grains panicle of 97.27 was recorded by T_{10} (60 kg N applied as 100% CF and 30 kg K_2O).

Table 5. Effect of treatments on number of productive tillers hill^{-1}, panicle length and panicle weight

Treatments	Number of productive tillers hill^{-1}	Panicle length (cm)	Panicle weight (g)
T_1	10.60	23.46	2.41
T_2	10.87	22.82	2.29
T_3	10.60	23.70	2.35
T_4	12.00	24.18	2.30
T_5	12.87	24.41	2.68
T_6	10.67	24.51	2.55
T_7	12.80	22.80	2.56
T_8	11.60	23.93	2.49
T_9	12.87	24.96	3.11
T_{10}	7.67	21.20	1.87
SEm(±)	0.81	0.43	0.20
C.D (0.05)	2.41	1.29	0.59

Table 6. Effect of treatments on number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and 1000 grain weight

Treatments	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	1000 grain weight (g)
T_1	139.87	126.80	25.51
T_2	123.47	106.33	25.53
T_3	141.73	127.87	26.34
T_4	151.60	133.60	25.00
T_5	156.47	140.20	26.07
T_6	151.33	136.03	26.95
T_7	130.73	114.67	26.65
T_8	136.27	116.47	27.61
T_9	166.87	147.33	28.28
T_{10}	110.20	97.27	25.15
SEm(±)	8.58	8.08	1.44
C.D (0.05)	25.52	24.05	NS

4.2.6. 1000 Grain Weight

The data on 1000 grain weight are presented in Table 6.

Though not treatment differed significantly, the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the maximum weight of 28.28 g was closely followed by the treatment T_8, T_6, T_7 and T_3. The treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) recorded the lowest value of 25.15 g which was 12.4 per cent lesser than T_9.

4.2.7. Grain Yield

The grain yield as influenced by various treatments is presented in Table 7.

The grain yield was significantly influenced by the treatments. The maximum grain yield of 2822 kg ha^{-1} was recorded by the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) and was on par with the grain yield of 2785 kg ha^{-1} produced by the treatment T_8. The treatment T_9 was found to be significantly superior to rest of the treatments. The treatment T_7 produced the next highest grain yield of 2600 kg ha^{-1} and was on par with the grain yield of 2485 kg ha^{-1} produced by the treatment T_6 and superior to other treatments. The grain yield of 2281 kg ha^{-1} produced by treatment T_5 was par on with the grain yield of 2120 kg ha^{-1} recorded by T_4. The lowest grain yield of 1668 kg ha^{-1} was recorded by T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) and significantly inferior to rest of the treatments. The treatment T_9 recorded 69.2 per cent increase in grain yield over T_{10}

4.2.8. Straw Yield

The data on straw yield are presented in Table 7.

There was significant difference among the treatments and the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) produced the maximum straw yield of 3560 kg ha^{-1} which was par with T_8, T_7 and T_6 recording 3457 kg ha^{-1}, 3406 kg ha^{-1} and 3383 kg ha^{-1} and superior to rest of the treatments. T_5 produced the next highest straw yield of 3129 kg ha^{-1} and was on par with T_2 which produced a straw yield of 2949 kg ha^{-1} and superior to rest of the treatments. The lowest straw yield of 2482kg ha^{-1} was recorded by the treatment T_3 (80 kg N applied as 40 kg as CF, 40 kg as FYM and 40 kg K_2O) and was on par with T_{10} and inferior to other treatment. The treatment T_9 recorded 43.4 per cent increase in straw yield over T_3.

4.2.9. Harvest Index

The data on harvest index are presented in Table 7.

There was significant difference among treatments. The treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) registered the maximum harvest index of 0.45 and was found to be on par with T_9, T_7, T_6, T_5, T_4 and T_3 and superior to rest of the treatments. The treatment T_2 registered a harvest index of 0.41 and was on par with T_1 and T_{10}. The lowest HI of 0.39 was recorded by the treatment T_{10}. The harvest index of T_8 was 15.4 per cent more than T_{10}.

4.3. PHYSIOLOGICAL AND CHEMICAL ESTIMATIONS

4.3.1. Relative Leaf Water Content (RLWC)

RLWC content at panicle initiation and flowering stage as influenced by treatments are presented in Table 8.

The treatments showed no significant variation at panicle initiation stage. However treatment T_6 (100 kg N applied as 50 kg as CF, 50 kg as FYM and 50 kg K_2O) registered the maximum value of 80.63 per cent at PI stage. The lowest value of 72.62 per cent was recorded by T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O).

Table 7. Effect of treatments on grain yield, straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1	1797	2716	0.40
T_2	2044	2949	0.41
T_3	1780	2482	0.42
T_4	2120	2919	0.42
T_5	2281	3129	0.42
T_6	2485	3383	0.42
T_7	2600	3406	0.43
T_8	2785	3457	0.45
T_9	2822	3560	0.44
T_{10}	1668	2571	0.39
SEm(±)	96.29	68.83	0.01
C.D (0.05)	202.30	204.52	0.03

2.a. At seedling stage

2.b. At maximum tillering stage

2.c. At grain filling stage

2.d. At harvest stage

Plate 2. Experimental field at different growth stages

3.a. T_9 - 120:60 kg ha^{-1} NK (50% N as CF, 50% N as FYM)

3.b. T_8 - 120:60 kg ha^{-1} NK (75% N as CF, 25% N as FYM)

3.c. T_6 - 100:50 kg ha^{-1} NK (50% N as CF, 50% N as FYM

3.d. T_{10} - 60:30 kg ha^{-1} NK (control)

Plate 3. Treatmental variation at grain filling stage

At flowering stage also there was no significant difference between the treatments and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the highest value of 82.29 and the lowest value of 73.17 per cent was recorded by T_7 (120 kg N applied as 100% CF and 60 kg K_2O).

4.3.2. Protein Content of Grain

The data on protein content of grain are presented in Table 8.

Analysis of the data showed that treatments differ significantly and the treatment T_4 (100 kg N applied as 100% CF and 50 kg K_2O) registered the maximum value of 5.96 per cent which was on par with T_8 recording a value of 5.94 per cent and was significantly superior to rest of the treatments. The treatment T_5 registered the next highest protein value of 5.60 per cent and was on par with T_9 recording a value of 5.31 per cent and superior to rest of the treatment. The lowest value of 3.20 per cent was recorded by T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) and was significantly inferior to all treatments.

4.3.3. Leaf Temperature

The data on leaf temperature at 60 DAS are presented in Table 8.

The data did not reveal significant difference between treatments. However the treatment T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O) and T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) registered the lowest leaf temperatures of 28 °C. The maximum leaf temperature of 30.23 °C was recorded by the treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) closely followed by T_1, T_9 and T_7.

4.3.4. Stomatal Conductance

The data on stomatal conductance are presented in Table 8.

Table 8. Effect of treatments on physiological parameters

Treatments	Protein content of grain (per cent)	Relative leaf water content (%)		Leaf temperature (°C)	Stomatal conductance (M mol m^{-2} s^{-1})
		PI stage	Flowering stage		
T_1	5.09	77.41	75.08	29.93	222.10
T_2	3.85	76.57	78.91	28.90	219.43
T_3	4.46	77.66	80.05	29.13	245.07
T_4	5.96	73.79	75.73	29.00	247.30
T_5	5.60	72.62	81.52	28.00	269.37
T_6	3.67	80.63	80.65	28.53	245.90
T_7	4.06	78.43	73.17	29.20	224.87
T_8	5.94	75.27	81.38	30.23	234.77
T_9	5.31	74.98	82.29	29.20	266.17
T_{10}	3.20	73.87	75.45	28.00	226.93
SEm(±)	0.15	5.89	3.66	1.03	25.58
C.D (0.05)	0.31	NS	NS	NS	NS

Though not significant T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O) registered the highest value of 269.37 M mol m^{-2} s^{-1} closely followed by T_9 recording 266.17 M mol m^{-2} s^{-1}. The lowest value of 219.43 M mol m^{-2} s^{-1} recorded by the treatment T_2.

4.3.5. Uptake of Nitrogen

The data on uptake of nitrogen at harvest as influenced by various treatments are presented in Table 9.

The treatments had a profound influence on N uptake by grain and straw. The results revealed that T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) registered the highest values of 26.44, 22.48 and 48.92 kg ha^{-1} respectively for uptake of nitrogen by grain, straw and total and was significantly superior to rest of the treatments. The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the next highest value for uptake of nitrogen by grain and straw (23.98 and 19.56 kg ha^{-1}) and was superior to rest of the treatments. The lowest N uptake by grain and straw was recorded by T_{10} (60 kg N applied as 100% CF and 30 kg K_2O).

4.3.6. Uptake of Phosphorus

The data on phosphorus uptake are presented in Table 9.

The treatment showed significant difference between the treatments. The results revealed that the treatment T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O) registered the highest values of 7.33, 7.02 and 14.35 kg ha^{-1} respectively for uptake of phosphorus by grain, straw and total. The treatment T_5 was significantly superior to rest of the treatments. The treatment T_8 recorded the next highest value of 5.68 kg ha^{-1} for uptake of P by grain whereas treatment T_6 registered the next highest value of 4.67 kg ha^{-1} for uptake of P by straw. The total uptake of P at harvest was maximum (14.35 kg ha^{-1}) for the treatment T_5 and was superior to rest of the treatments. The treatment T_{10} (60 kg N applied as

100% CF and 30 kg K_2O) registered the lowest value for grain uptake and total uptake while treatment T_3 (80 kg N applied as 40 kg as CF, 40 kg as FYM and 40 kg K_2O) recorded the lowest value for P uptake by straw.

4.3.7. Uptake of Potassium

The data on potassium uptake are presented in Table 9.

The treatments differed significantly and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the maximum K uptake of 7.80, 44.96 and 52.76 kg ha^{-1} respectively for grain, straw and total. The treatment T_8 registered the next highest value for grain uptake of K (6.78 kg ha^{-1}) and was on par with T_7 and superior to rest of the treatments with respect to straw uptake of K. The next highest value of 40.33 kg ha^{-1} was recorded by T_8 which was on par with T_6, T_2, T_7, T_4, T_5 and T_1. The lowest value for K uptake by straw and total was recorded by the treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O), while for grain uptake, it was T_1.

4.4. SOIL PROPERTIES

4.4.1. Physical Properties

4.4.1.1. Bulk Density

The data on bulk density of soil after harvest are presented in Table 10.

Analysis of the data showed that treatments different significantly and the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the lowest Db value of 1.07 g cc^{-1} which was on par with the treatment T_8, T_6, T_2 and T_7. The maximum Db value of 1.20 g cc^{-1} was registered by the treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) and this was on par with T_5, T_1, T_3, T_4, T_7, T_2 and T_6.

Table 9. Effect of treatments on the uptake of N, P and K at harvest, kg ha^{-1}

Treatments	Uptake of N			Uptake of P			Uptake of K		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	14.64	13.96	28.60	3.28	3.21	6.49	3.93	34.53	38.46
T_2	12.60	9.33	21.93	2.87	2.49	5.35	4.59	38.65	43.25
T_3	12.68	10.25	22.93	3.45	2.30	5.75	4.39	26.99	31.38
T_4	20.21	19.09	39.30	3.34	2.39	5.73	4.31	35.57	39.88
T_5	20.43	18.65	39.07	7.33	7.02	14.35	5.38	35.25	40.64
T_6	14.54	9.68	24.21	5.30	4.67	9.97	5.69	40.02	45.71
T_7	16.90	11.93	28.84	4.87	4.07	8.94	6.14	38.30	44.45
T_8	26.44	22.48	48.92	5.68	4.30	9.98	6.78	40.33	47.10
T_9	23.98	19.56	43.54	4.17	2.86	7.03	7.80	44.96	52.76
T_{10}	8.53	5.43	13.96	2.80	2.37	5.16	4.12	22.13	26.25
SEm(±)	0.75	0.90	1.41	0.82	0.47	0.69	0.41	3.59	3.58
C.D (0.05)	1.57	1.88	2.95	1.73	0.99	1.45	0.85	7.55	7.52

4.4.1.2. Porosity

The data on porosity of soil after harvest are presented in Table 10.

The treatments differed significantly and T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the maximum porosity of 50.76 per cent and was on par with T_8, T_6, T_2 and T_7 and significantly superior to other treatments. The treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) recorded the lowest porosity of 44.95 per cent.

4.4.1.3. Water Holding Capacity (WHC)

The data on water holding capacity of soil after harvest as influenced by treatments are presented in Table 10.

The treatment showed significant difference between the treatments. The results revealed that the treatment T_6 (100 kg N applied as 50 kg as CF, 50 kg as FYM and 50 kg K_2O) registered the highest WHC value of 22.66 per cent and was on par with T_8 and T_9. The lowest WHC value of 17.44 per cent was recorded by the treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O).

4.4.2. Chemical Properties

4.4.2.1. Available Nitrogen

The data on available nitrogen content of soil after the experiment are presented in Table 11 and there is significant difference between the treatments.

The treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) recorded the maximum available N content of 265.63 kg ha^{-1} and was on par with T_9 and T_6. The treatment T_7 recorded the next highest value of 248.73 kg

Table 10. Effect of treatments on soil physical properties after the experiment.

Treatments	Bulk Density (g cc^{-1})	Porosity (%)	Water Holding Capacity (%)
T_1	1.18	45.73	20.11
T_2	1.14	47.94	20.23
T_3	1.15	47.48	20.67
T_4	1.15	47.32	19.92
T_5	1.18	45.70	20.67
T_6	1.13	48.20	22.66
T_7	1.14	47.86	20.79
T_8	1.11	49.25	22.30
T_9	1.07	50.76	22.14
T_{10}	1.20	44.95	17.44
SEm(±)	0.03	1.07	1.09
CD (0.05)	0.07	3.19	1.86

ha^{-1} and was on par with T_5, T_4 and T_2. The lowest value of 207.17 kg ha^{-1} was recorded by the treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O).

4.4.2.2. Available Phosphorus

The data on available phosphorus content of soil after the experiment are presented in Table 11.

Analysis of the data showed that treatments different significantly and the treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) recorded the maximum value of 15.29 kg ha^{-1} and was on par with T_6 and T_9. The treatment T_3 recorded the next highest value of 12.16 kg ha^{-1} and was on par with T_1 and T_7. The treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) recorded the lowest value of 6.59 kg ha^{-1}.

4.4.2.3. Available Potassium

The data on available potassium content of soil after the experiment are presented in the Table 11.

The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the maximum value of 277.17 kg ha^{-1} and was on par with T_8 and T_5. The treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) recorded the lowest value of 185.63 kg ha^{-1} and was on par with T_2 and T_1.

4.4.2.4. Soil Organic Carbon

The data on organic carbon of soil after the experiment are furnished in Table 11 and indicates that there was significant difference between treatments.

The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the highest value of 0.69 per cent and was on par with T_8. The treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) recorded the lowest value of 0.40 per cent and was on par with T_1.

Table 11. Effect of treatments on chemical properties of soil after the experiment

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic carbon (%)
T_1	220.70	10.27	203.13	0.41
T_2	241.53	8.84	199.67	0.45
T_3	228.80	12.16	211.87	0.56
T_4	244.83	8.55	204.50	0.53
T_5	246.67	9.52	261.00	0.61
T_6	254.07	14.95	226.07	0.64
T_7	248.73	9.87	240.13	0.59
T_8	265.63	15.29	267.77	0.66
T_9	261.73	13.05	277.17	0.69
T_{10}	207.17	6.59	185.63	0.40
SEm(±)	5.69	0.84	6.30	0.02
CD (0.05)	16.89	2.51	18.71	0.03

4.5. OBSERVATIONS ON MAJOR WEEDS

The major weeds observed in the field were *Stachytarpheta indica, Phyllanthus maderaspetansis, Mimosa pudica, Portulaca oleracea, Hemidesmus indicus, Cyperus rotundus, Cynodon dactylon, and Digitaria sanguinalis.*

4.6. PEST AND DISEASE INCIDENCE

The major pests observed in the field were leaf roller and earhead bug. The important diseases noticed were blast, bacterial leaf blight and leaf spot. The incidence of pest and diseases never reached the threshold level and hence uniform score was given to all plots.

4.7. ECONOMIC ANALYSIS

The data on economics of cultivation are given in Table 12. The treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) registered the maximum net returns of Rs. 19149 ha^{-1} and was on par with T_9 and T_7. The treatment T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) registered the lowest value of Rs. 160 and was on par with T_3 and T_1.

With regard to benefit-cost ratio, the treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) recorded the maximum value of 1.62 and was on par with T_9, T_7, T_6, T_5, T_4 and T_2. The lowest BCR of 1.00 was recorded by the treatment T_{10}.

4.8. WEATHER PARAMETERS

The data on weather parameters are furnished in Appendix 1. The standard weeks 18^{th} (Apr 30-May 6) and 21^{st} (May 21-27) experienced the highest maximum (33.07°C) and minimum temperature (25.14°C) respectively and whereas the lowest maximum (28.5°C) and minimum temperature (20.67°C) were recorded by the standard weeks 29^{th} (July 15-21) and 23^{rd} (June 4-10) respectively. The daily average relative humidity was maximum (93.71%) during

Table 12. Effect of treatments on economics of cultivation

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	BCR
T_1	41945	43211	1266	1.03
T_2	43105	48597	5492	1.28
T_3	41650	41960	310	1.01
T_4	42345	49843	7498	1.34
T_5	43795	53572	9777	1.39
T_6	45245	58252	13007	1.46
T_7	43065	60424	17359	1.59
T_8	44805	63954	19149	1.62
T_9	46545	65036	18491	1.59
T_{10}	40145	40305	160	1.00
SEm(±)			1795	0.17
CD (0.05)			3772	0.36

Cost of inputs

Nitrogen - Rs. 12 kg^{-1}

Phosphorus - Rs. 34 kg^{-1}

Potassium - Rs. 16 kg^{-1}

FYM - Rs. 800 t^{-1}

Cost of seed - Rs. 39 kg^{-1}

Price of produce

Grain - Rs. 18 kg^{-1}

Straw - Rs. 4 kg^{-1}

the standard week 29th (July 15-21) and minimum (76%) during 18th (Apr 30-May 6) respectively. The maximum rainfall of 385.40 mm was registered during the standard week 29th (July 15-21). The lowest rainfall of 1.90 mm was recorded in the standard week 21st (May 21-27). The standard week 35th (Aug 26-Sep 1) recorded the maximum evaporation of 4.00 mm and the standard week 25th (June 18-24) recorded the minimum evaporation of 1.49 mm. The duration of sunshine hours was maximum during the standard week 18th (Apr 30-May 6) and lowest sunshine hours was recorded in the standard week 24th (June 11-17).

DISCUSSION

5. DISCUSSION

The results of the experiment to study the influence of upland rice to NK levels and FYM substitution are discussed here under. The data on growth attributes, yield and yield attributes, nutrient uptake, physiological parameters, soil physical and chemical properties, and economics of cultivation are discussed in this chapter.

5.1. GROWTH CHARACTERS

Levels of nitrogen, potassium, FYM and their combined effects significantly influenced the growth attributes of upland rice.

Statistical analysis of the data as evident from Tables 2, 3 and 4 revealed that plant height at 30 DAS, 60 DAS and at harvest, tiller number at 30 DAS, 60 DAS and at harvest, LAI at 60 DAS and DMP at harvest were favourably influenced by the treatments.

The result presented in Table 2 revealed a profound significant influence of NK levels and FYM on plant height at all stages of growth viz. 30 DAS, 60 DAS and at harvest. At 30 DAS, the maximum plant height was recorded by the treatment T_3 (80 kg N applied as 40 kg CF, 40 kg as FYM and 40 kg K_2O). At later stages of growth (60 DAS and at harvest), the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the maximum value for plant height. Nitrogen is a major nutrient essential for plant growth as it is a constituent of physiologically active compounds like proteins, enzymes, nucleic acids and other body building compounds. Nitrogen influences plant height through its effect on rapid meristamatic activity. Favourable effect of nitrogen on plant height have also been reported by various workers like Reddy and Reddy (1989), Babu (1996), Anu (2001), Ranjini (2002) and Mini (2005). Similar effects were found due to application of K on plant height at 30 DAS, 60 DAS and at harvest. Application of K at 40 kg K_2O ha^{-1} at 30 DAS and 60 kg K_2O ha^{-1} at 60 DAS and harvest significantly influenced plant height. K favours growth of meristamatic tissues, induces drought tolerance and thereby the plant height is improved (Tisdale *et al.*, 1995). Similiar findings on the favourable effect of K were reported by Babu (1996), Anu (2001), Ranjini (2002), and Mini (2005). The effect of FYM in influencing growth parameters is well known. FYM favourably influences soil physical and chemical properties, improves the microflora in the rhizosphere of the soil and thereby improves plant growth. This is in conformity with the findings of Ramasamy (1990), Sharma (1992) and Ranjini (2002). The positive influence of N, P, K and FYM on plant height may be due to the synergistic effect on cell division and cell elongation (Vaijayanthi, 1986). The favourable positive effect of combined application of N, P, K and FYM on plant height was also reported by Ranjini (2002), Bharathy (2005), Maiti *et al.* (2006) and Setty (2007).

Tiller production at later stages of growth (60 DAS and harvest) was significantly influenced by treatments. At 60 DAS, the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) produced maximum tiller number, while at harvest the treatment T_7 (120 kg N applied as 100% CF and 60 kg K_2O) produced the maximum tiller number. Tillering was favourably influenced by incremental increase in nitrogen level. Anu (2001) observed positive influence of nitrogen on tillering and stated that tiller number increased with incremental dose of nitrogen upto 80 kg ha^{-1}. Mini (2005) reported that application of nitrogen at 100 kg ha^{-1} produced the maximum number of tillers $hill^{-1}$. Application of higher levels of K tends to increase tillering in rice. Similiar findings were reported by Anu (2001), Ranjini (2002) and Mini (2005). Potassium, an element favouring protein syntheisis might have exerted positive influence on tiller production. Potassium tends to induce drought tolerance and this also favourably influenced tiller production. FYM is important organic manure used in rice cultivation. It improves physico-chemical properties of the soil, microbial flora, soil water holding capacity and improves soil residual nitrogen. Favourable effects of FYM on tillering were reported by Ranjini (2002) and Rao *et al.* (2004). The favourable effect of combined application of N, P, K and FYM on tiller production was reported by Ranjini (2002), Setty (2007) and Kumar (2014).

LAI at 60 DAS was favourably influenced by N and K application. The favourable influence of nitrogen on tiller number and leaf area resulted in higher LAI. Increase in plant height and tiller number resulted in more number of leaves which might have contributed to higher LAI. The extent of leaf area available for photosynthesis is nearly proportional to the amount of nitrogen applied. This is in conformity with the findings of Anu (2001), Ranjini (2002) and Mini (2005) who obtained higher LAI due to nitrogen application in upland rice. Higher LAI due to K application in upland rice was reported by Anu (2001), Ranjini (2002) and Mini (2005). Ranjini (2002) obtained higher LAI of 3.99 due to application of 90 kg N $ha^{-1}$and 45 kg K_2O ha^{-1}. FYM exerted a positive influence on LAI. Increased in LAI due to FYM application may be due to the improvement in physico-chemical and biological properties of soil, besides supplying N, P, K, micronutrients and improving the fertilizer use efficiency (Motsara, 2000). Combined application of chemical fertilizers and FYM favourably influenced the growth characters such as plant height, tiller number and leaf number which in turn resulted in higher LAI. This is supported by the findings of Anu (2001) and Ranjini (2002). Since organic manures were applied as basal, there was enough time for completion of mineralisation and release of nutrients, thereby the nutrient loss is minimised and fertilizer use efficiency is enhanced. The enhanced production of leaves and increased leaf duration of plants supplied with chemical fertilizers and FYM might have increased the LAI.

The data (Fig 3.) revealed that DMP at harvest was significantly influenced by the treatments. The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the maximum DMP. Increasing nitrogen levels enhanced the photosynthetic efficiency of the crop leading to greater DMP. Higher levels of nitrogen caused significant increase in DMP. This might be due to higher availability of nitrogen to plants leading to its higher uptake and translocation to the different parts of the plant. The overall growth attributes like plant height, tiller number and number of leaves was increased with higher levels of nitrogen upto 120 kg ha^{-1}. Higher leaf area for photosynthesis coupled with more tiller number resulted in increased growth and higher DMP. This could be attributed to the higher nitrogen application which might have increased the chlorophyll formation and improved photosynthesis and thereby increased the plant height, number of leaves and number of tillers per unit area leading to the production of high dry matter. This is in accordance with the findings of Dubey *et al.* (1983), Ranjini (2002), Mini (2005) and Rao *et al.* (2014). DMP increased with higher levels of potassium. Increase in K level enhanced the ability of the plant to grow well and thus accumulate more dry matter. Higher DMP at higher K levels have been reported by Anu (2001), Ranjini (2002) and Mini (2005). Potassium is involved in the activation of enzymes which control various metabolic reactions, uptake and translocation of photosynthates and thereby resulted in dry matter accumulation in plant parts. FYM resulted in high DMP at harvest. DMP was maximum when 50 per cent of 120 kg N ha^{-1} was applied as FYM. Combined application of FYM and chemical fertilizers might have favourably influence the growth attributes such as plant height, leaf number and tiller number which in turn increased the DMP. FYM by virtue of improving the physical, chemical and biological properties of the soil and supplying N, P, K and micronutrients has contributed to increase DMP at harvest.

5.2. YIELD ATTRIBUTES AND YIELD

Results of the study revealed that yield attributes viz., number of productive tiller m^{-2}, length of panicle, weight of panicle, number of spikelets $panicle^{-1}$ and number of filled grains $panicle^{-1}$ were significantly influenced by the treatments. All the characters were improved by the application of treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) as evident from

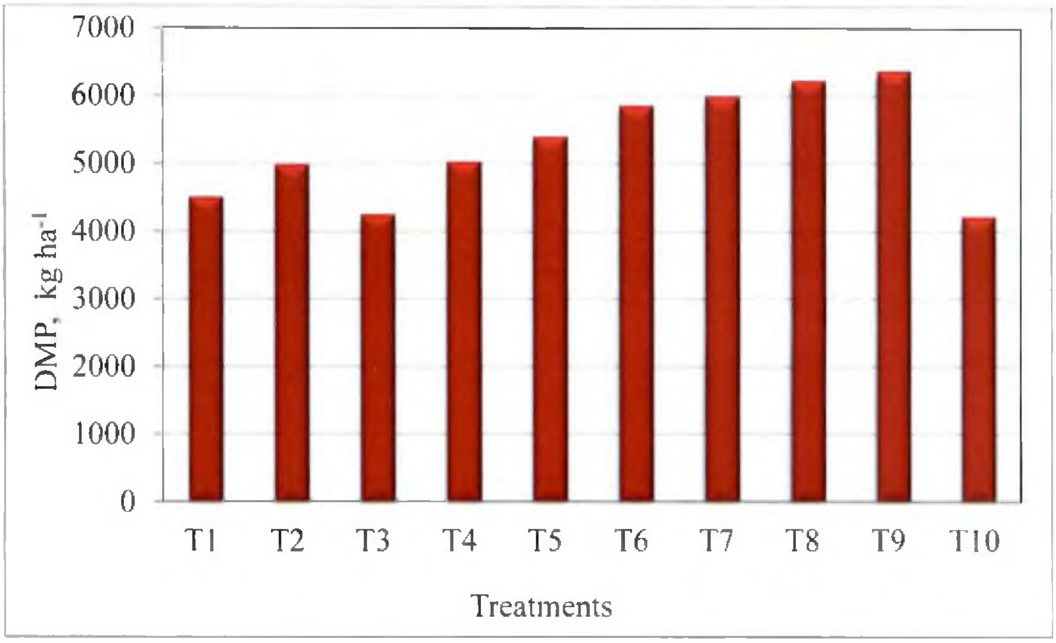

Fig.3. Effect of treatments on dry matter production (DMP) at harvest

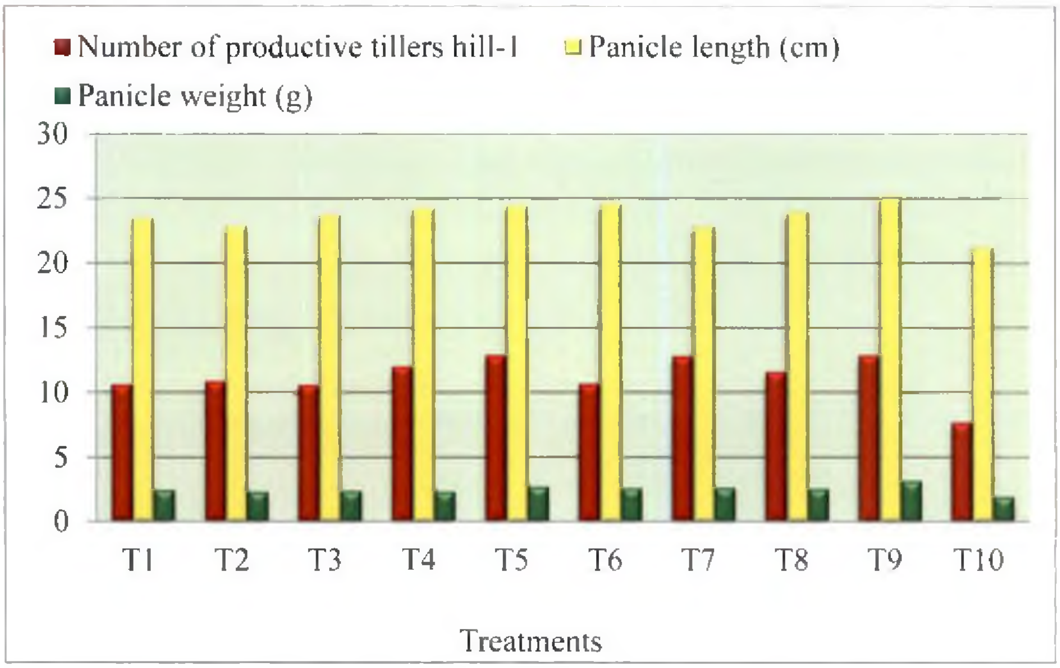

Fig.4. Effect of treatments on number of productive tillers hill^{-1}, panicle length and panicle weight

the Fig 4 and 5. At higher levels of nitrogen application, DMP and N uptake were more which resulted in the higher values for yield attributes. Nitrogen being a constituent of enzymes and proteins, higher levels of N enhanced cell expansion and metabolic processes resulting in higher values for yield attributes. Effective translocation of assimilates from source to sink might have resulted in good grain filling as revealed by the higher number of filled grains panicle^{-1} at higher N levels. This was in agreement with the findings of Anu (2001) and Mini (2005). At higher levels of N and K, length and weight of panicles, productive tillers, number of spikelets and filled grains were more. This might be due to increased availability and uptake of nutrients and increased tiller production in treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O). Potassium induced drought tolerance and stimulated the build up and translocation of carbohydrates from source to sink and resulted in higher values of yield attributes. Higher levels of N and K increased the weight of panicles due to better translocation of assimilates to the sink resulting in higher test weight of grains. Similiar reports were made by Anu (2001) and Ranjini (2002).

The results revealed that N and K significantly influenced the grain and straw yields (Fig 6.). Application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 50 per cent as chemical fertilizer with 30 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}(T_9) produced the maximum grain and straw yields of 2822 and 3560 kg ha^{-1}. Growth, yield attributes and yield of rice were favourably influenced by application of potassium conjunction with nitrogen (Shrivastava and Tripathi, 1999). Significant increase in grain yield could be attributed to the fact that N application improved the N, P and K uptake by rice and ultimately accelerated the photosynthetic activities resulting in better growth and yield attributes which laid down the foundation for accumulating higher plant dry matter. As yield is a manifestation of the individual yield components, the nitrogen dose which resulted in highest grain yield (120 kg N ha^{-1}) was due to the increased in yield attributes coupled with higher nitrogen uptake and efficient translocation to sink. Similar findings were reported by Roy and Mishra (1999) and Rao *et al.* (2014).

Favourable effect of N on grain and straw yields were reported by Anu (2001), Ranjini (2002) and Mini (2005). Potassium is involved in the production and translocation of starch from source to sink. Higher levels of K increased the grain and straw yields primarily due to its favourable effect on productive tiller number, nutrient uptake filled grains panicle^{-1} and 1000 grain weight. Similar findings were reported by Sheela (1993), Anu (2001) and Mini (2005). Combined application of N and K was found to increase the grain and straw yield mainly due to their favourable effect on yield attributes.

FYM application significantly influenced the yield and yield attributes of upland rice (Table 5, 6 and 7). Slow release of macro and micronutrients are added to soil through decomposition of farmyard manure, which could contribute to the superior yield of rice. FYM addition enhanced the soil properties (physical, chemical and biological) which provides the optimum condition for root growth, increased nutrient uptake, growth and yield of rice. (Naphade *et al.* 1993). Due to decomposition and subsequent mineralization of FYM plant nutrients became readily available to crop. FYM increased the yield attributes such as productive tillers, length and weight of panicle, number of filled grains and 1000 grain weight. Improvement in yield attributes due to FYM application which release nutrients slowly to the crop during the entire growth period. Favourable effects of FYM on yield attributes were reported by Babu (1996) and Ranjini (2002).

FYM application favourably influenced the grain and straw yields. Higher grain yield might be due to combined effect of nutrient supply, synergism and improvement in physical, chemical and biological properties of soil. The accumulation of autotoxins excreted by rice roots to the soil is alleviated by FYM addition through its nutrient supplying power and favourable effect on physico-chemical and biological properties of soil. The overall improvement in yield and yield attributes might be due to the synergistic effect of FYM and NK application. The higher efficiency of chemical fertilizers together with steady supply of plant

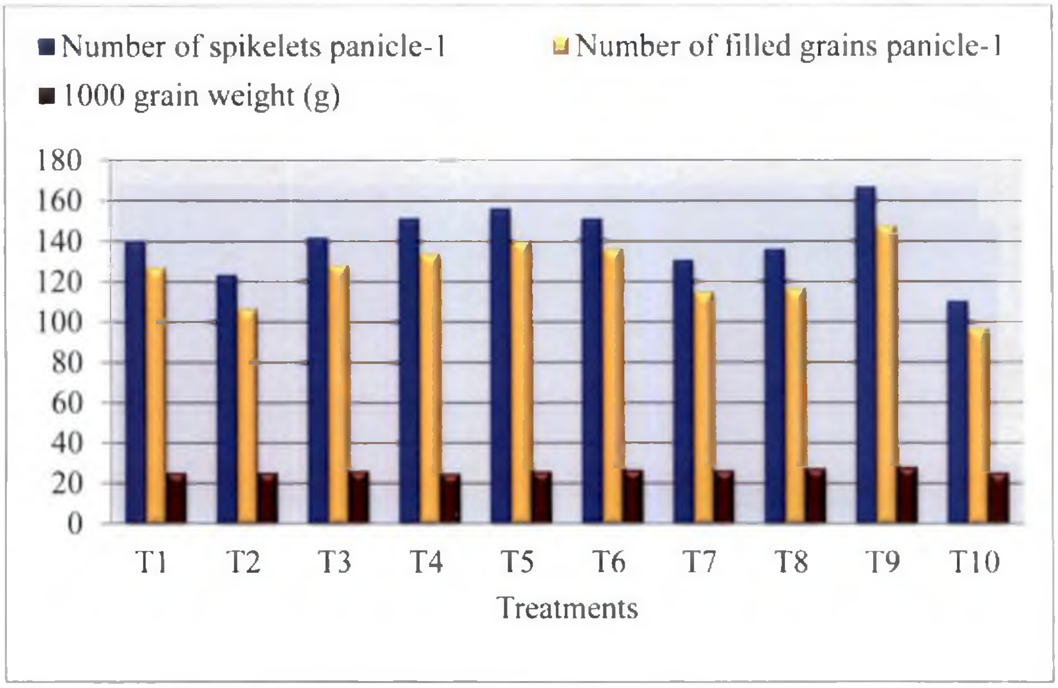

Fig.5. Effect of treatments on number of spikelets panicle-1, filled grains panicle and 1000 grain weight.

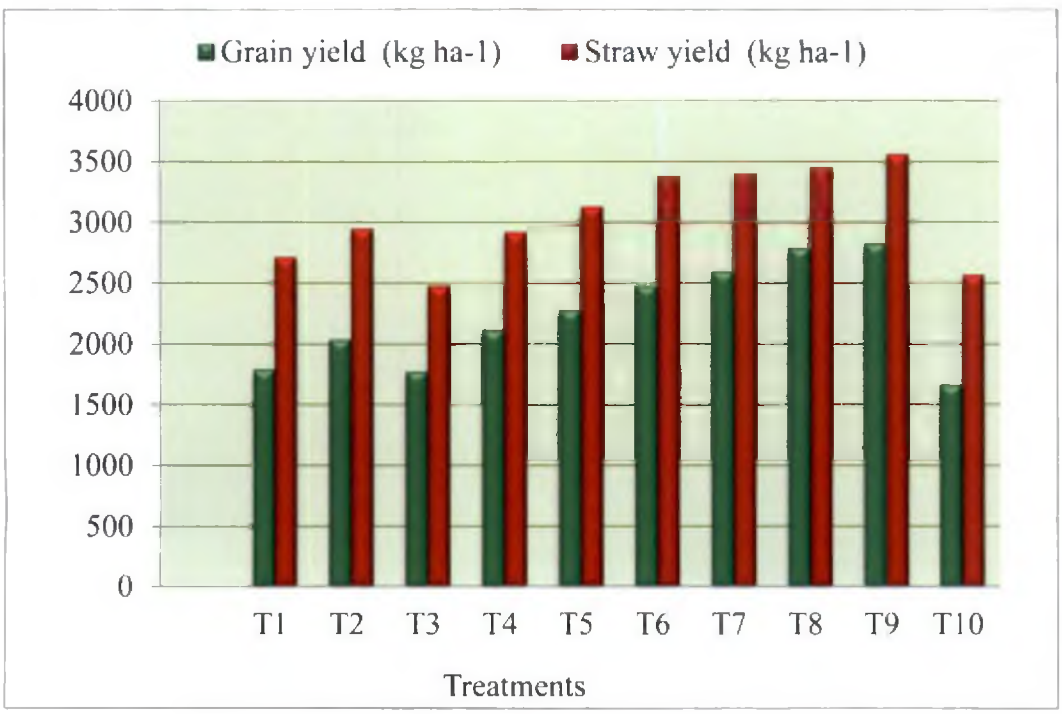

Fig.6. Effect of treatments on grain and straw yield

nutrients throughout the growth period resulted in higher grain yield. This is in conformity with the findings of Babu (1996) and Ranjini (2002). The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) in which 50 per cent of 120 kg N was substituted with FYM produced the maximum straw yield. The favourable effect of T_9 on growth characters such as plant height, tiller number, LAI and DMP besides improving the physicochemical and biological characteristics of the soil might have contributed to higher straw yield. The favourable effect of FYM on rice straw yield was reported by Babu (1996), Deepa (1998) and Ranjini (2002).

The maximum HI of 0.45 was recorded by the treatment T_8 in which 25 per cent of 120 kg N was substituted as FYM. Combined application of N, K and FYM produced higher HI values probably because of their synergestic effect on yield and yield attributes. Similar finding was reported by Ranjini (2002).

5.3. PHYSIOLOGICAL AND CHEMICAL ESTIMATIONS

5.3.1. Relative Leaf Water Content (RLWC)

The data on effect of treatments on RLWC is presented on Table 8. Though not significant, maximum RLWC of 82.29 per cent was recorded at flowering stage by the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O). The impact of nitrogen on RLWC is well established under upland condition. Higher nitrogen levels intensified water stress and reduced the water potential in rice. FYM improves the physical properties of the soil especially porosity and WHC. There is higher moisture retention in the soil due to FYM application and the crop has extracted more moisture from the soil resulting in higher RLWC. This is in conformity with the findings of Ranjini (2002).

5.3.2. Protein Content of Grain

The treatments differed significantly and treatment T_4 (100 kg N applied as 100% CF and 50 kg K_2O) registered the maximum value of 5.96 per cent which was on par with T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) recording a value of 5.94 per cent (Table 8). Protein content of grain was significantly increased by elevated levels of N. This might be due to increased nitrogen assimilation (protein synthesis) in plants because nitrogen is a major component of amino acids and proteins. Increase in protein content at higher nitrogen levels was reported by Rao *et al.* (2014). Potassium is involved in the formation of proteins through polymerisation of amino acids. Increase in grain protein content at higher doses of N and K was reported by Anu (2001), Ranjini (2002) and Mini (2005). FYM is found to improve the grain protein content through mineralisation and subsequent release of nitrogen. Combined application of N, K and FYM has improved the grain protein content as evident from the findings of Ranjini (2002) and Aruna *et al.* (2012).

5.3.3. Leaf Temperature

The data on leaf temperature at flowering stage are presented on Table 8. Though not significant, treatment T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O) and T_{10} (60 kg N applied as 100% CF and 30 kg K_2O) registered the lowest leaf temperatures of 28°C. Combined application of N, K and FYM resulted in retention of more moisture in soil, reduced the leaf temperature and thereby modified the micro climate favourable to the crop. This is in agreement with the findings of Farsanashamin (2015).

5.3.4. Stomatal Conductance

The data on stomatal conductance are presented in Table 8. Though not significant, T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O) registered the highest value of 269.4 M mol m^{-2} s^{-1} closely followed by T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recording 266.2 M mol m^{-2} s^{-1}. Integrated use of organic and inorganic sources of nutrients increased the stomatal conductance, photosynthetic rate and subsequent crop growth. FYM applied to the soil will be subjected to decomposition and mineralisation leading to the slow release of N to the soil and CO_2 to the microclimate of the crop. As a result the CO_2 flux in the crop canopy is increased leading to higher stomatal conductance and increased rate of photosynthesis. This is in agreement with the findings of Farsanashamin (2015). FYM improves the physical properties of the soil especially porosity and water holding capacity as a result of which available moisture content of the soil is improved and moisture stress is reduced. This leads to higher stomatal conductance and a proportionate increase in the assimilation rate and photosyntheisis (Lini, 2006).

5.3.5. Uptake of Nutrients

The data on uptake of nutrients are presented on Fig 7, 8 and 9. The results revealed that the treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) registered the highest values of 26.44, 22.48 and 48.92 kg ha^{-1} respectively for uptake of nitrogen by grain, straw and total and was significantly superior to rest of the treatments. The treatment T_5 (100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O) registered the highest values of 7.33, 7.02 and 14.35 kg ha^{-1} respectively for uptake of phosphorus by grain, straw and total. The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the maximum K uptake of 7.80, 44.96 and 52.76 kg ha^{-1} respectively for grain, straw and total. Increased nutrient uptake might have resulted from higher DMP, grain and straw yields and better growth and yield attributes. Increase in uptake of nutrients due to increased dosage of nitrogen and potassium. Nitrogen, potassium and FYM had a significant influence on nutrient uptake by the crop. Similar findings were reported by Sharma *et al.* (1999) who found that united application of organic and inorganic source of nutrients was beneficial in enhancing the uptake of NPK by soil. Increased uptake might be due to higher availability of nutrients from the soil reservoir and also from the added sources of organic manures. The increased available nutrients resulted in better uptake of N, P, and K which inturn improved the vegetative growth as indicated by taller plants, more leaves, roots, tillers and increased leaf size leading to higher LAI (Rao, 1988). Increased uptake of N, P and K by upland rice at higher nutrient levels is in conformity with the results of Anu (2001), who obtained the maximum uptake of NPK at 80:40 kg NK ha^{-1}. Ranijini (2002) recorded the highest uptake of nutrients at an NK level of 90:45 kg ha^{-1}. Similar findings were reported by Mini (2005) in which the maximum nutrient uptake was obtained by the application of NK at 100:50 kg ha^{-1}.

Organic manures had a significant influence on nutrient uptake. The beneficial effect of combined source of organic and inorganic nutrients in rice crop might be due to their favourable effect on DMP, grain and straw yields and nutrient uptake (Gill and Meelu, 1982). The enhanced nutrient availability coupled with higher nutrient uptake due to organic manure incorporation could be attributed to higher DMP and nutrient absorption (Reddy, 1988 and Sriramachandrasekaran, 1994). Deepa (1998) observed that FYM treated plots showed higher nutrient uptake throughout the growth period of rice crop. Higher nutrient uptake in rice might be due to the increase in available nutrients which might have contributed to mineralization of organic manures or decomposition of native soil sources releases soluble nutrients was reported by Walia and Kler (2005).

Singhania and Singh (1991) observed higher N and P uptake when nitrogen was applied in combined form, both organic and inorganic than all as inorganic form. Shekara *et al.* (2010) reported that application of FYM @ 20 t ha^{-1} recorded significantly higher nutrient uptake (NPK) in rice. Brijal and Singh (1998) reported increased K uptake due to integrated use of organic and inorganic source of nutrients. Higher uptake could be attributed to adequate supply of nutrients and higher recovery of applied nutrients with application of FYM, which in turn must have improved synthesis and translocation of metabolites to various reproductive structures of the plant.

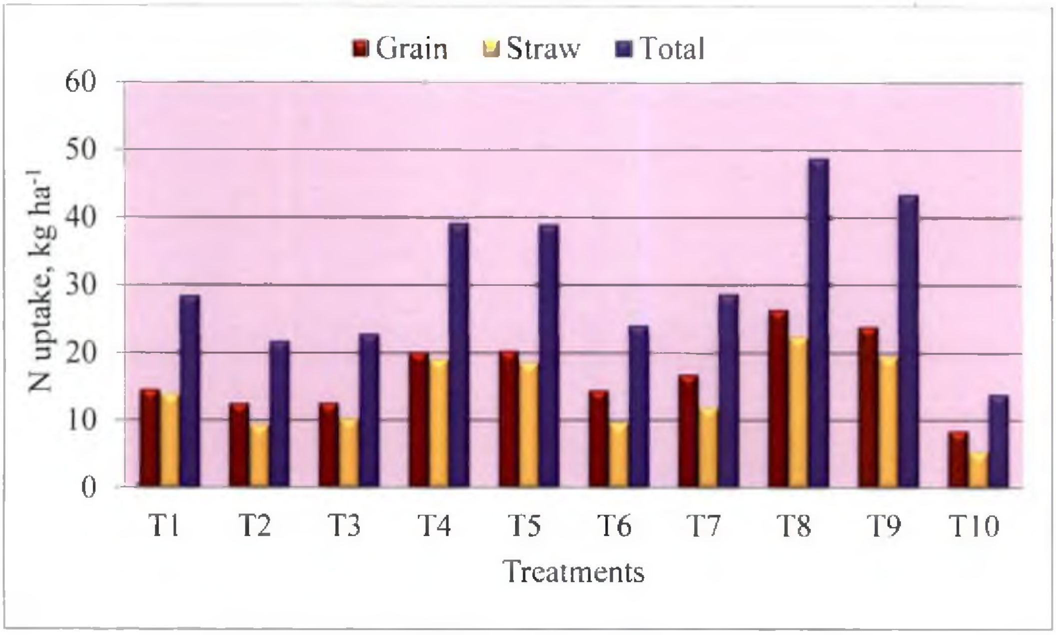

Fig 7. Effect of treatments on N uptake (kg ha^{-1})

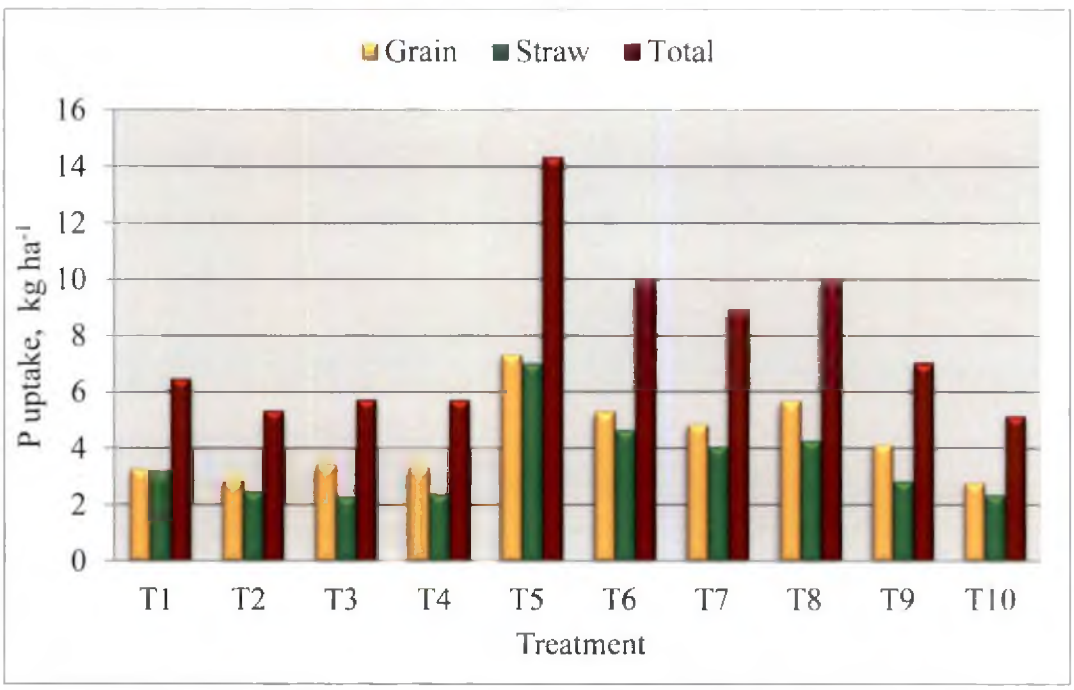

Fig 8. Effect of treatments on P uptake (kg ha^{-1})

5.4. SOIL PROPERTIES

5.4.1. Soil Physical Properties

The physical properties of soil were significantly influenced by the treatments Table 10. The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the lowest Db value of 1.07 Mg m^{-3} which was on par with the treatment T_8, T_6, T_2 and T_7. The extent of reduction in bulk density was more when organic manures were applied along with chemical fertilizers. Reduction in bulk density due to combined application of organic and inorganic nutrients was ascribed to the increased root biomass production that increased organic matter content of the soil. Lowering of bulk density due to continuous application of chemical fertilizers along with organics might be due to addition of higher organic carbon that resulted in more pore space and good soil aggregation (Sepehya *et al.*, 2012). FYM enhanced the organic matter of soil resulting in better aggregation and subsequent lowering of bulk density as reported by Mishra and Sharma (1997).

The data on porosity (Table 10) revealed that the treatments showed significant difference. The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the maximum porosity of 50.76 per cent and was on par with T_8, T_6, T_2 and T_7. This is in the line with the findings of Bhatia and Shukla (1982) who reported that continuous addition of organic manures not only influenced bulk density but also increased the porosity of soils which in turn positively influenced the soil condition for optimum plant growth. Soil porosity was increased due to integrated use of FYM and chemical fertilizers as reported by Sepehya *et al.* (2013). These results are in conformity with the findings of Ranjini (2002).

Combined application of chemical fertilizers and FYM increased the WHC of the soil as evident from the Table 10. This could be ascribed to the improvement in structural condition of soil due to the application of FYM with inorganics (Bhatnagar *et al.* 1992). Also the higher water holding capacity of the added organic matter in turn might have increased the water holding capacity of the soil. The results are in agreement with the findings of Ranjini (2002).

5.4.2. Soil Chemical Properties

5.4.2.1. Available Nitrogen

The data on available nitrogen status of the soil after the experiment (Table 11) revealed significant difference between treatments. Available N status was maximum for the treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O). Combined application of chemical fertilizers and FYM not only increase the efficiency of nitrogen fertilizer by slow release and prevent loses but also substitute the chemical fertilizer (Lowendorf, 1982). Similiar findings were reported by Ranjini(2002) on upland rice. Integrated use of fertilizer and organic manures improved the soil status has been amply indicated by Kishor *et al.* (2008). Biswas and Shukla (2010) reported that combined application of NPK and FYM favourably increased the initial nutrient status of soil whereas application of NPK alone shown depletion of initial nutrient status. Sharma and Sharma (1994) reported that the available nitrogen content of soil was increased due to FYM application. Integrated application of organic and inorganic fertilizers tended to increase the available nitrogen status of the soil might be due to the release of aliphatic and aromatic hydroxy acids, humates and lignins from organic manures which would release nutrients into the soil (Aruna *et al.*, 2012). Post soil fertility status revealed that the soil available nitrogen status increased progressively with incremental levels of N up to the highest dose tried (Rao *et al.*, 2014). Higher N availability in the soil due to FYM addition might be due to continuous and slow release of nutrients from FYM, increased biomass and accumulated soil organic matter as reported by Ajaykumar (2015).

5.4.2.2. Available Phosphorus

The treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) recorded the maximum value of 15.29 kg ha^{-1} and was on par with T_6

and T_9 (Table 11). Combined application of N, K and FYM registered a build up of available P in the soil. Application of organic manure increased the P status of soil. Organic materials like FYM formed a protective cover on sesquioxides and this facilitated reduction in the P fixation capacity of soil (Tandan, 1987). The integrated use of organic manures in plant nutrition not only increased the P supply to plants by direct enrichment, but also enhanced solubilisation of native P, accelerated the mineralization of added chemical P and reduced P fixation (Kutty and Anilakumaran, 1991). This might be due to the fact that during the mineralization of enriched organics, a number of organic acids, especially the hydroxyl ions (product of microbial metabolism) are produced, which released P through chelation or by removal of metal ions from the insoluble metal phosphates as observed by Mohandas and Appavu (2000). Similiar findings were reported by Ranjini (2002). Higher soil available P could be attributed to decomposition of organic manures in the production of organic acids which in turn stabilize native insoluble P and made it available for a longer period.

5.4.2.3. Available Potassium

The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the maximum value of 277.17 kg ha^{-1} and was on par with T_8 and T_5 (Table 11). Ranjini (2002) reported higher available K in soils supplied with both organic and inorganic nutrients. Combined application N, K and FYM improved the available K status of the soil. The increase in available K might be due to the combined effects of addition of K through fertilizers and organic sources, and weathering of K minerals and loss of K from the soil including crop removal (Dutta and Yhome, 2014). Addition of organic manure increased the available potassium in soil due to reduction in K fixation and release of K (Ajaykumar, 2015).

5.4.2.4. Soil Organic Carbon

The treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) registered the highest value of 0.69 per cent and was on par with T_8

(Table 11). United application of organic and inorganic sources of nutrients increased the soil organic carbon status. Improvement in soil organic carbon status in plots treated with different organics continuously might be due to the stimulating effect of organics on growth and activity of microorganisms (Babhulkar *et al.*, 2000). Similar findings were reported in upland rice by Ranjini (2002). Higher organic carbon content of the soil might be due to the effect of integrated nutrient management on root growth, consequently resulted in the production of more biomass to soil (Kishor *et al.*, 2008). Increase in organic carbon status of the soil due to FYM application was mainly due to addition of organic matter (Patnaik *et al.*, 1989). The increase in organic matter content could be attributed to the higher carbon released by FYM.

5.5. ECONOMIC ANALYSIS

The results of net return and BCR (Table 12) indicated that there was significant difference between treatments. The treatment T_8 (120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O) registered the maximum net return and BCR of Rs. 19149 ha^{-1} and 1.62. Inclusion of organic sources along with chemical fertilizers increased the cost of cultivation but additional cost of these organic manures was compensated by the additional grain and straw yield of rice, which in turn gave higher B:C ratio. This was in accordance with the results of Ajaykumar (2015). Combined application of organic and inorganic nutrients enhanced crop yield resulting in higher net returns and BCR as compared to application of chemical fertilizers alone (Medhi *et al.*, 2002). This is in agreement with the findings of Ranjini (2002).

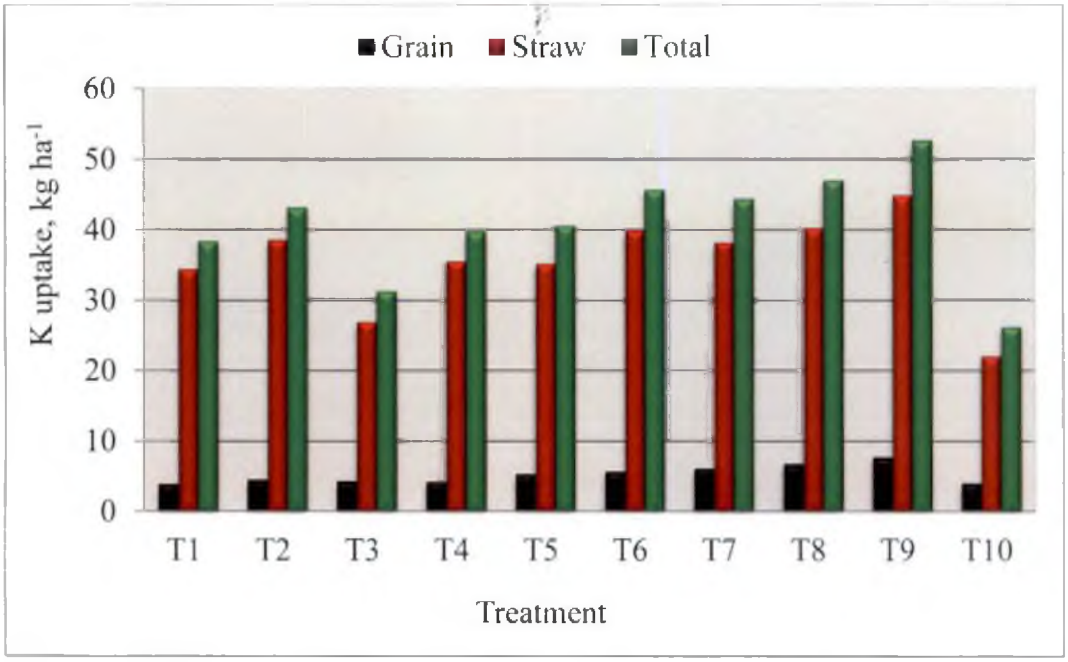

Fig.9. Effect of treatments on K uptake (kg ha^{-1})

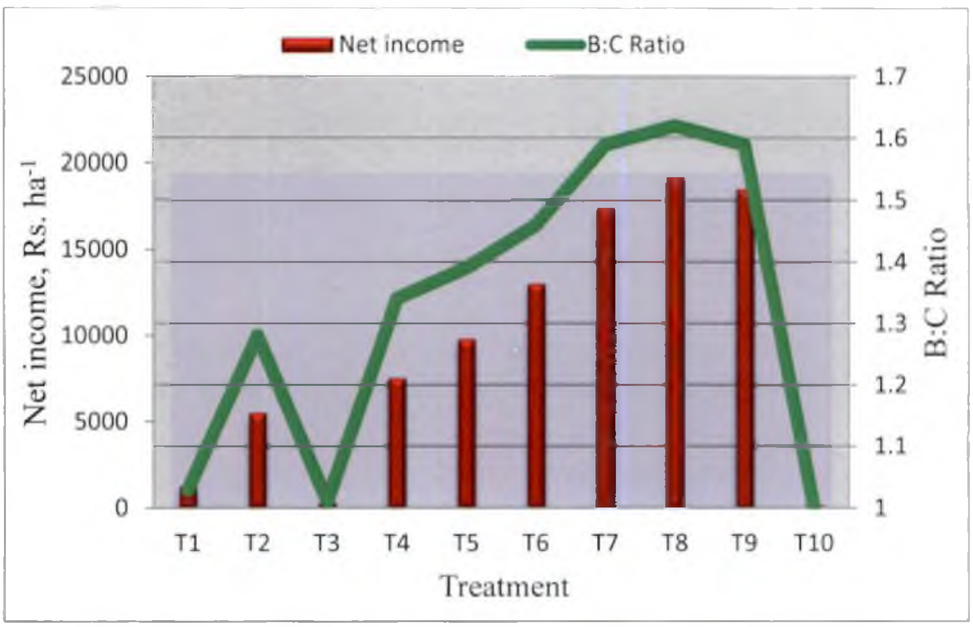

Fig.10. Effect of treatments on economics of cultivation

SUMMARY

6. SUMMARY

A field experiment was conducted in the field of Sri. Ambu, Akshaya Koolome road, Madikkai, Kasaragod during the *virippu* season of 2015 to study the influence of different levels of N and K on growth, yield attributes, yield of upland rice and to assess the possibility of substitution of inorganic N by FYM. The soil of the experimental field was sandy loam belonging to the taxonomical order Inceptisol, acidic, low in available N, P and medium in available K. The experiment was laid out in randomised block design with 10 treatments with 3 replications. The treatments were T_1 - 80 kg N applied as 100% CF and 40 kg K_2O, T_2 - 80 kg N applied as 60 kg as CF, 20 kg as FYM and 40 kg K_2O, T_3 - 80 kg N applied as 40 kg as CF, 40 kg as FYM and 40 kg K_2O, T_4 - 100 kg N applied as 100% CF and 50 kg K_2O, T_5 - 100 kg N applied as 75 kg as CF, 25 kg as FYM and 50 kg K_2O, T_6 - 100 kg N applied as 50 kg as CF, 50 kg as FYM and 50 kg K_2O, T_7 - 120 kg N applied as 100% CF and 60 kg K_2O, T_8 - 120 kg N applied as 90 kg as CF, 30 kg as FYM and 60 kg K_2O, T_9 - 120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O and T_{10} - 60 kg N applied as 100% CF and 30 kg K_2O. A dose of 30 kg P_2O_5 ha^{-1} was uniformly applied to all treatments. Observations were recorded on growth parameters such as plant height, number of tillers $hill^{-1}$, LAI and dry matter production. The yield parameters like number of productive tillers m^{-2}, panicle length, panicle weight, 1000 grain weight, total number of spikelets and filled grains $panicle^{-1}$ were recorded at harvest stage. Grain and straw yield were recorded at the time of harvest and harvest index was computed. The physiological and chemical estimations like RLWC, protein content of grain, leaf temperature and stomatal conductance were recorded. The plant nutrients uptake and nutrient status in soil after the harvest were also estimated. Economics was worked out based on the existing local market price of inputs and produce. The data were tabulated statistically analysed and results of the study are briefly presented here under.

The treatments had a significant influence on plant height at 60 DAS and at harvest stage. Among the treatments, T_9 (120 kg N applied as 60 kg as CF, 60

kg as FYM and 60 kg K_2O) produced the tallest plants at 60 DAS and at harvest. The Highest tiller production was noticed when N applied at 120 kg ha^{-1}. At 60 DAS, the treatment T_9 (120 kg N applied as 60 kg as CF, 60 kg as FYM and 60 kg K_2O) recorded the highest tiller number while, at harvest the treatment T_7 (120 kg N applied as 100% CF and 60 kg K_2O) produced highest tiller number. The LAI was significantly influenced by the treatments and application of 120 kg ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1}(T_9) gave the highest LAI. The highest DMP was recorded by the treatment T_9.

Application of 120 kg N ha^{-1} with 50 per cent substituted by FYM and 60 kg K_2O ha^{-1} (T_9) registered highest number of productive tillers m^{-2}, panicle weight, panicle length, total spikelets $panicle^{-1}$, filled grains $panicle^{-1}$ and 1000 grain weight.

The highest grain and straw yields were obtained with the application of 120 kg N ha^{-1} with 50 per cent substituted by FYM and 60 kg K_2O ha^{-1} (T_9) and was on par with 120 kg N ha^{-1} with 25 per cent substituted as FYM and 60 kg K_2O ha^{-1} (T_8). The treatment T_8 registered the highest HI.

RLWC was not significantly influenced by the treatments. Though not significant, nitrogen applied at 100 kg ha^{-1} with 50 per cent substituted as FYM and 50 kg K_2O ha^{-1} (T_6) recorded the highest RLWC at panicle initiation stage, whereas T_9 (120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1}) recorded the highest value at flowering stage.

The treatment had a favourable influence on grain protein content. Application of 100 kg N ha^{-1} as chemical fertilizer and 50 kg K_2O ha^{-1} (T_4) recorded the highest grain protein content.

Though not significant, application of 100 kg N ha^{-1} with 25 per cent substituted as FYM and 50 kg K_2O ha^{-1} (T_5) recorded the lowest leaf temperature and highest stomatal conductance.

The uptake of N, P and K differed significantly. The highest uptake of N was recorded by the application of 120 kg N ha^{-1} with 25 per cent substituted by FYM and 60 kg K_2O ha^{-1}(T_8). The P uptake was highest for N applied at 100 kg ha^{-1} with 25 per cent substituted as FYM and 50 kg K_2O ha^{-1} (T_5). The highest K uptake was recorded by the application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1} (T_9).

At post harvest stage, the soil physical properties like bulk density, porosity and water holding capacity were favourably influenced by treatments. The lowest bulk density and highest porosity values were recorded by the application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1} (T_9). The highest water holding capacity was recorded by the application of 100 kg N ha^{-1} with 50 per cent substituted as FYM and 50 kg K_2O ha^{-1} (T_6).

The available nutrient of the soil was significantly improved by the application of treatments. At post harvest stage, soil available N and P_2O_5 were found to be enhanced due to the application of 120 kg N ha^{-1} with 25 per cent substituted by FYM and 60 kg K_2O ha^{-1}(T_8). The highest value for soil available K_2O was recorded by the application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1} (T_9).

There was significant increase in the organic carbon status of the soil after the experiment. The application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1} (T_9) recorded the highest organic carbon status of the soil.

The highest net return and benefit cost ratio was registered with application of 120 kg N ha^{-1} with 25 per cent substituted by FYM and 60 kg K_2O ha^{-1}(T_8).

Future Line of Work

Nutrient irrigation interaction studies on upland rice under varying levels of shade offer tremendous scope in future. The possibility of foliar application of macro and micronutrients on upland rice at different growth stages has to be explored.

REFERENCES

7. REFERENCE

Ahmed, S., Basumatary, A., Das, K.N., Medhi, B.K., and Srivastava, A.K. 2014. Effect of integrated nutrient management on yield, nutrient uptake and soil fertility in autumn rice in an Inceptisol of Assam. *Ann. Plant Soil Res.* 16(3): 192-197.

Ajaykumar, R. 2015. Effect of organic and inorganic sources of nutrients on rice. M.Sc. Thesis. Tamil Nadu Agricultural University, Coimbatore, 103p.

Akanda, K.I., Prodhan, A.K.M.A., Rahman, S., Alam, M.S., and Afrin, S. 2012. Effect of nitrogen and potassium on morpho-physiological characteristics of fine grain aromatic rice. *J. Agrofor. Environ.* 6(1): 99-103.

Ali, H., Hasnain, Z., Shahzad, A.N., Sarwar, N.M., Qureshi, K., Khaliq, S., and Qayyum, M.F. 2014. Nitrogen and zinc interaction improves yield and quality of submerged basmati rice (*Oryza sativa* L.). *Not Bot HortiAgrobo.* 42(2): 372-379.

Anu, S. 2001. Nutrient management of upland rice (*Oryza sativa* L.) varieties in coconut garden. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 99p.

Arivazhagan, K. and Ravichandran, M. 2005. Interaction effect of nitrogen and potassium on yield and yield attributes in rice cv. IR 20. *Advance Plant Sci.* 18(1): 425-427.

Aruna, P., Reddy, G.P., and Sagar, G.K. 2012. Effect of integrated nitrogen management on growth, yield, quality and post-harvest nutrient status of soil in aerobic rice (*Oryza sativa* L.). *Crop Res.* 43: 1-4.

Awan, T.H., Manzoor, M.Z., Safdar, E., and Ahmad, M. 2007. Yield response of rice to dynamic use of potassium in traditional rice growing area of Punjab. *Pakist. J. Agric. Sci.* 44(1): 130-135.

Babhulkar, P.S., Wandile, R.M., Badole, W.P., and Balpande, S.S. 2000. Residual effect of long-term application of FYM and fertilizers on soil properties (vertisols) and yield of soybean. *J. Indian Soc. Soil Sci.* 48(1): 89-92.

Babu, S.D. 1996. Yield maximisation of direct sown rice under puddled condition. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 142p.

Bachkaiya, V., Patil, S.K., Sarwgi, S.K., and Chowdhary, V.K. 2008. Effect of potassium application on yield and potassium content and uptake in Vertisols of Chhattisgarh under rice-wheat cropping sequence. *Environ. Ecol.* 25(1): 89-91.

Bahmanyar, M.A. and Mashaee, S.S. 2010. Influences of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice (*Oryza sativa* L.). *Afr. J. Biotechnol.* 9(18): 2648-2653.

Battacharya, B.K. and Nain, A.S. 2001. Performance evaluation of deficient soil amendments for improving soil physical conditions and direct seeded rice production. *Environ. Ecol.* 19(2): 309-312.

Bharathy, V.E. 2005. Effect of FYM and rotary weeding on crop yield in the system of rice intensification (SRI). *Indian J. Agric. Sci.* 4(1): 201-204.

Bhatia, K.S. and Shukla, K.K. 1982. Effect of continuous application of fertilizers and manures on some physical properties of eroded alluvial soils. *J. Indian Soc. Soil Sci.* 30: 30-36.

Bhatnagar, V.K., Kundu, S., and Vedprakash, K. 1992. Effect of long-term manuring and fertilization on soil physical properties under soybean

(*Glycine max*) wheat (*Triticum aestivum*) cropping sequence. *Indian J. Agric. Sci.* 62: 212-214.

Bhattacharya, P. and Chakraborty, G. 2005. Current status of organic farming in India and other countries. *Indian J. Fertil.* 1(9): 111-123.

Bhattacharya, S.P., Sitangshu, S., Karimadkar, A.J., Bera, P.S., Latika, M., Sarkar, S., and Mandal, L. 2003. Effects of humic acid (earth) on the growth and yield of transplanted summer rice. *Environ. Ecol.* 21(3): 680-683.

Biswas, B.C. and Shukla, D.K. 2010. Poverty alleviation through grass-root-based planning and execution of vegetable farming system: An experience of Himachal Pradesh farmers. *Fertil. Mark. News* 41(9): 13-18.

Brar, D.S. and Sindhu, A.S. 1995. Effect of soil water on pattern of nitrogen release during decomposition of added green manure residue. *J. Indian Soc. Soil. Sci.* 43(2): 14-17.

Brijlal, S. and Singh, D. 1998. Crop yield and uptake of potassium by maize (*Zea mays*), wheat (*Triticum aestivum*) and cowpea (*Vigna unguiculata*) fodder in relation to various forms in soil under intensive cropping and continuous fertilizer use. *Indian J. Agric. Sci.* 68: 734-735.

Chamely, S.G., Islam, N., Hoshain, S., Rabbani, M.G., Kader, M.A., and Salam, M.A. 2015. Effect of variety and nitrogen rate on the yield performance of *boro* rice. *Progressive Agric.* 26(1): 6-14.

Chettri, G.B., Ghimiray, M., and Floyed, C.N. 2003. Effects of farm yard manure, fertilizers and green manuring in rice-wheat systems in Bhutan: Results from a long-term experiment. *Cambridge J.* 39(2): 129-144.

Choudhary, A.K. and Suri, V.K. 2014. Integrated nutrient management technology for direct- seeded upland rice (*Oryza sativa* L.) in northwestern Himalayas. *Commun. Soil Sci. Plant Anal.* 45: 777-784.

Deepa, S. 1998. Integrated nutrient management in rice-rice cropping system. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 130p.

Devendra, S., Vinay, S., Ravendra, S., and Singh, D. 1999. Potassium status of soils and response of rice to applied potassium. *J. Potassium Res.* 13(1-4): 83-87.

Devi, M.G., Reddy, S.T., Sumati, V., Pratima, T., and John, K. 2012. Nitrogen management to improve the nutrient uptake, yield and quality parameters of scented rice under aerobic culture. *Int. J. Appl. Biol. Pharma. Technol.* 3(1): 340-344.

Dixit, K.G. and Gupta, B.R. 2000. Effect of farmyard manure, chemical and biofertilizers on yield and quality of rice (*Oryza sativa* L.) and soil properties. *J. Indian Soc. Soil Sci.* 48(4): 773-780.

Dubey, O.P., Namdeo, K.N., Verma, S.N., Singh, S., Mishra, V.P., and Pande, P.C. 1983. Response of paddy varieties to levels of nitrogen under rainfed conditions. *Indian J. Agron.* 28(2): 134-136.

Dutta, M. and Yhome, V. 2014. Soil fertility and performance of upland rice after nine years of integrated nutrient management and continuous cropping in terraced land. *Environ. Ecol.* 32(3): 1034-1038.

Dutta, S., Ghose, T.J., and Dey, P.C. 2013. Influence of potash levels on growth, yield, nutrient uptake and economics in irrigated summer rice of Assam. *Oryza* 50(4): 334-339.

Dwivedi, A.P., Dixit, R.S., and Singh, G.R. 2006. Effect of potassium levels on growth, yield and quality of hybrid rice (*Oryza sativa* L.). *Oryza* 43(1): 64-66.

El-Lattief, E.A.A. 2014. Effect of integrated use of farm yard manure (FYM) and chemical fertilizers (NPK) on productivity of bread wheat under arid conditions. *Int. J. Advanced Res. Eng. Appl. Sci.* 3(12): 22-27.

Faraji, F., Esfahani, M., Kavousi, M., Nahvi, M., and Forghani, A. 2013. Effect of nitrogen fertilizer levels on Fe and protein content, grain breakage and grain yield of rice (*Oryza sativa* L. cv. Khazar). *Biharean Biologist* 7(1): 25-28.

Farinelli, R., Penariol, F.G., Filho, D.F., and Bordin, L. 2004. Effects of nitrogen and potassium fertilization on agronomic characteristics of upland rice cultivated under no-tillage. *RevistaBrasileira de Ciência do Solo*. 28(3): 447-454.

Farsanashamin, P. 2015. Nutrient management for coconut based multi-storied cropping system in a typical coastal sandy zone. M.Sc. (Ag) Thesis, Kerala Agricultural University, Kerala. 141p.

Gill, H.S. and Meelu, O.P. 1982. Studies on the substitution of inorganic fertilizers with organic manures and their effect on soil fertility. *Indian J. Agron.* 30: 116-118.

Gogoi, B., Kalita, B., Deori, B., and Paul, S.K. 2015. Soil properties under rainfed rice (*Oryza sativa* L.) crop as affected by integrated supply of nutrient. *Int. J. Agric. Innovations Res.* 3(6): 1720-1724.

GOK [Government of Kerala]. 2015. *Economic review 2015* [on-line]. Available: http://www.keralacm.gov.in/images/stories/topnews/2016/February/ER_2015_Eng_01.pdf [Feb 2016].

Gopakkali, P., Channanaik, D., Rajanna, G.A., Sannathimmappa, H.G., Ramesha, Y.M., and Veeresha. 2012. Economics and nutrient uptake of rice (*Oryza sativa* L.) as influenced by various levels of FYM and cattle urine application in Bhadra command area of Karnataka. *Crop Res.* 43: 10-14.

Gupta, A.P., Neve, H.U., and Singh, V.P. 1995. Increasing rice productivity through phosphatic fertilizer and poultry manure application in acid upland. *Ann. Biol.* 11(2): 151-157.

Islam, M.S., Hossain, M.A., Chowdhury, M.A.H., and Hannan, M.A. 2008. Effect of nitrogen and transplanting date on yield and yield components of aromatic rice. *J. Bangladesh Agric. Univ.* 6(2): 291-296.

Jackson, M.L. 1973. Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., New Delhi. 498p.

Jalali-Moridani, M. and Amiri, E. 2014. Effect of nitrogen and potassium on yield and yield components of rice cultivar "Hashemi". *Indian J. Fundamental Appl. Life Sci.* 4(4): 417-424.

Kale, V.B. and Chavan, A.S. 1998. Critical limit of potassium in relation to paddy yield in Kumbhave soil series of Konkan (India). *Field Crop Abstr.* 51(1): 29.

Kaliha, U., Oiha, J., and Talukdar, M.C. 1995. Effect of levels and time of potassium application on yield and yield attributes of upland rice. Assam (India). *J. Potassium Res.* 11(2): 203-206.

Kandil, A.A., Sultan, M.S., Badawi, M.A., El-Rahman, A.A.A., and Zayed, B.A. 2010. Performance of rice cultivars as affected by irrigation and potassium fertilizer under saline soil conditions, yield and yield components. *Crop Environ.* 1: 18-21.

Khan, H.R., Elahi, S., Hussain, M.S., and Adachi, T. 1994. Soil characteristics and behaviour of potassium under various moisture regimes. *Soil Sci. Plant Nutr.* 40(2): 234-254.

Kishor, K.K., Alam, P., and Pal, K. 2008. Nutrient utilization by upland rice (*Oryza sativa* L.) as influenced by integrated nutrient management. *J. Res. BAU.* 20(1): 5-10.

Krishnappa, M., Gowda, K.N., Shankarnarayan, V., Maharudrappa, K., and Khan, M.M. 2006. Effect of graded levels and split application of potassium on its availability and yield of rice. *J. Potassium. Res.* 6(4): 156-161.

Kumar, M., Singh, R.P., and Rana, N.S. 2003. Effect of organic and inorganic sources of nutrient on productivity of rice. *Indian J. Agron.* 48: 175-177.

Kumar, R., Kumar, R., Shivani, and Kumar, S. 2005. Effect of nitrogen and potassium levels on growth and yield of hybrid rice. *J. Appl. Biol.* 15(1): 31-34.

Kumar, R., Kumar, S., Kumar, A., Singh, H., and Kumar, S. 2013. Effect of top dressing nitrogen and potassium on yield and yield components of rice (*Oryza sativa* L.). *Agriways* 1(2): 90-94.

Kumar, S. and Shivay, Y.S. 2009. Effect of eco-friendly modified urea materials and nitrogen levels on growth and productivity of aromatic hybrid and an aromatic high yielding variety of rice. *Ann. Agric. Res. New Ser.* 30: 4-8.

Kumar, V., Parihar, A.K.S., Kumar, S., and Chourasiya, A. 2014. Performance of hybrid rice (*Oryza sativa* L.) to integrated nutrient management (INM) in partially reclaimed sodic soil. *The bioscan* 9(2): 835-837.

Kutty, J.I. and Anilakumaran, K. 1991. Integrated nutrient supply improves physical, electro-chemical and biological properties of submerged rice soils. *Farmer Parliament.* 26(12): 11-12.

Lawal, M.I. and Lawal, A.B. 2002. Influence of nitrogen rate and placement method on growth and yield of rice (*Oryza sativa* L.) at Kadawa, Nigeria. *Crop Res*. 23: 403-411.

Lini, J. 2006. Effect of abiotic stress factors on growth and secondary plant metabolism in *Withania somnifera* (L.) Dunal. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 126p.

Lowendorf, H.S. 1982. Biological N fixation in flooded rice field. Cornell University Inst. Agric. Monograph. 76: 96.

Luka, G.L., Yahaya, R.A., Mahmud, M., Babaji, B.A., Arunah, U.L., Hinjari, A.D., and Isah, A.S. 2013. Growth response of upland rice (*Oryza sativa* L.) varieties to nitrogen and seed rates in the northern Guinea Savahah. *J. Biol. Agric. Healthc.* 3(20): 12-14.

Madhav, M.R., Ravikumar, A., and Venkateswarlu, B. 1996. Effect of different sources of nitrogen on growth, yield and nutrient uptake of rice. *The Andhra Agric. J.* 43: 119-122.

Maheswari, J., Bose, J., Sangeetha, S.P., Sanjutha, S., and Priya, S.R. 2008. Irrigation regimes and N levels influence chlorophyll, leaf area index, proline and soluble protein content of aerobic rice (*Oryza sativa* L.). *Int. J. Agric. Res.* 3(4): 307-316.

Maiti, S., Saha, M., Banerjee, H., and Pal, S. 2006. Integrated nutrient management under hybrid rice- (*Oryza sativa* L.) hybrid rice cropping sequence. *Indian J. Agron.* 51(3): 157-159.

Mankotia, B.S., Shekhar, J., Thakur, R.C., and Negi, S.C. 2008. Effect of organic and inorganic sources of nutrients on rice (*Oryza sativa L.*) - wheat (*Triticum aestivum*) cropping system. *Indian J. Agron.* 53(1): 32-36.

Mannan, M.A., Bhuiya, M.S.U., Hossain, H.M.A., and Akhan, M.I.M. 2010. Optimization of nitrogen rate for aromatic basmati rice (*Oriza sativa* L.). *Bangladesh J. Agril. Res.* 35(1): 157-165.

Mannan, M.A., Bhuiya, M.S.U., Akhand, M.I.M., and Zaman, M.M. 2012. Growth and yield of basmati and traditional aromatic rice as influenced by water stress and nitrogen level. *J. Sci. Foundation.* 10(2): 52-62.

Manzoor, Z., Awan, T.H., Ahmad, M., Akhter, M., and Faiz, F.A. 2008. Effect of split application of potash on yield and yield related traits of basmati rice. *J. Anim. Plant Sci.* 18(4): 120-124.

Maragatham, N. 1996. Direct effect of organic and biodigested organic manures on groundnut and their residual effect on lowland rice in groundnut – rice cropping system. Ph.D. (Thesis), Tamil Nadu Agricultural University, Coimbatore, 187p.

Medhi, D.N., Sarma, A.C., and Medhi, B.D. 2002. Effect of integrated nutrient management on rice-linseed cropping sequence in high rainfall areas of Assam. *Ann. Agric. Res.* 23(1): 17-21.

Meena., S.L., Singh, S., and Shivay, Y.S. 2003. Response of rice (*Oryza sativa* L.) to N and K application in sandy clay loam soils. *Indian J. Agric. Sci.* 73(1): 8-11.

Mehla, D.S. 1995. Potassium fertilizer for higher yields in scented rice. *Int. Rice Res. Notes* 20(1): 21-22.

Mhaskar, N.V., Thorat, S.T., and Bhagat, S.B. 2006. Effect of nitrogen levels on leaf area, leaf area index and grain yield of scented rice varieties. *J. Soils Crops.* 15(1): 218-220.

Mini, G. 2005. Response of upland rice (*Oryza sativa* L.) to NK ratios and S under partial shade. M.Sc. (Ag) thesis, Kerala Agricultural University, 104 p.

Mishra, V.K. and Sharma, R.B. 1997. Effect of fertilizer alone and in combination with manures on physical properties and productivity of Entisol under rice based cropping systems. *J. Indian Soc. Soil Sci.* 41: 84-88.

Mitra, G.N., Sahoo, D., and Rout, K.K. 2001. Effect of N-K interaction on yield, nutrient uptake and grain quality of rice-groundnut cropping sequence in the alluvial soils of Orissa. *J. Potassium Res.* 17: 71-78.

Mohandas, S. and Appavu, K. 2000. Direct and residual effect of combined application of basic slag with green leaf manures on soil available nutrients and yield of rice. *Madras Agric. J.* 87: 53-56.

Monapara, K.B., Kanijadia, B.B., and Mehta, P.M. 1993. Yield and nutrient uptake by rice as influenced by nitrogen management. *Gujarat Agric. Res. J.* 18: 49-55.

Motsara, M.R. 2000. Role of micro nutrients. The Hindu survey of Indian Agriculture. p.215.

Mukherjee, D. and Sen, A. 2005. Influence of rice husk and fertility levels on the nutrient content of rice (*Oryza sativa* L.). *India Agric. Sci. Digest.* 25(2): 151-152.

Nakashgir, G.H., Handoo, G.M., and Wani, S.A. 2000. Transformation, availability and relative response of rice to applied K in presence of ammonical nitrogen in alfisols of Kashmir. *J. Potassium Res.*16: 55-58.

Naphade, K.T., Deshmukh, V.N., Rewatkar, S.S., and Solanke, B.U. 1993. Grain yield and nutrient uptake by irrigated wheat grown on vertisol under various nutrient levels. *J. Indian Soc. Soil Sci.* 41: 370-371.

Nath, C.K. 2012. Effect of potassium on growth, yield and nutrient concentration of BRRI dhan29. M.Sc. (Ag) thesis, Bangladesh Agricultural University, 75p.

Nayak, B.R., Pramanik, K., Panigrahy, N., Dash, A.K., and Swain, S.K. 2015. Yield, nitrogen uptake and nitrogen use efficiency indices of aerobic rice (*Oryza sativa* L.) under various irrigation regimes and nitrogen levels. *Int. J. Bio-resource Environ. Agric. Sci.* 1(2): 8-13.

Onaga, G., Asea, G., Lamo, J., Kikafunda, J., and Bigirwa, G. 2012. Comparison of response to nitrogen between upland NERICAs and ITA (*Oryza sativa* L.) rice varieties. *J. Agric. Sci.* 4(6): 197-205.

Panigrahi, T., Garnayak, L.M., Ghosh, M., Bastia, D.K., and Ghosh, D.C. 2014. Productivity and profitability of basmati rice varieties under SRI. *Int. J. Bio-resource Stress Manag.* 5(3): 333-339.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical methods for Agricultural Workers*. Fourth edition. Indian Council for Agricultural Research, New Delhi, 458p.

Pasha, M.L., Reddy, M.D., Reddy, M.G., and Devi, M.V. 2013. Influence of irrigation schedule, weed management and nitrogen levels on grain yield, nutrient uptake and water productivity of aerobic rice. *Indian J. Agric. Res*. 47(1): 26-34.

Patnaik, S., Panda, D., and Dash, R.N. 1989. Long term fertilizer experiments in wetland rice. *Fertil. News*. 34(4): 47-52.

Pattanayak, S.K., Mukhi, S.K., and Majumdar, K. 2008. Potassium unlocks the potential for hybrid rice. *Better Crops*. 92(2): 8-9.

Pillai, R.N. and Anasuya, P. 1997. Effect of graded levels of applied potassium on dry matter production and potassium concentration in leaves of rice. *J. Potassium Res.* 13: 137-142.

Pradhan, A., Thakur, A., and Sonboir, H.L. 2014. Response of rice (*Oryza sativa* L.) varieties to different levels of nitrogen under rainfed aerobic ecosystem. *Indian J. Agron.* 59(1): 76-79.

Pradhan, S. and Moharana, S. 2015. Effect of organic nutrient management on growth rate and crop productivity in sustainable rice-rice system. *J. Crop Weed.* 11(2): 28-33.

Pramanik, K. and Bera, A.K. 2013. Effect of seedling age and nitrogen fertilizer on growth, chlorophyll content, yield and economics of hybrid rice (*Oryza sativa* L.). *Int. J. Agron. Plant Prod.* 4: 3489-3499.

Prasad, D., Singh, J.P., Singh, J.K., and Bharti, V. 2003. Effect of irrigation and nitrogen on growth and yield of early rice (*Oryza sativa* L.). *RAU J. Res.* 13: 148-150.

Rajput, A.L. and Warsi, A.S. 1991. Contribution of organic materials to nitrogen economy in rice (*Oryza sativa* L.) production. *Indian J. Agron.* 36(3): 455-456.

Ramasamy, A. 1990. Yield maximization in lowland transplanted rice through nitrogen, integrated use of organic manure and fertilizer N under varying plant density. M.Sc. (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore, India. 126p.

Ranjini, P.R. 2002. Integrated nutrient management for upland rice (*Oryza sativa* L.). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 106p.

Rao, V.P., Subbaiah, G., and Sekhar, K.C. 2013. Response of rice varieties to high level nitrogen on drymatter production, yield and nitrogen uptake of rice. *Int. J. Appl. Biol. Pharma. Technol.* 4(4): 216-218.

Rao, K.T., Rao, A.U., Sekhar, D., Ramu, P.S., and Rao, N.V. 2014. Effect of different doses of nitrogen on performance of promising varieties of rice in high altitude areas of Andhra Pradesh. *Int. J. Farm Sci.* 4(1): 6-15.

Rao, S.N.S. 1988. *Biofertilizers in Agriculture*. Oxford and IBH Publishing Co. (Pvt.) Ltd., New Delhi, p.456.

Rao, U.V., Ramu, Y.R., Kumara, C.R., and Reddy, C.R. 2004. Effect of organic and inorganic sources of nitrogen on growth, yield, nitrogen uptake and economics of low land rice. *Madras Agric. J.* 91(7): 289-293.

Reddy, D.S. 1988. Integrated nutrient management in a rice based cropping system. *Int. J. Agri. Res.* 2(8): 701-711.

Reddy, M.M., Padmaja, B., Veeranna, G. and Reddy, D.V.V. 2012. Evaluation of popular *kharif* rice (*Oryza sativa* L.) varieties under aerobic condition and their response to nitrogen dose. *J. Res. ANGRAU.* 40(4): 14-19.

Reddy, R. and Reddy, A. 1989. Effect of levels and sources of N on rice. *Indian J. Agron.* 34: 362-366.

Reddy, V.C. and Shivraj, B. 1999. Response of hybrid rice and varieties to NPK, FYM and poultry manure under punaji cultivation. Mysore *J. Agric. Sci.* 33: 133-138.

Revathi, P., Devi, K.B.S., Reddy, B.G., Rao, V.P., Padmaja, G., and Shanker, A.S. 2014. Influence of planting methods and integrated nutrient management on growth, yield and economics of rice. *J. Rice Res.* 7: 62-76.

Robinson, G.W. 1922. A new method for the mechanical analysis of soils and other dispersions. *J. Agric. Sci.* 12: 306-321.

Roy, D.K. and Mishra, S.S. 1999. Effect of weed management in direct seeded, upland rice (*Oryza sativa* L.) at varying nitrogen levels. *Indian J. Agron.* 44(1): 105-108.

Saito, K., Linquist, B., Atlin, G.N., Phanthaboon, K., Shiraiwa, T., and Horie, T. 2006. Response of traditional and improved upland rice cultivars to N and P fertilizer in northern Laos. *Field Crops Res.* 96: 216-223.

Sandyarani, K., Reddy, M.M., Reddy, R.U., and Rao, P.V. 2013. Influence of nitrogen and weed management on growth and yield of aerobic rice (*Oryza sativa* L.). *J. Res. ANGRAU.* 41(1): 61-65.

Sarkar, A.K. 2000. Integrated nutrient management for better livelihood of farmer's in rainfed areas. *J. Indian Soc. Soil Sci.* 48(4): 690-696.

Sarker, R.K., Bhattacharya, B., Chakraborty, A., Raha, S., and Satpathy. 1995. Response of rice nitrogen and potassium application Gangetic alluvial soils of West Bengal. *J. Potassium Res.* 11: 297-301.

Satyanarayana,V., Prasad, P.V.V., Murthy, V.R.K., and Boote, K.J. 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *J. Plant Nutr.* 25(10): 2081-2090.

Seema, Krishna, M. and Devi, M.T.T. 2014. Effect of nitrogen and weed management on nutrient uptake by weeds under direct seeded aerobic rice. *Int. Q. J. life Sci.* 9(2): 535-537.

Sekhar, D., Prasad, P.V.N., Rao, K.T., and Rao, N.V. 2014. Productivity of rice as influenced by planting method and nitrogen source. *Int. J. Curr. Microbiol. Appl. Sci.* 3(8): 1063-1068.

Selvi, D., Santhy, P., and Dhakshinamoorthy, M. 2005. Effect of inorganics alone and in combination with farmyard manure on physical properties and productivity of Vertichaplustepts under long-term fertilization. *J. Indian Soc. Soil Sci.* 53(3): 302-307.

Senthivelu, M. and Prabha, A.C.S. 2007. Studies on rice productivity, nitrogen uptake and nitrogen balance in wet seeded rice under integrated nitrogen management practices. *Int. J. Agric. Sci.* 3(2): 92-95.

Senthivelu, M., Pandian, B.J., and Prabha, A.C.S. 2009. Dry matter production and nutrient removal in wet seeded rice–cotton cropping sequence under integrated nutrient management practices. *Oryza* 46(4): 279-289.

Sepehya, S., Subehia, S.K., Rana, S.S., and Negi, S.C. 2012. Effect of integrated nutrient management on rice-wheat yield and soil properties in a north western Himalayan region. *Indian J. Soil Conserv.* 40(2): 135-140.

Setty, P., Bandi, T.K., Singh, A.G.S., and Sanjay, M.T. 2007. Influence of integrated nutrient management on growth and yield of hybrid rice under system of rice intensification (SRI) and aerobic method of cultivation. In: *SRI India 2007. Second National Symposium on System of Rice Intensification (SRI) in India* – Progress and Prospects. Papers and Extended Summaries, 3-5th October, Agartala, Tripura, India, 82-84.

Sharma, A.R. and Mitra, B.N. 1990. Complementary effect of organic bio and mineral fertilizers in rice based cropping system. *Fertil. News* 35(2): 43-51.

Sharma, G.D. 1992. Fertility management and crop geometry for yield maximization in rice-wheat cropping system. Ph.D thesis, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh. 194p.

Sharma, G.D. and Sharma, H.L. 1994. Utilization of weed plants as organic manure under different methods of rice establishment. *Indian J. Agric. Sci.* 64(3): 184-186.

Sharma, M.P., Bali, S.V., and Gupta, D.K. 1999. Soil fertility and productivity of rice (*Oryza sativa* L.) wheat (*Triticum aestivum*) cropping system in an Inceptisol as influenced by integrated nutrient management. *Indian J. Agric. Sci.* 7(2): 82.

Sharma, R., Gangwar, R.K., Yadav, V., and Kumar, R. 2014. Response of basmati rice (*Oryza sativa* L.) cultivars to graded nitrogen levels under transplanted condition. *Int. J. Res. Appl. Nat. Social Sci.* 2(9): 33-38.

Sharma, R.P., Pathak, S.K., and Singh, R.C. 2007. Effect of nitrogen and weed management in direct-seeded rice (*Oryza sativa* L.) under upland conditions. *Indian J. Agron.* 52(2): 114-119.

Sheela, K.R. 1993. Agronomic evaluation of rice cultivars for rainfed condition of Kerala. Ph.D. Thesis, Kerala Agricultural University, Thrissur, 263p.

Shekara, B.G., Sharnappa, and Krishnamurthy, N. 2010. Effect of irrigation schedules on growth and yield of aerobic rice (*Oryza sativa* L.) under varied levels of farmyard manure in Cauvery command area. *Indian J. Agron.* 55(1): 35-39.

Shrivastava, B.K. and Tripathi, R.S. 1999. Effect of nitrogen levels on hybrid and high yielding varieties of rice under lowland ecology of eastern Madhya Pradesh, India. *Oryza* 36: 386-388.

Siddaram, Murali, K., Manjunatha, B.N., Jagadeesha, N., Basavaraja, M.K., and Ramulu. 2011. Effect of nitrogen levels through organic sources on dry matter production and nutrient uptake of irrigated aerobic rice (*Oryza sativa* L). *Mysore J. Agric. Sci.* 45(1): 191-193.

Sikdar, M.S.I., Rahman, M.M., Islam, M.S., Yeasmin, M.S., and Akhter, M.M. 2008. Effect of nitrogen level on aromatic rice varieties and soil fertility status. *Int. J. Sustain. Crop Prod.* 3(3): 49-54.

Simpson, J.E., Adair, C.R., Kobler, G.O., Dawson, E.H., Dobald, H.A., Kester, E.B., and Klick, J.J. 1965. *Quality Evaluation studies of foreign and Domestic Rices*. Second edition. Tech. Bull. No. 1331. United States Department of Agriculture, Virginia, 206 p.

Singh, A.K., Singh, R.D., and Awasthi, R.D. 1996. Organic and inorganic sources of nutrients for sustained productivity in rice-wheat sequence on humid hilly soils of Sikkim. *Indian J. Agron.* 41: 191-194.

Singh, G.R., Dixit, R.S., and Dwivedi, A.P. 2006. Effect of nitrogen, phosphorus and potassium levels on growth, yield and quality of hybrid rice (*Oryza sativa* L.). *Indian J. Agron.* 43(1): 64-66.

Singh, K. and Tripathi, H.P. 2007. Effect of nitrogen and weed control practices on performance of irrigated direct-seeded rice (*Oryza sativa* L.). *Indian J. Agron.* 52(3): 231-234.

Singh, R.K., Mandal, N.P., Singh, C.V., and Anantha, M.S. 2011. *Upland rice in India*. Scientific publishers. 376p.

Singh, T., Singh, C., and Kaur, J. 2014. Productivity and quality of hybrid rice in relation to different plant spacings and nitrogen levels under transplanting conditions. *Crop Res.* 48: 1-5.

Singhania, R.A. and Singh, S. 1991. Effect of manure and nitrogen fertilizers on uptake and grain yield of paddy. *Curr. Res.* 20: 249-250.

Slatyer, R.O. and Baars, H.D. 1965. *Methodology of plant eco-physiology*. United Nations Educational, Scientific and Cultural Organisation, Rome, p.468.

Sriramachandrasekaran, M.V. 1994. Studies on N transformation and enzymatic activities as influenced by integrated nutrient management on rice. Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, 246p.

Stanford, G. and English, L. 1949. Use of flame photometer in rapid soil test for K and Ca. *Agron. J.* 41: 446.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* 25: 259-260.

Sudhakar, G., Solaimalai, A., and Ravisankar, N. 2003. Influence of cultivars and levels of nitrogen on yield, nutrient uptake and residual nutrient status of soil in semi dry rice. *Agric. Sci. Digest.* 23(2): 88-91.

Sunil, C.M. and Shankaralingappa, V. 2014. Impact of integrated package of agrotechniques on growth and yield of aerobic rice. *Agric. Sci.* 5(1): 60-65.

Surendran, U. 2005. Split application of muriate of potash and sulphate of potash on growth, yield attributes, uptake and availability of nutrients in lowland rice cv. Py-5. *J. Agric. Sci.* 1(2): 42-48.

Tadesse, T., Dechassa, N., Bayu, W., and Gebeyehu, S. 2013. Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem. *Am. J. Plant Sci.* 4: 309-316.

Tandan, H.L.S. 1987. *Phosphorus Research and Agricultural Production in India.* Fertiliser Development and Consultation Organization (FDCO), New Delhi.

Tasnin, T. 2014. Optimization of potassium dose for yield maximization of BRRI dhan49. M.Sc. (Ag) thesis, Bangladesh Agricultural University, Mymensingh, 76p.

Thakur, R.B., Jhan, A.K., and Sharma, R.P. 1993. Effect of levels and times of K application on wetland rice. Proc. Int. Symp. New Delhi, India. p.138.

Thomas, U.C. 2000. Response of seed priming, nutrient management and irrigation on upland rice (*Oryza sativa* L.). M.Sc. (Ag) thesis, Kerala Agricultural University, 59 p.

Tisdale, S.L., Nelson, W.L., and Beatson, J.D. 1995. *Soil Fertility and Fertilizers* (5th Ed.). McMillan publishing Co., New York, 733p.

Tripathi, B.N., Dixit, V.K., and Chaubey, C.N. 1990. Influence of fertilizers and FYM on dry matter and harvest of economic products in rice. *Bharatiya Krishi Anusandhan Patrika.* 5(4): 217-223.

Tripathy, R. and Singh, A.K. 2002. Influence of water and nitrogen on soil physical properties in puddled rice. *J. Agric. Physics* 2(1): 1-8.

Uddin, S., Sarkar, M.A.R., and Rahman, M.M. 2013. Effect of nitrogen and potassium on yield of dry direct seeded rice cv. NERICA 1 in *aus* season. *Int. J. Agron. Plant Prod.* 4(1): 69-75.

Vaijayanthi, C.P. 1986. Fertilizer management in rice variety Cheradi. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 140p.

Vennila, C., Jayanthi, C., and Nalini, K. 2007. Nitrogen management in wet seeded rice - a review. *Agric. Rev.* 28(4): 270-276.

Verma, T.S. and Bhagat, R.M. 1994. Nutrient dynamics and wheat yield as influenced by paddy straw management practices. *Crop Res. Hisar* 7(3): 382-390.

Walia, S.S. and Kler, D.S. 2005. Effect of organic and chemical sources of nutrition on soil properties in maize-wheat system. *Indian J. Ecol.* 32(2): 124-127.

Walkley, A. and Black, C.A. 1934.An examination of the digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 40: 233-243.

Weatherly, P.E. 1950.Studies on water relations of cotton plant. I. The field measurement of water deficit in leaves. *New Phytologist* 49(1): 81-97.

Yoshida, S., Doughlas, A., Fornojamesh, W., Cock., and Geomez, K.A. 1976. *Laboratory Manual for Physiological Studies in Rice.* IRRI, Los Banos, Philippines.75p.

Zayed, B.A., Elkhoby, W.M., Shehata, S.M., and Ammar, M.H. 2007. Role of potassium application on the productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils. *Afr. Crop Sci. Conf. Proc.* 8: 53-60.

PERFORMANCE OF UPLAND RICE (*Oryza sativa* L.) AS INFLUENCED BY NK LEVELS AND FYM SUBSTITUTION.

SARAVANA KUMAR. M

(2014 - 11 – 209)

Abstract of the Thesis

submitted in partial fulfilment of the requirement

for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
PADANNAKKAD, KASARAGOAD – 671 314

2016

ABSTRACT

The experiment entitled 'Performance of upland rice (*Oryza sativa* L.) as influenced by NK levels and FYM substitution' was conducted in the field of Sri. Ambu, Akshaya Koolome road, Madikkai during the *virippu* season of 2015 to study the influence of different levels of N and K on growth, yield attributes, yield of upland rice and to assess the possibility of substitution of inorganic N by FYM (Farmyard Manure). The experiment was laid out in randomised block design with 10 treatments and 3 replications. The treatments were T_1 - 80 kg N applied as 100% CF (Chemical Fertilizer) and 40 kg K_2O, T_2 - 80 kg N applied as 60 kg CF, 20 kg FYM and 40 kg K_2O, T_3 - 80 kg N applied as 40 kg CF, 40 kg FYM and 40 kg K_2O, T_4 - 100 kg N applied as 100% CF and 50 kg K_2O, T_5 - 100 kg N applied as 75 kg CF, 25 kg FYM and 50 kg K_2O, T_6 - 100 kg N applied as 50 kg CF, 50 kg FYM and 50 kg K_2O, T_7 - 120 kg N applied as 100% CF and 60 kg K_2O, T_8 - 120 kg N applied as 90 kg CF, 30 kg FYM and 60 kg K_2O, T_9 - 120 kg N applied as 60 kg CF, 60 kg FYM and 60 kg K_2O and T_{10} - 60 kg N applied as 100% CF and 30 kg K_2O. A dose of 30 kg P_2O_5 ha^{-1} was uniformly applied to all treatments.

The results of the experiment revealed that application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1} significantly increased the growth and yield attributes such as height, leaf area index, number of productive tillers m^{-2}, panicle weight, panicle length, total spikelets $panicle^{-1}$, filled grains $panicle^{-1}$ and 1000 grain weight.

Higher grain and straw yields were obtained with the application of 120 kg N ha^{-1} with 50 per cent substituted by FYM and 60 kg K_2O ha^{-1} and was on par with 120 kg N ha^{-1} with 25 per cent substituted as FYM and 60 kg K_2O ha^{-1}. Application of 120 kg N ha^{-1} with 25 per cent substituted as FYM and 60 kg K_2O ha^{-1} registered the highest harvest index.

Application of 100 kg N ha^{-1} as chemical fertilizer and 50 kg K_2O ha^{-1} recorded the maximum grain protein content. The uptake of N, P and K differed significantly. The highest uptake of N was recorded by the application of 120 kg N ha^{-1} with 25 per cent substituted by FYM and 60 kg K_2O ha^{-1}. The P uptake was highest for N applied at 100 kg ha^{-1} with 25 per cent substituted as FYM and 50 kg K_2O ha^{-1}. The highest K uptake was recorded by the application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1}.

The soil physical properties were favourably influenced by treatments. The lowest bulk density and highest porosity values were recorded by the application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1}. The highest water holding capacity was recorded by the application of 100 kg N ha^{-1} with 50 per cent substituted as FYM and 50 kg K_2O ha^{-1}.

The available nutrient status of the soil was significantly improved by the application of treatments. At post harvest stage, soil available N and P_2O_5 were found to be enhanced due to the application of 120 kg N ha^{-1} with 25 per cent substituted by FYM and 60 kg K_2O ha^{-1}. The Highest value for soil available K_2O was recorded by the application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1}. There was significant increase in the organic carbon status of the soil after the experiment. The application of 120 kg N ha^{-1} with 50 per cent substituted as FYM and 60 kg K_2O ha^{-1} recorded the highest organic carbon status of the soil.

The highest net return and benefit cost ratio were registered with application of 120 kg N ha^{-1} with 25 per cent substituted by FYM and 60 kg K_2O ha^{-1}.

The results indicated that integrated use of organic and inorganic source of nutrients not only increased the growth, yield attributes and yield of upland rice, but also improved the soil physical, chemical properties and economics of cultivation.

സംഗ്രഹം

കേരളത്തിന്റെ പ്രധാനപ്പെട്ട ഭക്ഷ്യ വിളയാണ് നെല്ല്. എന്നാൽ നെൽകൃഷി ഇന്ന് കേരളത്തിൽ മറ്റു കൃഷികൾക്കുവേണ്ടി തഴയപ്പെടുന്നു. മൊത്തം നെൽകൃഷി ചെയ്യുന്ന സ്ഥലത്തിന്റെ വിസ്തീർണം ഏതാണ്ട് 2 ലക്ഷം ഹെക്ടറും, ഉല്പാദനം 5 ലക്ഷം ടണ്ണുമാണ്. ഈ അവസ്ഥയിൽ കേരളത്തിന്റെ മൊത്തം ആവശ്യത്തിന്റെ 25% താഴെ മാത്രമേ ഇവിടെ നെൽകൃഷി ചെയ്യുന്നുള്ളൂ. ബാക്കി ഇതര സംസ്ഥാനങ്ങളിൽ നിന്നും ഇറക്കുമതി ചെയ്യുന്നു. നെൽകൃഷിയിൽ വിവിധ ഘടകങ്ങളുടെ അധിക ആവശ്യവും കൃഷി ചെയ്യുന്നതിനു വേണ്ട തൊഴിലാളി ക്ഷാമവും, അധിക വേതനവും കൃഷിക്കാരെ ഈ കൃഷിയിൽ നിന്നും പിന്തിരിപ്പിക്കുന്നു. ഇവിടെയാണ് കരനെൽകൃഷിയുടെ പ്രാധാന്യം. മറ്റു കരകൃഷിയെപ്പോലെ തന്നെ കരനെൽകൃഷി ചെയ്യാം. കരനെൽകൃഷിയിലെ ഗവേഷണങ്ങൾ കേരളത്തിൽ കുറച്ചു മാത്രമേ നടന്നിട്ടുള്ളൂ

കരനെൽ കൃഷിയിൽ സംയോജിത വളപ്രയോഗത്തിൽ ഒരു പരീക്ഷണം പടന്നക്കാട് കാർഷിക കോളേജിൽ 2015 ഒന്നാം വിളയിൽ നടത്തി. ആ പരീക്ഷണത്തിൽ പാക്യജനകത്തിന്റെ വിവിധ അളവും, കാലിവളത്തിന്റെ വിവിധ അവളവുകളും പരീക്ഷണ വിധേയമാക്കി. പരീക്ഷണത്തിന്റെ വിവിധ അളവുകൾ താഴെ പറയുന്ന രീതിയിൽ ക്രമീകരിച്ചു.

T_1 – 80 kg N രാസവളമായി മാത്രം കൊടുത്തു, 40 kg K_2O രാസവളമായി മാത്രം.

T_2 – 80 kg N (60kg രാസവളമായും, 20 kg കാലിവളമായും), 40 kg K_2O രാസവളമായി മാത്രം.

T_3 – 80 kg N (40kg രാസവളമായും 40 kg കാലിവളമായും), 40 kg K_2O രാസവളമായി മാത്രം.

T_4 – 100 kg N രാസവളമായി മാത്രം, 50 kg K_2O രാസവളമായി മാത്രം.

T_5 – 100 kg N (75kg രാസവളമായും, 25 kg കാലിവളമായും), 50 kg K_2O രാസവളമായി മാത്രം.

T_6 – 100 kg N (50kg രാസവളമായും 50 kg കാലിവളമായും), 50 kg K_2O രാസവളമായി മാത്രം.

T_7 – 120 kg N മുഴുവനായി രാസവളമായി കൊടുത്തു, 60 kg K_2O രാസവളമായി മാത്രം.

T_8 – 120 kg N (90kg രാസവളമായും 30 kg കാലിവളമായും), 60 kg K_2O രാസവളമായി മാത്രം.

T_9 – 120 kg N (60 kg രാസവളമായും 60 kg കാലിവളമായും), 60 kg K_2O രാസവളമായി മാത്രം.

T_{10} – 60 kg N രാസവളം, 30 kg ഫോസ്ഫറസ് രാസവളം, 30 kg പൊട്ടാഷ് രാസവളം എന്ന രീതിയിൽ

ഈ പരീക്ഷണങ്ങളിൽ നിന്നും താഴെ പറയുന്ന നിഗമനങ്ങളിൽ എത്തിച്ചേർന്നു.

120 kg N (60 kg രാസവളമായും, ബാക്കി 60 kg കാലിവളമായും) കൊടുക്കുന്നതാണ് ഉയരം കൂടിയ ചെടിക്കും, കൂടുതൽ ചിനപ്പുകളുണ്ടാക്കുന്നതിനും നല്ലതെന്ന് തെളിഞ്ഞു. കൂടുതൽ നെൽമണികൾ ഉണ്ടാക്കുന്നതിനും ഈ വളപ്രയോഗമാണ് നല്ലതെന്ന് തെളിഞ്ഞു.

നെല്ലിന്റെ വിളവിനും വൈക്കോൽ ഉല്പാദനത്തിനും 120 kg N (60 kg രാസവളമായും, ബാക്കി 60 kg കാലിവളമായും) കൊടുക്കുന്നതാണ് നല്ലതെന്ന് തെളിഞ്ഞു.

സംയോജിത വളപ്രയോഗം മണ്ണിന്റെ ഘടനയേയും അനുകൂലമാക്കി. മണ്ണിൽ ജൈവാംശത്തിന്റെയും ഈർപ്പത്തിന്റെയും അളവ് കൂടി. മണ്ണിലെ ഈർപ്പത്തിന്റെ പൂരിതാവസ്ഥയിലെ അളവ് ഗണ്യമായി കൂടിയതായി കണ്ടു. സംയോജിത വളപ്രയോഗം വഴി കർഷകന്റെ ലാഭവും ഗണ്യമായി വർദ്ധിച്ചതായി തെളിഞ്ഞു.

ഈ പരീക്ഷണത്തിൽ നിന്നും വ്യക്തമായ നിഗമനത്തിൽ എത്താൻ കഴിഞ്ഞു. സംയോജിത വളപ്രയോഗം വഴി (120 kg N - 60 kg രാസവളമായും, ബാക്കി 60 kg കാലിവളമായും) കരനെൽ ചെടിയുടെ വളർച്ചയേയും ഉല്പാദന ഘടകങ്ങളേയും അനുകൂലമാക്കി കൂടുതൽ വിളവ് നൽകുന്നതായി കണ്ടു. കൂടാതെ കർഷകന്റെ അറ്റാദായവും, മണ്ണിന്റെ പോഷകമൂലകങ്ങളുടെ അളവും വർദ്ധിക്കുന്നതായി തെളിഞ്ഞു.

APPENDIX

Appendix I. Weather parameters during the standard weeks from 18th to 36th

Standard week	Temperature (°C)		Relative humidity (%)	BSS hours	Rainfall (mm)	Evaporation (mm)
	Maximum	Minimum				
18 (Apr 30 - May 6)	33.07	23.44	76.00	6.71	15.00	3.99
19 (May 7 - 13)	32.57	22.79	79.00	2.27	89.30	3.00
20 (May 14 - 20)	32.11	23.86	79.43	4.03	11.80	2.56
21 (May 21-27)	32.90	25.14	76.36	5.93	1.90	3.97
22 (May 28 - June 3)	32.50	24.50	79.21	3.90	8.10	2.93
23 (June 4 - 10)	31.46	20.67	82.14	2.81	95.00	1.77
24(June 11 - 17)	29.87	22.39	88.43	0.36	154.10	1.51
25 (June 18 - 24)	30.57	24.00	85.36	0.73	152.70	1.49
26 (June 25-30)	30.27	23.83	87.25	2.15	130.80	3.14
27 (July 1 - 7)	31.47	24.00	84.86	6.07	70.60	3.83
28 (July 8- 14)	29.71	23.66	88.07	2.14	279.40	2.20
29 (July 15- 21)	28.50	23.37	93.71	0.37	385.40	1.53
30 (July 22- 28)	29.87	23.14	88.07	1.40	164.60	1.83
31 (July 29 - Aug 4)	30.71	23.04	88.71	2.46	58.80	3.16
32 (Aug 5- 11)	29.93	23.29	89.14	0.53	214.50	2.49
33(Aug 12- 18)	30.23	23.77	86.43	2.19	88.30	2.80
34(Aug 19- 25)	30.50	23.61	85.79	3.56	79.10	2.99
35(Aug 26- Sep 1)	30.89	22.96	83.00	2.76	108.60	4.00
36(Sep 2 - 8)	31.39	23.17	87.29	2.03	213.80	3.50