INTEGRATED NUTRIENT APPROACH ON PRODUCTIVITY ENHANCEMENT OF RICE IN OXYAQUIC FLUENT SOILS OF NORTHERN KERALA

By

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(2016-11-038)

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, KASARAGOD 671314

KERALA, INDIA

2018

DECLARATION

I, hereby declare that this thesis entitled **"INTEGRATED NUTRIENT APPROACH ON PRODUCTIVITY ENHANCEMENT OF RICE IN OXYAQUIC FLUENT SOILS OF NORTHERN KERALA"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

I take this opportunity to look back on the path traversed during the course of this endeavour and to remember the guiding faces behind the task with a sense of gratitude.

It is with great respect I express my deep sense of gratitude and indebtedness to **Dr. Bridgit T. K.**, Chairman of my Advisory Committee, Professor, Department of Agronomy, College of Agriculture, Padannakkad for her expert advice, valuable suggestions, inspiring guidance, enthusiastic approach, constructive criticisms, unreserved help and kind concern during the conduct of this research work and preparation of thesis. I value her knowledge and wisdom which nurtured this research in right direction without which fulfillment of this endeavor would not have been possible, she has been a support to me during each step of this venture and my obligation to her lasts forever, I really consider it my greatest fortune in having her guidance for my research work.

I take this opportunity to express sincere thanks to my advisory committee consisting **Dr.P. R. Suresh.**, Associate Dean, College of Agriculture, Padannakkad, **Dr. Yamini Varma C. K.**, Associate Professor, Department of Plant Pathology, College of Agriculture, Padannakkad, and **Dr. G. V. Sudarsana Rao**, Professor and Head, Department of Plant Physiology, College of Agriculture, Padannakkad, for their constant help, valuable suggestions during the investigation, sensible criticism in animating and ameliorating the manuscript and valuable counsel during the period of study. I pay my heartful thanks to **Dr. M. Govindan** and **Dr. A. Rajagopalan**, former Associate Dean, College of Agriculture, padannakkad for providing me all facilities from the University during the whole course of study.

I express my sincere thanks to my teachers, **Dr. P.K. Mini, Dr. M. Sreekumar, Dr.Sujatha N., Dr. Binitha, Dr. Ramesha B., Mrs. Sangeetha K. G., Dr. N. Rajivasudevan, Dr. Chandran, Ms. Dona, Mrs. Rameeza, Ms. Limisha, Mr. Shivamurthy, Dr. Rajesh kumar, Mr. kiran, Mr. Ajamal, Mr. Arunjith, Mr.**

Ashique, Mrs. Namitha, Ms. Anusha Anwar, Mrs. Rejitha, Ms. Beena, Ms. Amrutha, Ms. Neethu S Kumar, Dr. Shruthi, Ms. Anju *for their expert teaching, moral support and valuable guidance during the course of study.*

My diction doesn't seem too rich enough to provide suitable words to articulate my sincere and heartfelt gratitude to my batchmates ***Shiva, Ajeesh, Hassain, Anto, Mubarack, Amrutha, Eurekha, Ashwini, Laya, Sreelaja, Shana and Manju,*** *my seniors,* ***Swaroop, Ashiba, Ashok, Sunu, Sherin, Ashwathy, Shanti, Ebimol, Vishnupriya, Vineetha, Nusruth and Giridhari,*** *and my juniors* ***Chethan, , Adarsh, Giffy, Roshni,*** *who has given sound and fruitful advice, timely help and also a constant encouragement throughout my venture of this study.I specially thank to* ***Remya chechi*** *who has given sound and fruitful advice, timely help and also a constant encouragement throughout my venture of this study.*

I am thankful to ***Kerala Agricultural University*** *for financial support in the form of fellowship during the tenure of the M.Sc. (Agriculture) programme.*

I specially thank to ***Chethan*** *and other farmers who has given sound and fruitful advice, timely help and also a constant encouragement throughout my venture of this study. I express gratitude to my friends* ***Anjana, Unni*** *and other friends for their support.*

This research work would be incomplete if I do reckon the sacrifices, love, affection and support of my family members, it is immense pleasure to express my sincere gratitude and heartfelt respect to my grandparents ***Late. Sri. Kitta moolya*** *and* ***Late. Smt. Seetha,*** *Father* ***Sri. Kunha moolya,*** *mother* ***Smt. Kamala*** *and brothers* ***Krishna Prasad and Vinod Kumar*** *and my whole* ***Family.***

God Almighty for all the bountiful blessings showered on me at each and every moment without which this study would never have seen light.

Any omission in this acknowledgement does not mean lack of gratitude.

Chanchala. A

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%	-	Per cent
@	-	At the rate of
BCR	-	Benefit: cost ratio
BSS	-	Bright sun shine
B	-	Boron
Ca	-	Calcium
CEC	-	Cation exchange capacity
cm	-	Centimeter
cm^2	-	Square centimeter
Cu	-	Copper
CV	-	Coefficient of variation
DAS	-	Days after sowing
DAT	-	Days after transplanting
dSm^{-1}	-	deci Siemens per meter
EC	-	Electric conductivity
et al	-	And others
ET	-	Evapotranspiration
Fe	-	Iron
Fig.	-	Figure
FYM	-	Farmyard manure

g kg^{-1}	-	Gram per Kilogram
g	-	Gram
ha^{-1}	-	Per hectare
K	-	Potassium
K_2O	-	Potash
KAU	-	Kerala Agricultural University
kg ha^{-1}	-	Kilogram per hectare
kg^{-1}	-	Per kilogram
LAI	-	Leaf Area Index
lit^{-1}	-	Per liter
Ltd.	-	Limited
m	-	Meters
M	-	Million
m^{-2}	-	Per square meter
Mg	-	Magnesium
mg kg^{-1}	-	milli gram per kilogram
ml	-	Milliliter
mm	-	Milli meter
Mn	-	Manganese
N	-	Nitrogen
NS	-	Not significant

^{o}C	-	Degree Celsius
^{o}E	-	Degree East
^{o}N	-	Degree North
P	-	Phosphorous
pH	-	Soil reaction
P_2O_5	-	Phosphate
plant^{-1}	-	Per plant
Pvt.	-	Private
RARS	-	Regional Agricultural Research
RBD	-	Randomised Block Design
RDF	-	Recommended dose of fertilizers
RLWC	-	Relative Leaf Water Content
S	-	Sulphur
Si	-	Silicon
SPAD	-	soil plant analysis development
t ha^{-1}	-	Tonnes per hectare
Zn	-	Zinc

INTRODUCTION

1. INTRODUCTION

Organic farming has emerged as an important priority area especially in northern parts of Kerala in view of the growing demand of safe and healthy food, long term sustainability and concern on environmental pollution associated with indiscriminate use of agrochemicals. Though the use of chemical inputs in agriculture is inevitable to meet the growing demand for food, an integrated approach of organics and inorganics especially micronutrients for providing an environment suited for growth and development is an appropriate choice of the time. The integrated approach with restricted use of chemicals is reported to impart pest and disease resistance to the crop along with the exploitation of maximum production potential.

More than 68 per cent of the Kerala soils are lateritic, which is mostly acidic in nature in the wetland rice soils of the tropics. Several studies have shown that acid soils, in addition having a lower p^H, are low in bases like calcium (Ca), magnesium (Mg) and potassium(K), lacking in phosphorus (P) and high in iron (Fe), manganese (Mn) and aluminium (Al). In northern parts of Kerala the soils are mostly laterite and availability of N, P and K is less. The crop productivity has been found to be low due to nutritional imbalance and there is substantial scope for improving the productivity of these acid soils by management practices. In the midland rice fields of northern Kerala, the soils are oxyaquic fluent, highly acidic, rich in iron (Fe) and the yield of rice is lower than actual yield potential of the crop.

Supplementation of secondary nutrients will boost the growth and yield of rice grown in lateritic lowlands. As micronutrients play an important role in all metabolic and cellular functions of the plant, application of micronutrient will enhance the growth characters due to improved photosynthetic and other metabolic activities related to cell division and cell elongation (Hatwar *et al.*, 2003). The micronutrient deficiencies in soil not only inhibit the crop productivity but also decline the quality of produce (Patel and Singh, 2010). Greater exhaustion of available micro and

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secondary nutrients in the soil is due to the unscientific fertilizer management practices where fertilizer application is intended to meet the needs of major nutrients (NPK) only.

Micronutrient deficiencies are observed in most of the rice growing tracts of Kerala. The micronutrient combination formulated and developed by Kerala Agricultural University (KAU) is found to be effective in banana and certain other crops. Its effect on rice is not studied in detail. 'Sampoorna KAU multi-mix' is a crop-specific formulation for use in rice, banana and vegetables. It is a nutrient mixture with soluble materials suitable for foliar spray and it is released from Regional Agricultural Research Station (RARS), Pattambi, KAU. 'Ayar' is an another nutrient mixture mainly recommended for banana, is released from College of Agriculture Padannakkad. The effect of these nutrient mixtures in rice will be studied in detail in this experiment.

In addition to 17 essential elements, there are other elements that promote plant nutrition, such as silicon (Si). It is not considered as an essential element for higher plants, but it is beneficial for the healthy growth and development of many plant species particularly graminaceous plants such as rice, sugarcane *etc*. Silicon is considered as a beneficial element for rice and is agronomically necessary for improving plant growth and sustaining rice productivity. In addition to yield enhancement in rice, Si has several other advantages like increasing nutrient availability (N, P, K, Ca, Mg, S, Zn), diminishing nutrient toxicity (Fe, Mn, Al) and minimizing biotic and abiotic stress in plants. Continued supply of silicon source is needed because of the silicon (Si) is not much mobile in plants, therefore the application of Si to soil or plant is basically useful in laterite derived paddy soils, not only to boost the yield but also to alleviate the iron toxicity problems. Bridgit (1999) reported that K and Si have significant influence in increasing the productivity of rice in lateritic alluvium by alleviating the ill effects of Fe and thereby increasing the nutrient availability in the soil. Hence the effect of Si application also will be studied in this trial.

Soil test crop response (STCR) is considered as an efficient tool for formulating fertilizer schedule crops. In Kerala, most commonly and widely used method for developing fertilizer recommendation to crop is soil test based fertilizer recommendation. This technique also will be evaluated in this study.

In higher agricultural production system, imbalanced use of fertilizers creates problems of soil fertility exhaustion and plant nutrient imbalances not only of major, but also of secondary and micronutrients. Balanced nutrient application through organics and inorganics will help to impart resistance in plants, reduce the use of chemical pesticide and ultimately leads to higher productivity.

Hence the study on "Integrated nutrient approach on productivity enhancement of rice in oxyaquic fluent soils of Northern Kerala" was taken up with the following objectives

1. To study the effect of organic manures along with micronutrient on growth, yield and nutrient uptake of wetland rice.
2. To study the effect of organic manures along with micronutrient on pest and disease incidence and economics of wetland rice.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In this chapter literature belongs to influence of different nutrient practices on growth parameters, yield attributes, nutrient uptake, economics, pest and diseases of rice were reviewed critically and expounded in this chapter.

2.1. EFFECT OF DIFFERENT TREATMENTS ON RICE

2.1.1 Growth Parameters

2.1.1.1 Effect of N on growth characters of rice

Quyen and Sharma (2003) conducted a field experiment at the Indian Agricultural Research Institute, New Delhi, during the *Kharif* season and recorded that grain yield of rice improved significantly with increasing rate of N application from 0 to 60 kg ha^{-1} (50 % recommended fertilizer dose).

Balasubramaniyam and Palaniappan (2005) revealed that nitrogen played an important role in all living plant tissues and was a constituent of protein, enzymes, hormones, vitamins, alkaloids, chlorophyll *etc*. Plant growth was negatively affected in its absence (Reddy and Reddy, 2005).

Maqsood *et al.* (2005) confirmed that application of 150 kg N ha^{-1} significantly increased the plant height whereas highest leaf area index was recorded by the application of 125 kg N ha^{-1}. Naseer and Bali (2007) observed that leaf area index at flowering stage was significantly increased by the application of nitrogen up to 120 kg N ha^{-1}.

Sharief *et al.* (2006) confirmed that increasing nitrogen fertilizer rates up to 150 kg N ha^{-1} was produced maximum plant height, flag leaf area and number of tillers m^{-2}.

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Manzoor *et al.* (2006) observed higher plant height by the increasing N levels from 0-175 kg ha^{-1}.

Awan *et al.* (2011) reported that application of the 110 kg N ha^{-1} produced maximum plant height (80 cm) and application of 156 kg N ha^{-1} recorded maximum 1000 grain weight (25.40 g).

2.1.1.2 Effect of P growth characters of rice

According to Guo *et al.* (2002), in rice phosphorus was an essential nutrient for root growth, root activities and dry matter accumulation.

Ali *et al.* (2006) recorded the highest dry matter production by the application of 60 kg P_2O_5 ha^{-1} in rice crop. Watanabe *et al.* (2007) conducted an experiment at Japan and showed that pre-transplanting phosphorus application increased the total dry weight, leaf area and tiller number in lowland rice.

Sharma *et al.* (2009) recorded that the number of tillers $hill^{-1}$ increased significantly with the application of diammonium phosphate (DAP) @ 35 kg ha^{-1} and mussoorie rock phosphate (MRP) @ 52.5 kg P ha^{-1} and the plant height increased significantly when the rate of P_2O_5 application was increased from 0 to 35 kg ha^{-1} either as DAP or MRP.

Application of 80 kg P_2O_5 ha^{-1} recorded the highest values of growth parameters *viz*., plant height, leaf area index and total tillers m^{-2}(Prakash *et al*., 2013).

Meena (2014) concluded that increase in the phosphorous levels up to 60 kg P_2O_5 ha^{-1} enhanced the growth attributes like plant height, number of tillers $hill^{-1}$, LAI at 90 DAT and dry matter accumulation at harvest.

2.1.1.3 Effect of K on growth characters of rice

Thakur *et al.* (1993) reported that increased application of K level upto 66 kg K_2O ha^{-1} increased the total number of tillers $hill^{-1}$.

According to Sorour *et al.* (1998), the plant height was significantly increased by the application of K fertilizer from 57 to 114 kg K ha^{-1}. Kumar *et al.* (2005) claimed that the growth of hybrid rice was significantly influenced by the addition of 60 kg K_2O ha^{-1}.

Mini (2005) reported that plant height was increased at harvest by the application of potassium @ 50 kg ha^{-1}.

Shekara *et al.* (2011) recorded significantly higher plant height, more number of tillers $hill^{-1}$ and total dry matter accumulation by the application of potassium 62.5 kg K_2O ha^{-1}. Uddin *et al.* (2013) recorded that application of 60 kg K_2O ha^{-1} produced the tallest plants.

An experiment conducted at Nagaon, Assam showed maximum plant height at 50 kg K ha^{-1} application. However, it was comparable with 37.5 kg K ha^{-1}(Dutta *et al.*, 2013). Ajaykumar (2015) reported that application of 50 kg K_2O ha^{-1}produced maximum number of tillers $hill^{-1}$.

2.1.1.4 Effect of secondary nutrients on growth characters of rice

Sadapal and Das (1961) reported that application of magnesium increased the production of tillers.

According to Padmaja and Verghese (1965), application of magnesium as magnesium carbonate and silicon as sodium silicate increased the plant height and panicle length. According to Bustrom (1968) calcium played an important role in cell elongation and cell division.

For producing one tone hulled grain 1.67 kg sulphur was needed in rice (Suzuki 1977). Liu *et al.* (1989) observed organic matter accumulation in paddy soil was decreased with application of sulphur, but available phosphorous and sulphur and released potassium from the clay crystal lattice were increased.

When the soil acidity increased the proportion of exchangeable Al increased in strongly acid soil. Al toxicity was the major limiting factor for plant growth and crop production (Foy, 1992). Tandon (1986) and Nair (1995) recorded that in India more than 80 % soils are deficit in sulphur.

Application of S up to 60 kg ha^{-1} was increased the growth attributes and yield (Raju *et al.*, 1994). Choudhury and Khanif (2002) observed increased grain and straw yields by the application of Mg fertilizer to the rice field. However, the uptake of Mg and K also significantly increased.

Sheela *et al.*, (2006) and John *et al.*, (2005) revealed that 70 % of the soil samples collected from different parts of four districts of Kerala *viz.*, Palghat, Thrissur, Kollam and Trivandrum were grouped as S deficient.

According to Lekshmi (2016) the application of calcium silicate recorded the maximum number of panicles $hill^{-1}$, number of spikelets $hill^{-1}$, 1000 grain weight and minimum number of chaffy grains $panicle^{-1}$.

2.1.1.5 Effect of micronutrients on growth characters of rice

According to Tandano and Yoshida (1978) high Mn content in rice tissue was associated with high yields. De Datta (1981) reported that the critical limits of deficiency and toxicity of Mn in rice plants were 20 ppm and 2500 ppm, respectively.

Das (1986) reported that application of $ZnSO_4$ @ 25 kg ha^{-1} significantly enhanced the plant height and number of tillers in lateritic soil. Pulla rao and Shukla

(1996) recorded highest plant height, number of tillers and dry matter production in sandy clay loam soils of Varanasi by the application of 30 kg $ZnSO_4$ ha^1.

Application of Zn increased the plant height, tillers $plant^{-1}$ LAI, root growth and yield (Salam and Subramanian, 1993). Tomar *et al.* (1994) reported that application of $ZnSO_4$ @ 7.5 kg ha^{-1} significantly improved dry matter production on clay loam soil. According to Chapahle and Badole (1999), application of $ZnSO_4$ @ 15 kg ha^{-1} significantly improved the plant height on silt clay loam soil.

An experiment was conducted in greenhouse with flooded rice cv. with different treatments including organic, humic gley and poorly humic gley soil was given with 0, 0.75, 1.5, 2.25 or 3.0 mg Cu kg^{-1} soil and found that Cu reduced shoot dry matter production (Bertoni *et al.*, 1996).

Olaleye *et al.* (2001) reported that with increasing Fe^{2+} content dry matter yield, number of tillers pot^{-1} and height of the two rice cultivars were decreased. Mehraban *et al.* (2008) recorded maximum plant growth of rice at iron concentration of 10 and 50 mg L^{-1} and growth decline due to iron toxicity was observed at iron concentration of 250 and 500 mg L^{-1}.

Chaudhury and Khanif (2002) reported that single or combined application of Cu and Mg significantly improved rice yield and agronomic efficiency. Kulandaivel *et al.* (2004) observed that application of 30 kg $ZnSO_4$ along with 5 kg $FeSO_4$ ha^{-1} significantly improved the number of tiller m^{-2}, and dry matter production on sandy clay loam soil.

Zayed *et al.* (2011) conducted field trial for rice on the effect of Zn , Fe and Mn as single or combined application in soil to the rice and he observed that the application of these micronutrients either as single or in combination significantly improved the plant height and panicle length.

Suresh and Salakinkop (2016) conducted a study at Agricultural Research Station (MARS), Dharwad on rice to study the biofortification of zinc and iron. The study revealed that combination of soil and foliar application of $ZnSO_4$ and FeSO4 each @25 kg ha^{-1} and @0.5% respectively improved the growth parameters *viz.*, number of tillers per meter row length, LAI, soil plant analysis development(SPAD) chlorophyll meter value, leaf area and total dry matter production.

2.1.1.6 Effect of Silicon on growth characters of rice

In laterite soil application of sodium silicate enhanced the tillering, plant height, depth of root penetration and the proportion of thicker to thinner roots (Padmaja and Verghese, 1966). According to Sadanandan and Verghese (1968), in laterite soil, higher tillering capacity and better root development was observed due to the application of Si. They also reported that sodium silicate application at initial stage increased the number of tillers, but calcium magnesium silicate application performed better at the later stages.

Yoshida *et al.* (1969) have shown that decrease in erectness of rice leaves following excess of N application can be mitigated if Si is supplied to the nutrient solution.

Ahmad *et al.* (2013) concluded that increase in level of applied silicon improved the number of productive tillers and total number of tillers m^{-2}. Reduction in kernel sterility due to silicon application might be due to balanced nutrition, optimum metabolic activities or nullification of stresses.

Gholami and Falah (2013) reported that the plant height, number of tillers $plant^{-1}$ and number of productive tillers were improved by the application of Si fertilizers in rice crop.

2.1.1.7 Effect of Organic Manures on growth characters of rice

According to Rajput and Warsi (1991), the number of tillers hill^{-1} was increased by the application of FYM @ 10 t ha^{-1} with and without inorganic nitrogen on silt loam soil.

In sandy loam soil application of N along with 12 t of FYM ha^{-1} at different growth stages improved the tiller production (Tripathi *et al.,* 1996). Jadhav *et al.* (1998) concluded that there is a chance of substituting 25 to 50 kg N ha^{-1} N as FYM for improving dry matter production in rice.

According to Usman (2001), the effects of organic sources alone on the growth parameters were not significant in rice plant due to their slow supply of nutrients. Hence growth parameters were enhanced when the organic manures applied along with mineral fertilizers at the rate of 100-75-60 kg NPK ha^{-1}.

According to Bhattacharya *et al.* (2003) application of FYM @ 9.0 t ha^{-1} recorded the highest plant height and dry matter accumulation at 45 and 90 DAT.

According to Kumar and Singh (2006), growth parameters *viz.* plant height, LAI, CGR and number of effective tillers, significantly improved by the application of organic manure.

Shekara *et al.* (2011) recorded the improved plant height (92.81 cm), number of productive tillers hill^{-1} (27.51) and total dry matter accumulation (106.89 g hill^{-1}) by the application of farmyard manure at 20 t ha^{-1}

2.1.1.8 Effect of Integrated nutrient management (INM) on growth and growth characters of rice

Mohapatra (2003) reported that application of S + Zn + B along with RFD @ 120 – 60 - 60 N - P - K kg ha^{-1} resulted in vigorous crop growth at all phases of

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growth and produced maximum dry matter followed by application of S + Zn + RFD which remained at par with Zn + B + recommended fertilizer dose (RFD). Application of Zn @ 5 kg ha^{-1} along with RFD was found to be superior in recording all higher growth parameters than application of FYM @ 5 t ha^{-1}+RFD.

Sahoo (2005) revealed that application of Zn 5 kg ha^{-1}($ZnSO_4$) + RFD @ 60-30-30 N-P-K kg ha^{-1} along with green manuring recorded highest growth parameters than foliar application of Zn-EDTA +RFD.

According to Maiti *et al.* (2006), maximum plant height, dry matter accumulation and LAI were obtained when the crop received 125 % recommended doses of fertilizer along with 5 tonnes of FYM ha^{-1}. Banterng *et al.* (2010) reported that shoot dry matter, LAI, tillers hill^{-1} were improved by using the combination of FYM and inorganic fertilizers.

Alagappan And Venkitaswamy (2016) reported that higher plant height and panicle m^{-2} were recorded by the application of 100 % recommended dose of nitrogen (RDN) through green manure followed by 25 % RDN through each organic manures combination.

Mondal *et al.* (2015) revealed that plant height, number of tillers m^{-2}, leaf area index (LAI), dry matter accumulation (DMA) and crop growth rate (CGR) were significantly increased by the application of 50 % recommended dose of fertilizer (RDF) + 50 % recommended dose of nitrogen (RDN) through mustard oil cake (MOC) and 75 % RDF + 25 % RDN through MOC + biofertilizer.

2.1.2 Yield and Yield attributes

2.1.2.1 Effect of N on yield and yield attributes of rice

Sharma and Tomar (1997) reported that increase in nitrogen level up to 100 kg ha^{-1} was recorded higher yield and yield attributes of different rice varieties.

Ramamoorthy *et al.* (1997) claimed that grain yield was significantly increased due to increasing rate of N application up to 200 kg ha^{-1} in rice. According to Singh and Sharma (2000), significant increase in grain and straw yield of rice was observed when the rate of N application was increased from 0 to 120 kg N ha^{-1}. Sharief *et al.* (2006) observed that addition of nitrogen fertilizer @ 120 kg N ha^{-1} was resulted in maximum grain yield and its quality as well as reduced environmental pollution.

Application of 125 kg N ha^{-1} was enhanced the productive tillers m^{-2}, 1000-grain weight, harvest index and yield of rice crop (Maqsood *et al.,* 2005). According to Srinivasan *et al.* (2007), the grain yield was improved by the application of nitrogen up to 150 kg ha^{-1}.

Zaidi and Tripathi (2007), observed a significant improvement in grain yield, straw yield, number of panicles m^{-2} and panicle weight with every increase in dose of nitrogen up to 150 kg N ha^{-1}. Application of N up to 120 kg ha^{-1} significantly enhanced the grain yield of rice up to 62 per cent (Singh *et al.*, 2007).

Application of N up to 90 kg ha^{-1} increased the dry matter accumulation whereas, application of 120 kg ha^{-1} N improved number of grains per panicle (Naseer and Bali, 2007).

Pandey *et al.* (2008) reported that with increasing levels of nitrogen from 50 to 150 kg N ha^{-1}, the number of effective tillers m^{-2}, number of filled grains $panicle^{-1}$, test weight and grain yield of rice was increased to maximum.

Awan *et al.* (2011) reported that application of 156 kg N ha^{-1} produced maximum number of grains $panicle^{-1}$ (132.97), straw yield (9662.03 kg ha^{-1}) and grain yield (5461.03 kg ha^{-1}) in rice.

Murthy *et al.* (2013) conducted a field experiment at Andhra Pradesh Rice Research Institute, Maruteru, during rabi seasons of 2007, 2008 and 2009 and reported that increase in recommended dose of N from 100 % (120 kg ha^{-1}) to 125 % and 150 % increased the grain yield up to 11.5 % and 6.3 % respectively. They have also reported that increases in P & K doses from 100 to 125 % (P from 60 to 75 and K from 40 to 50 kg ha^{-1}) also improved grain yield significantly.

2.1.2.2 Effect of P on yield and yield attributes of rice

Sharma and Tomar (1997) reported that phosphorus levels up to 40 kg ha^{-1} increased the yield attributes and yield of rice varieties. According to Singh *et al.* (2002), the application of 60 kg P_2O_5 ha^{-1} was significantly increased the rice yield.

Shivay *et al.* (2002) revealed that the phosphorous fertilization had a prominent effect on rice grain yield and application of 50 kg P_2O_5 ha^{-1} led to significant improvement in the grain yield of rice and further increase in P and not have any effect on yield. Application of P up to 35 kg ha^{-1} was significantly enhanced the yield parameters and yield (Sharma *et al.*, 2009).

Li *et al.* (2010) concluded that for enhancing rice yield application of phosphatic fertilizer is most important. According to Chamani *et al.* (2015) the grain, and straw yield were improved with the application of P level up to 83 kg ha^{-1}.

Prakash *et al.* (2013) reported that the highest number of effective tillers m^{-2}, grain and straw yield were recorded with application of 80 kg P_2O_5 ha^{-1} and it was on par with application of 60 kg P_2O_5 ha^{-1}.

A field experiment was conducted to study the effect of phosphorus levels and bio-organic sources on growth and yield of wetland rice cv. HUR-105 and the result revealed that growth attributes, yield attributes, grain and straw yields were increased by the application of phosphorus up to 100 % RDP (60 kg P_2O_5 ha^{-1}) (Meena, 2014).

2.1.2.3 Effect of K on yield and yield attributes of rice

Ojha and Baroova (1997) recorded highest grain yield by the application of 60 kg K_2O ha^{-1} in rice. However, Singh *et al.* (2000) recorded the highest grain and straw yield by the application of 90 kg K_2O ha^{-1} on rice. Application of 50 kg K_2O ha^{-1} in two equal splits at basal and tillering stage observed significantly higher grain and straw yield (Mathad *et al.*, 2002).

In hybrid rice higher grain and straw yield was recorded by the application 60 kg K_2O ha^{-1}(Kumar *et al.*, 2005).

An experiment was conducted at OUAT, Bhubaneswar and observed that increasing doses of potassium up to 80 kg K_2O ha^{-1} recorded more number of fertile grains $panicle^{-1}$ in hybrid rice PA 6201 (Das *et al.,* 2009)

According to Dutta *et al.* (2013) addition of 37.5 kg K ha^{-1} improved yield attributes like panicle length, grains $panicle^{-1}$, panicles m^{-2} and test weight and also the grain and straw yield.

2.1.2.4 Effect of secondary nutrients on yield and yield attributes of rice

Kido (1958) concluded that application of calcium increased the 1000 grain weight. According to Nagai (1959) magnesium fertilizer application increased the yield in different crops.

Chakrabanhy *et al.* (1961), observed an increase in yield due to the application of lime in rice field.

Varghese and Money (1964) conducted a pot culture to study and revealed that application of fertilizers(40: 40: 40 NPK ha^{-1}) with calcium and magnesium increased the grain yield and nitrogen content of grains.

Combination of Mg and Si was influenced the early ripening of grain which resulted in increased 1000 grain weight and also significantly increased grain and straw yield (Padmaja and Verghese, 1965). Under flooded condition application of lime decreased the Fe content and increased the Mn content and rice yield (Verma and Tripati 1987).

Application of 40 kg S ha^{-1} in rice recorded the highest grain (5065 kg ha^{-1}) and straw (7524 kg ha^{-1}) yield in rice (Bhuvanesswari and Sreeramchandhrasekharan, 2006). According to Oo *et al.* (2007), P concentration in grain and straw was significantly increased by the application of 20 kg S ha^{-1} and it is on par with 40 and 60 kg S ha^{-1}

Lekshmi (2016) reported that application of fertilizer based on POP recommendation of KAU along with calcium silicate increased the grain yield upto 6.90 t ha^{-1}.

2.1.2.5 Effect of micronutrients on yield and yield attributes of rice

According to Harikrishnan and Koshy (1981) the grain yield was increased by the applications of different levels of N and MnO_2.

Nampoodiri and Subramoniam (1982) revealed that foliar application of 0.5 per cent Zn or soil application of $ZnSO_4$ @ 20 kg ha^{-1} significantly increased the grain yield in rice.

Studies conducted at RRS Moncompu revealed that, higher yield of rice was recorded by soaking the seeds in one per cent zinc sulphate solution and the application of $ZnSO_4$ @ 20 kg ha^{-1}(KAU, 1988). Koruth *et al.* (1995) concluded that grain yield of rice increased by adequate supply of different micronutrients.

Application of $ZnSO_4$ @ 25 kg ha^{-1} significantly improved the grain and straw yield in sandy loam soil (Ramadass *et al*., 1995).

Liew *et al.* (2010) showed that the application of a special formulation of fertilizer with 29.9 kg of K, 4 kg of Cu, 4 kg of Zn, 3.6 kg of Mn, 2.43 kg of Mg and 2.25 kg of B could increase the rice yield by 27 %, from 4.62 tonnes to 5.87 tonnes ha^{-1}.

Mustafa *et al.* (2011) reported that maximum paddy yield (5.21 t ha^{-1}) was obtained due to the basal application of Zn at the rate of 25 kg ha^{-1} as well as Zinc application also increased the crop growth rate of rice.

The application of Zn at 1 kg ha^{-1} and Cu at 2 kg ha^{-1} with NPKS fertilizers showed as a potential combination for improving the growth and yield of rice (Siddika *et al.,* 2016). Kumar *et al.* (2016) showed that maximum productivity, profitability, as well as, quality of aromatic rice cv. HUBR 2-1 was obtained with the application of 10 kg Zn and 15 kg Fe along with 5 kg Mn ha^{-1}.

Combined soil application of $ZnSO_4$ and $FeSO_4$ each @ 25 kg ha^{-1} and foliar spray of $ZnSO_4$ and $FeSO_4$ each @ 0.5 % significantly improved the yield attributing characters like productive tillers m^{-2}, number of filled grains $panicle^{-1}$, grain yield (3739 kg ha^{-1}) and straw yield (5539 kg ha^{-1}) in rice (Suresh and Salakinkop, 2016).

Rani and Latha (2017) conducted an experiment in College of Horticulture, Vellanikkara, Kerala to study the influence of secondary and micronutrients on nutrient uptake and yield of rice in Kole lands. This study revealed that higher uptake of nutrients were observed by the application of boron and calcium silicate and lower uptake of Fe and Mn, thereby resulted in higher grain yields of 7.67 t ha^{-1} and 7.18 t ha^{-1} respectively. Application of magnesium resulted in higher straw yield.

2.1.2.6 Effect of Silicon on yield and yield attributes of rice

Si was required in large amount to promote the growth of rice (*Oryza sativa* L.) and to increase the grain yield (Okuda and Takahashi, 1962). Vijayakumar (1977) reported that application of silica increased the thousand-grain weight and also observed the better filling of grains.

According to Takahashi (1995), application of silicon increased the number of spikelets panicle^{-1} and spikelet fertility. According to Korndorfer *et al.* (2001) the number of grains per panicle and the percentage of ripening was increased by the adequate supply of silicon to rice from tillering to elongation stage and also minimizing the lodging incidence. Sunilkumar and Geethakumari (2002) recorded higher number of spikelets panicle^{-1} filled grains panicle^{-1} and panicle weight by the silica application

singh *et al.* (2006) conducted field experiment at Varanasi during rainy season of 1999 - 2002. This study suggested that application of 180 kg Si ha^{-1} as full basal dose will maintain crop productivity under high intensity rice ecosystem

Bridgit and Potty (2007) conducted experiment during *Kharif* and *Rabi* seasons as multilocational trials. The study revealed that application of higher level of potassium (120 kg ha^{-1}), silica (sodium silicate 250 kg ha^{-1}) and lime (150 kg ha^{-1}) increased the rice yield by reducing ill effects of Fe and Mn in laterite soils.

Gholami and Falah (2013) and Ahmad *et al.* (2013) claimed that application of Si fertilizers improved the growth parameters; enhance the yield, yield attributes and quality of rice crop.

Ahmad *et al.* (2013) revealed that application of silicon and boron significantly increased the kernel weight, biological yield, protein content and starch content in grain.

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Jawahar and Vaiyapuri (2014) reported that application of silicon upto 120 kg Si ha^{-1} increased the grain and straw yield of rice.

Nagula (2015) recorded that there was a significant influence of silicon and boron on yield attributes like panicle weight $plant^{-1}$ and thousand grain weight.

Jayant *et al.* (2015) reported that application of Si @ 400 kg ha^{-1} through rice husk ash significantly increased the growth and yield attributes in rice.

2.1.2.7 Effect of soil test crop response (STCR) on yield and yield attributes of rice

Singh and Singh (2008) recorded that the combined use of soil test based NPK fertilizers and S with FYM and green manuring resulted in higher grain yield over farmer's practice.

According to Singh (2008), application of organic inoculants *viz.* blue green algae (BGA) and phosphate solubilizing bacteria (PSB) with NPK nutrients on soil test crop response (STCR) basis recorded better plant height varied from 91.0 to 113.5 cm among all the treatments.

According to Tamuly (2011) application of fertilizer based on STCR with zinc sulphate significantly produced higher number of leaves and tillers at the flowering stage. Qureshi *et al.* (2016) reported that production of higher grain yield with less fertilizer N can be obtained in SSNM based fertilizer application.

According to Vidyavathi and Kammar (2017), STCR equation based application of fertilizers enhanced the grain and straw yield of DSR (variety BPT 5204) by 70.70 and 79.94 q ha^{-1}, respectively.

Babu *et al.* (2017) reported that STCR –INM based recommendation having 140 N: 60 P: 85 K kg ha^{-1} + 2 tonnes FYM recorded the highest grain yield in rice

2.1.2.8 Effect of Organic Manures on yield and yield attributes of rice

Jadhav *et al.* (1998) observed the possibility of substituting 25 to 50 kg N ha^{-1} of the recommended dose of N by FYM for achieving higher dry matter production. Verma *et al.* (2001) claimed that yield and yield attributes significantly increased with the application of FYM up to 10 t ha-1.

According to Satheesh and Balasubramanian (2003), improved nutrient uptake and higher grain yield was obtained by the application of farmyard manure (10 t ha^{-1}) in combination with neemcake (3 t ha^{-1}) when compared to chemical N fertilizer application.

Application of enriched poultry manure compost on equal N basis (2.3 t ha^{-1}) recorded higher yield attributes and grain yield of rice (Sangeetha *et al.,* 2013). In a cropping sequence experiment with organic and inorganic fertilizer,recorded significantly higher rice grain yield and stocks of soil and microbial nutrients than those of the MIN (mineral fertilizer) treatment and RRR(Rice-Rice-Rice) sequence, respectively (Murugan and Kumar. 2013).

Geetha and Balasubramaniyan (2015) reported that in rice (white ponni) not only the yield parameters such as number of panicles m^{-2}, panicle length, thousand grain weight and yield (4210 kg ha^{-1}) were significantly higher by combined application of green manure, FYM , poultry manure and neem cake but also significantly higher in dry matter production(14499 kg ha^{-1}) and LAI (5.41).

Theresa *et al.* (2017) conducted field experiment in silty clay loam soil to study the effect of application of fly ash alone and in combination with other different manures. This study revealed that integrated application of fly ash @ 20 t ha^{-1} and green leaf manure (GLM) @ 6.25 t ha^{-1} with recommended dose of fertilizers was helpful to increase the productivity of the rice crop.

2.1.2.9 Effect of INM on yield and yield attributes of rice

According to Solunke *et al.* (2006), the application of FYM (5 t ha^{-1}) + 100 per cent RDF (75 - 37.5 - 37.5 kg NPK ha^{-1}) improved the yield attributes *viz.* panicle length, panicle weight, filled grains $panicle^{-1}$, 1000-grain weight and grain, straw and biological yield of basmati rice under black clay soil of Akola

Maximum grain and straw yields and nutrient uptake by rice were obtained by the application of 100 % NPK fertilizers + FYM at 15 t ha^{-1} (Krishna *et al.*, 2007).

Pandey *et al.* (2007) reported that application of inorganic fertilizer @ 100 – 60 - 40 kg ha^{-1} NPK along with 10 tonnes farmyard manure (FYM) increased the grain yield in rice.

Gang *et al.* (2008) conducted experiment and indicated that application of half chemical fertilizers combined with half swine manure (NPKM) produced higher dry matter accumulation and nutrients absorption, higher panicle number per unit area and filled-grain number per panicle. Kayem (2008) reported that application of cow dung and poultry manure with the recommended dose of chemical fertilizer resulted in better performances of rice with respect to grain yield, nutrient content and uptake compared to fertilizers alone

Shah and kumar (2014) reported that the integration of NPK 50% RDF + Neem cake @ 2.5 tonnes ha^{-1} + FYM @5 tonnes ha^{-1} + Azotobacter + PSB @ 5kg ha^{-1} increased the productivity of hybrid rice.

Application of 100 % RDN through green manure followed by 25 % RDN through each organic manures recorded higher filled grain percentage and grain yield of rice (Alagappan and Venkitaswamy, 2014).

Sharma *et al.* (2015) conducted field experiment for 2 year during 2010 and 2011 and reported that significantly higher grain yield (3.96 t ha^{-1}) was recorded by the application of 25 % NPK through farmyard manure (FYM) along with recommended dose of NPK, 5 kg Zn ha^{-1} and PSB + BGA.

Mondal *et al.* (2015) found that application of 50 % recommended dose of fertilizer (RDF) + 50 % recommended dose of nitrogen (RDN) through mustard oil cake (MOC) and 75 % RDF + 25 % RDN through MOC + biofertilizer, increased number of panicles m^{-2} and number of grains $panicle^{-1}$.

Woolie and Admassu (2016) concluded that application of 50 % fertilizers through organic sources and 50 % through inorganic sources is the best combination for rice yield and soil properties improvement. According to Sharma *et al.* (2016), integrated use of inorganic fertilizers along with organics improved the productivity of rice and wheat significantly.

A long term experiment was conducted on sandy loam soil at Bhubaneswar, Odisha. The study revealed that application of 50 % recommended dose of chemical fertilizers together with 50 % recommended N through green manuring of azolla or through farm yard manure to kharif rice followed by supply of recommended dose of chemical fertilizers to summer rice can be recommended for rice – rice cropping system to achieve higher and sustainable yield and maintain soil health (mishra *et al.*, 2017).

2.1.3 Nutrient Content and Uptake

2.1.3.1 Effect of major nutrients on nutrient content and uptake by rice

According to Devendra *et al.* (1999) increase in K levels improved the potassium uptake by grain and straw.

According to Sharma and Verma (2000), uptake of N, P and K was enhanced by the application of N @ 20 kg ha^{-1}. Murali and Setty (2001), reported that N uptake significantly increased by the application of NPK up to 150 – 75 - 75 kg ha^{-1}.

Mathew (2002) reported that during *kharif* season higher P uptake was noticed in silica applied plots in lateritic soil. Surendran (2005) reported higher N and K in straw and grains by the application of 50 kg K ha^{-1}.

According to Krishnakumar (2005), total Phosphorus and K uptake was improved by the application of 150:50:50 kg N, P_2O_5 and K_2O ha^{-1} fertilizer. Sikdar *et al.* (2008) revealed that application of 60 kg ha^{-1} N increased the N uptake.

2.1.3.2 Effect secondary nutrients on nutrient content and uptake by rice

Varghese and Money (1964) in pot culture study revealed that application of calcium and magnesium helped to increase the soil pH, available phosphorus. Calcium application increased the available K_2O in the soil. According to Marykutty (1986) the pH was increased by the application of Ca but it never reduced the Fe content in laterite soil.

Varghese and Money (1964) concluded that application of magnesium increased the P_2O_5 content of grain.

Alam *et al.* (2002) reported that in all soil types, application of calcium phosphate and calcium sulphate increased N, P, K and Ca and decreased Na and Mg concentrations when compared to control in rice.

Singh and Singh (2005) observed that the application of $MgSO_4$ @ 10 kg ha^{-1} enhanced the absorption and translocation of Zn, Ca, P, K and that of Mg itself while Na accumulation was inhibited.

Kobayashi *et al.*, (2005) reported that in rice, Mg content of shoots and roots, and the potassium and chloride contents of roots were increased with the excess Mg treatment, but in shoots the Ca and K contents slightly decreased.

Application of 40 kg S ha^{-1} in rice enhanced the uptake of N, P, K and S (Bhuvanesswari and Sreeramchandhrasekharan, 2006).

According to Basumatary and Talukdar (2007), integrated use of 30 kg S ha^{-1} along with FYM of 1.5 or 3.0 t ha^{-1} recorded the highest seed and straw yield, uptake of N, P, K and protein content of rice.

2.1.3.3 Effect of micronutrients on nutrient content and uptake by rice

In lateritic soil application of $ZnSO_4$ @ 20 kg ha^{-1} recorded higher Zn uptake by rice grain and straw (Das, 1986). Ramadass *et al.* (1995) recorded increased Zn uptake by rice crop with the application of 25 kg $ZnSO_4$ ha^{-1} in sandy loam soil.

An experiment conducted at greenhouse in flooded rice cv. INCA with different treatments including organic, humic gley and poorly humic gley soil and 0, 0.75, 1.5, 2.25 or 3.0 mg Cu kg^{-1} soil. In this study Mg and S were influenced by Cu application and it showed effects on Cu, Zn, Fe and Mn uptake. Boron uptake was not influenced by any of the treatment (Bertoni *et al.*, 1996).

According to Binodkumar and Singh (1997), higher Zn uptake was recorded with application of 0.5 % $ZnSO_4$ solution sprays at 3rd and 5th weeks after transplanting in rice.

Sankaran *et al.* (2001) reported that application of $ZnSO_4$ @ 50 kg ha^{-1} enhanced the Zn uptake in rice grain in red loam soil.

In sandy loam soil Zn uptake was significantly increased by the Application of $ZnSO_4$ @ 30 kg ha^{-1} along with 5 kg $FeSO_4$ ha^{-1}(Kulandaivel *et al.,* 2004). Sahoo (2005) recorded higher uptake of all nutrients (N, K & Zn) by the combined application of Zn @ 5 kg ha^{-1} or FYM @ 5 t ha^{-1} with RFD.

2.1. 3.4 Effect of Silicon

According to Ma and Takahashi (1990), application of Silicon improves the accessibility of P by inhibiting excessive Mn uptake, which can antagonize P.

Epstein in 2001 showed the role of silicon in plants as enhancement of growth and yield, resistance against lodging, enhancement of photosynthesis, beneficial effect on surface properties, resistance against disease causing organisms, resistance to herbivores, resistance to metal toxicity, resistance to salinity stress, reduction of drought stress and protection against temperature extremes.

Batty and Younger (2003) observed that iron plaque on the surface of rice roots was harmful to the roots. It reduced root activity and inhibited nutrient uptake (Zhang *et al*., 2010). In addition, the epidermal and cortex cells within rice roots died when iron plaque was formed (Zhang *et al*., 2011). Singh *et al*. (2006) revealed that application of silicon up to 180 kg Si ha^{-1} significantly increased phosphorus contents in grain and straw phosphorus content.

Application of silicon improved the oxidative power of rice roots, resulting in enhanced oxidation of Fe from ferrous iron to insoluble ferric iron. As a result, excess Fe uptake indirectly prevented by Si application (Okuda and Takahashi, 1962; Qiang *et al*., 2012).

According to Nagula *et al*. (2015) the Fe and Mn content in straw and grain decreased with the application of silicon while its uptake in plant alone significantly increased the yield.

According to Lekshmi (2016) maximum Si uptake in straw and grain was observed by the application of POP recommendation of KAU + sodium silicate.

Experiment conducted by Rani and Latha (2017) to study the influence of secondary and micronutrients on nutrient uptake and yield of rice in Kole lands of

Kerala found that higher uptake of nutrients specially primary and micronutrients by the application of boron and calcium silicate and which reduced the uptake of Fe and Mn.

2.2 INFLUENCE OF DIFFERENT TREATMENTS ON ECONOMICS OF RICE

Pandey *et al.* (2007) reported higher B: C ratio by the application of inorganic fertilizer @ 100- 60-40 kg ha^{-1} NPK along with 10 tonnes farmyard manure (FYM).

Ahmed *et al.* (2015) conducted study on Soil Test Crop Response (STCR) on autumn rice under integrated plant nutrition system (IPNS) in Inceptisols (Aeric Endoaquepts) in Jorhat district of Assam. The fertilizer estimates under STCR - IPNS for 3000 and 4000 kg ha^{-1} targeted yield recorded maximum response ratio and economic benefit in the field trial and confirmed the validity of proposed fertilizer prescription equations for autumn rice. Sharma *et al.* (2015) claimed that integrated resource management improved the overall profit of the farmers. Baishya *et al.* (2015) revealed that micronutrient fortification enhanced gross and net returns of the rice.

Application of soil test based NPK and secondary nutrients along with foliar application of 0.5 per cent solution of computed dose of nutrient mixture @ 5 kg ha^{-1} in two splits at 15 DAS and 30 DAS reported higher B:C ratio (3.02) (Mini and Mathew, 2016).

Dibyendu *et al.* (2016) conducted an experiment to develop soil test crop response correlation based fertilizer prescription for north eastern hill region in direct seeded rainfed upland rice. The study proved that soil test based fertilizer prescription for direct seeded rice was economically viable in upland agro-ecosystems of Manipur.

According to Sharma *et al.* (2016), highest net returns in rice-wheat cropping sequence was recorded by the application of 50 % NPK combined with 50 % N through FYM to rice followed by 100 % NPK to wheat.

According to Vidyavathi and Kammar (2017), higher B: C ratio was recorded by the application of fertilizers on the basis of STCR equation.

Babu *et al.* (2017) reported STCR – INM based recommendation having 140 N: 60 P: 85 K kg ha^{-1} + 2 tonnes FYM recorded higher B :C ratio

Mishra *et al.* (2017) reported that the highest gross returns (Rs. 1,11,870/-), net returns (Rs. 65,644/-) and benefit: cost ratio(2.42) were recorded by the combined application of 50 % RDF through fertilizers along with 50 % recommended N through green manuring of azolla to rainy season (kharif) rice followed by supply of RDF through fertilizers to summer rice.

2.3 EFFECT OF DIFFERENT TREATMENTS ON PEST AND DISEASES OF RICE

Laing *et al.* (2006) stated that Si application was the feasible component for integrated management of pests and diseases because it never left pesticide residue in food or the environment.

Gao *et al.* (2011) reported that disease index of rice plants decreased by adding Si in a nutrient solution at a concentration of 2.0 mM. Hosseini *et al.* (2011) conducted a greenhouse study and concluded that application of 20 g silica fertilization improved the silica content in rice and reduced the stem borer attack.

In rice the intensity of pest and diseases due to excessive N application can be mitigated with the application of Si @ 200 kg ha^{-1} along with N @ 120 kg ha^{-1} as it helps in improving the productivity and fertility (Rajamani, 2012).

According to Ning *et al.*, (2014) application of slag - based Si fertilizers improved the growth and yield of rice and brown spot incidence. He *et al.* (2015) conducted experiment in greenhouse and reported that BPH performance in rice was restricted by the application of silicon.

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Jayant *et al.* (2015) reported that application of Si @ 400 kg ha^{-1} through rice husk ash helps to reduce the borer infestation in rice.

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MATERIALS AND METHODS

3. MATERIALS AND METHODS

The field experiment on "Integrated nutrient approach on productivity enhancement of rice in oxyaquic fluent soils of Northern Kerala" was conducted during *virippu* season at farmer's field in Mugu area of Kasaragod district of Kerala. The details of the research work carried out, methodologies adopted and materials used in this works are described here.

3.1 MATERIALS

3.1.1 Experimental site

The field experiment was conducted in the field of Sri. Kunha Moolya, Mugu coming under the district of Kasaragod. It is situated at 12°37'1" N latitude, 75° 2'48" E longitude and an altitude about 12 meters above mean sea level. It is located 14 km away from the Kasaragod town.

3.1.2 Soil

The soil of the experimental plot is a red ferruginous loam of lateritic origin with an admixture of clay and sand. It is coming under oxyaquic subgroup which is defined as being saturated (with water) within 100 cm of the mineral soil surface for 20 or more days consecutively, or 30 or more days cumulative, in normal years. Soil was strongly acidic in reaction. The physico-chemical properties of the soil are given in Table 2.

3.1.3 Climate and weather

The climate of the district was classified as warm humid tropical. The average maximum temperature was 31.5 °C and minimum temperature was 24.36 °C. The abstract of weather data is given in Table 1. The weather parameters were recorded during the crop period (June to October) and are furnished in Appendix I and Fig. 1

Weather element	Range	Mean
Maximum temperature (°C)	27.94 – 31.5	29.70
Minimum temperature (°C)	22.86 – 24.36	23.77
Rainfall (mm)	------	2027.20
Relative humidity (%)	69.575 – 87.85	81.97
Average daily evaporation (mm)	1.77 – 2.97	2.30

Table 1. The abstract of weather data during the experimental period

3.1.4 Season

The field experiment was conducted during the first crop season (*virippu*) of 2017. The nursery was sown on 26th June and was transplanted on July 19th , 2017. The crop was harvested on 25th October, 2017.

3.1.5 Crop variety

The rice variety Jyothi (PTB 39) was used for the study. The variety was released in 1974 from the Regional Agricultural Research Station, Pattambi, still continues to be the prominent variety in Kerala due to its higher yield and good cooking quality. It is having red long and bold grains and is mainly consumed as a staple food in Kerala in the form of table rice (Nair *et al.*, 2005). It has a test grain weight of 25.67 g and grain volume of 25.8 mm^3 with protein content of 8.11 per cent. Duration of this variety is about 110-125 days. It is moderately tolerant to brown plant hopper and blast; susceptible to sheath blight; suitable for direct seeding, transplanting and special systems of Kole and Kuttanad areas.

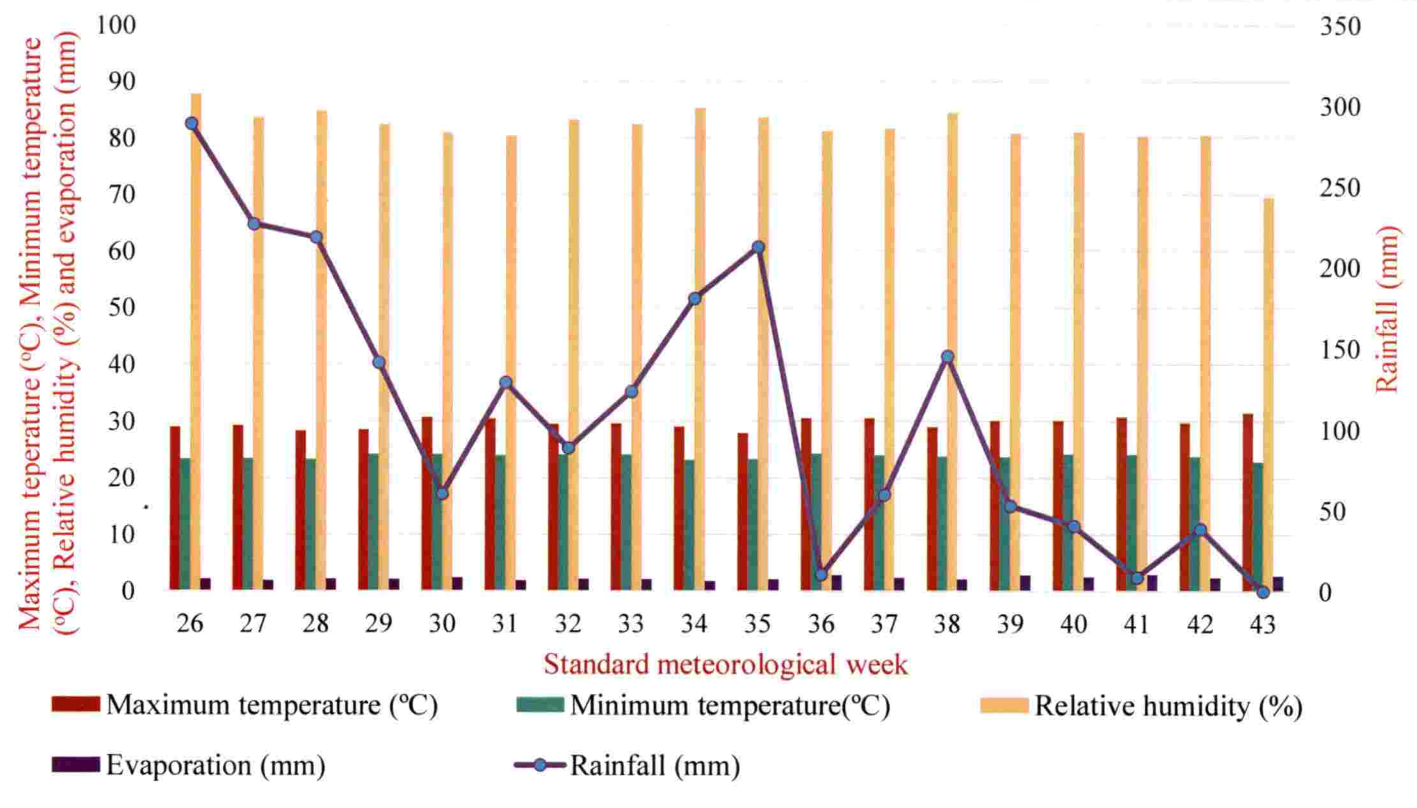

Fig. 1. Weather parameters prevailed during the crop season in standard weeks

3.1.6 Manures and Fertilizers

Dried and well decomposed farmyard manure (FYM) containing 0.5 per cent N, 0.2 per cent P_2O_5 and 0.3 per cent K_2O was applied @ 5 t ha^{-1}. The fertilizer was applied @ 90-45-45 kg ha^{-1} N, P_2O_5 and K_2O. The materials used were urea (46 per cent N), rajphos (20 per cent P_2O_5), muriate of potash (60 per cent K_2O), 18:18:18 complex fertilizer, calcium silicate, *Ayar, Sampoorna,* neem cake and groundnut cake.

"Ayar" is a nutrient mixture released from College of Agriculture Padannakkad, mainly recommended for banana. It contains Ca (15 %), Mg (5 %), S (6 %), Zn (1.5 %) and B (0.6 %).

"Sampoorna KAU multi-mix", is a crop-specific formulation for use in rice, banana and vegetables. It is a nutrient mixture with soluble materials suitable for foliar spray and it is released from Regional Agricultural Research Station (RARS), Pattambi. It contains K (15 %), Mg (2 %), S (6.5 %), Zn (5-7 %), B (3.5-4.5 %), Cu (0.3-0.5 %), Fe (0.2 %) and Mn (0.02 %).

3.2 DESIGN AND LAYOUT

Design : Randomized block design (RBD)

Treatments : 12

T_1 : Farmer's practice (FYM 5 t ha^{-1} + 18:18:18

T_2 : Fertilizer recommendation on the STCR basis (75.6 : 57.6 : 37.35 kg ha^{-1} NPK)

T_3 : POP Recommendation of KAU (90:45:45 kg ha^{-1} NPK)

T_4 : FYM (5 t ha^{-1}) + Neem cake (400 kg ha^{-1}) + Groundnut cake (400 kg ha^{-1})

T_5 : T_3 + *Ayar* (500 kg ha^{-1} as basal dose)

T_6 : T_3 + *Sampoorna* (5 g l^{-1} at 1-2 days before transplanting and 10 g l^{-1} and at 50 DAT as foliar spray respectively)

T_7 : T_4 + *Ayar* (500 kg ha^{-1} as basal dose)

T_8 : T_4 + *Sampoorna* (5 g l^{-1} at 1-2 days before transplanting and 10 g l^{-1} and at 50 DAT as foliar spray respectively)

T_9 : T_5 + Si (100 kg ha^{-1} calcium silicate as basal dose)

T_{10} : T_6 + Si (100 kg ha^{-1} calcium silicate as basal dose)

T_{11} : T_7 + Si (100 kg ha^{-1} calcium silicate as basal dose)

T_{12} : T_8 + Si (100 kg ha^{-1} calcium silicate as basal dose)

Replication : 3

Gross plot size : 5 m x 4 m (20 m^2)

Net plot size : 4.2 m x 3.6 m (15.12 m^2)

Spacing : 20 cm x 10 cm

Variety : Jyothi

Method of sowing : Transplanting

Seed rate : 80 kg ha^{-1}

3.3 FIELD CULTURE

3.3.1 Nursery

Rice seedlings were raised by wet nursery method. Seeds @ 80 kg ha^{-1} were sown in a well puddled and leveled nursery area.

3.3.2 Land preparation and layout

The field was ploughed uniformly and leveled by using tractor-drawn puddler. The experimental plots were laid out as per the technical programme. Soil samples were collected from the field for initial basic analysis. The details of the layout plan of the field experiment were given in fig. 2.

3.3.3 Transplanting of rice

Rice seedlings of 24 days old were transplanted on 19^{th} and 20^{th}, July 2017 by planting 3 seedlings per hill at a spacing of 20 cm x 10 cm.

3.3.4 Manures and Fertilizers

Farmyard manure was applied @ 5 t ha^{-1} to each experimental plot as per the treatments. Full dose of P and half the dose of N and K fertilizers were applied as basal and the remaining N and K were applied at panicle initiation stage.

Neem cake and ground cake were applied in two equal doses, first as basal and second at panicle initiation stage.

Ayar was applied as a single dose @ 2 kg $cent^{-1}$ as basal. Sampoorna was applied two times, first at 1-2 days before transplanting @ 5 g l^{-1} and second at 45 DAT @ 10 g l^{-1} as foliar spray respectively.

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For calculating the fertilizer requirement in STCR treatments, soil samples were collected from the experimental plot and analyzed for major nutrients. Based on the nutrient contents of the soil sample, nutrient requirement for the treatments were worked out and fertilizers were applied accordingly.

All other cultural practices were adopted as per the package of practices recommendations of KAU (KAU, 2016).

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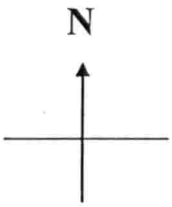

R_1T_8	R_1T_6	R_2T_9	R_2T_{12}	R_3T_1	R_3T_4
R_1T_7	R_1T_{12}	R_2T_5	R_2T_7	R_3T_{12}	R_3T_2
R_1T_5	R_1T_{11}	R_2T_6	R_2T_8	R_3T_9	R_3T_7
R_1T_3	R_1T_1	R_2T_{10}	R_2T_3	R_3T_{11}	R_3T_5
R_1T_{10}	R_1T_4	R_2T_{11}	R_2T_1	R_3T_3	R_3T_8
R_1T_2	R_1T_9	R_2T_2	R_2T_4	R_3T_6	R_3T_{10}

Fig. 2. Layout plan of the experiment

3.3.5 Weeding

The infestation of seasonal weed flora and their competition with the crop plants was started from the very beginning due to early onset of monsoon. The dominant weed flora in the experimental area were *Echinochloa crusgalli, E. colonum, Cyperus iria, Commelina cummunis, Eclipta alba* and *Ludwigia perennis* etc.

3.3.6 Plant protection

No chemical pesticide was used for plant protection measures. The incidence of pest and diseases were comparatively very less. Attack of rice bug was controlled by application of neem oil @ 2 ml L^{-1} of water at the milking stage.

3.3.7 Plant sampling

Samples were collected from each experiment plot at maximum tillering stage, panicle initiation stage, flowering stage and at harvesting stage for estimating nutrient content and uptake by the plant. For taking biometric observations five plants from each plot were selected randomly and tagged.

3.3.8 Harvesting and threshing

Harvesting of individual plot was done manually, when the crop attained the maturity. The physiological maturity of all the treatments were judged visually before the crop was harvested. Earmarked were collected before the harvest for post-harvest studies. The harvested plants were threshed, dried and winnowed separately; the weight of cleaned grains from each net plot was recorded in kilograms and then converted into tons hectare^{-1}.

Table 2. Physico-chemical characteristics of the soil

Sl.no.	Parameters	Constituent	Status	Methods
		A. Mechanical composition		
1	Coarse sand (%)	28.45		International pipette method (Robinson, 1922)
2	Fine sand (%)	29.65		
3	Silt (%)	19.85		
4	Clay (%)	22.05		
		B. Chemical composition		
1	p^H	4.69	Acidic	pH meter (Jackson, 1958)
2	EC (dS m^{-1})	0.07		Conductivity meter (Jackson,1958)
3	Organic Carbon (%)	0.9	High	Chromic acid wet digestion method (Walkley and Black, 1934)
4	Available Nitrogen (kg ha^{-1})	200.70	Low	Alkaline permanganate method (Subiah and Asija, 1956)
5	Available Phosphorus(P_2O_5) (kg ha^{-1})	2.29	Low	Bray extraction and photoelectric colorimetry (Jackson, 1958)
6	Available Potassium (K_2O) (kg ha^{-1})	156	Medium	Flame photometry (Pratt, 1965)

3.4 OBSERVATIONS

3.4.1 Observations on growth parameters

In each plot, five sample plants were randomly selected and tagged for recording the observations on growth parameters at different growth stages and yield-attributing characters at harvest stage.

3.4.1.1 Plant height (cm)

Plant height at the maximum tillering stage, panicle initiation stage, flowering stage and harvest stage was measured from the base of the stem at ground level to the tip of the last emerged leaf and reported in cm.

3.4.1.2 Number of tillers hill^{-1}

The total number of tillers plant^{-1} from the selected plants was recorded at maximum tillering, panicle initiation stage, flowering stage and harvest stage and average was computed and recorded.

3.4.2 Observations on yield and yield attributes

3.4.2.1 No of panicles hill^{-1}

The number of panicles hill^{-1} was counted from the selected plants in each plot and recorded the mean number of panicles per hill.

3.4.2.2 Panicle length (cm)

At harvest, ten panicles were randomly selected and the length of each panicle was measured in "centimeter" from the ciliate ring at the base to the tip of panicle and mean value was recorded.

3.4.2.3 Total grains panicle^{-1}

Grains from 10 panicles selected from each treatment plot were separated and counted. The mean value was worked out expressed as total grains per panicle.

3.4.2.4 Filled grains panicle^{-1}

The filled grains per panicle were counted from 10 selected panicles in treatment wise and the average values were worked out.

3.4.2.5 Number of chaffy grains panicle^{-1}

The chaffy grains per panicle from each treatment was recorded from 10 randomly selected panicles and the average values were worked out.

3.4.2.6 Test weight

Sample grains were collected from each individual plot, from that 1000 grains were counted and their weight was recorded in gram.

3.4.2.7 Grain yield

After the threshing and cleaning grain yield per plot was recorded separately for each treatment and was converted into grain yield tons hectare^{-1}.

3.4.2.8 Straw yield

After threshing and drying straw weight from each treatment was recorded separately in kilogram and was converted into straw yield tons hectare^{-1}.

3.4.2.9 Harvest index

The harvest index was calculated using the formula

$$\text{Harvest index} = \frac{\text{Economical yield (grain yield t ha}^{-1}\text{)}}{\text{Biological yield (grain + straw yield t ha}^{-1}\text{)}}$$

3.4.3 Plant analysis

Plant samples were collected at maximum tillering stage, panicle initiation stage and at the harvest stage from each treatment and dried in an oven at 60-70ºC. Plant samples were separated into root and shoot and analysed for N P, K, Ca, Mg, S, Fe, Mn, Zn and Cu using standard procedures (Table 4). For silicon analysis, the powdered samples were digested by using microwave digestion chamber.

Table 3. Method used for plant analysis

Element	Methods used	Reference
Total nitrogen	Modified kjeldhal method	Jackson (1958)
Total phosphorus	Vanadomolybdate yellow colour method	Piper (1966)
Total potassium	Flame photometry	Jackson (1958)
Total Ca and Mg	Atomic Absorption Spectroscopy	Issac and Kerber (1971)
Total sulphur	Turbidimetric method	Bhargava and Raghupathi (1995)
Total Fe and Mn	Atomic Absorption Spectroscopy	Piper (1966)
Total Cu and Zn	Atomic Absorption Spectroscopy	Emmel *et al.* (1977)
Silicon	Blue silicomolybdous acid method	Ma *et al.* (2002)

3.4.4 Soil analysis

Soil samples were collected at the depth of 0 - 10 cm before sowing and after harvest. After harvest, soil samples were collected from each plot and dried under shade. After drying the soil samples were grinded and sieved through an appropriate sieve according to the need of analysis and preserved in a plastic bag.

Table 4. Methods for soil analysis

Elements	Method used
p^H	pH meter (Jackson, 1958)
Electrical conductivity	Conductivity meter (Jackson,1958)
Nitrogen	Alkaline permanganate method (Subbiah and Asija, 1956)
Phosphorus	Bray extraction and photoelectric colorimetry (Jackson, 1958)
Potassium	Ammonium acetate method (Jackson, 1973)

3.4.5 Disease and pest incidence

Incidence of pest and diseases were comparatively less. Disease and pest incidence were recorded from each experiment plot as and when noted.

3.4.6 Economics

Cost of cultivation incurred in each treatment was worked out by considering the prevailing market price of inputs used. It is the summation of all the individual costs carried out in different cultivation practices in rice.

3.4.6.1 Gross income

The gross monetary return was calculated by adding the cost of grain and cost of straw according to the prevailing market in both the crops.

Gross monetary return = Price of grain + Price of straw

3.4.6.2 Net income

The net monetary returns (NMR) per hectare under each treatment were determined by subtracting the cost of cultivation of a particular treatment from the GMR of the treatment.

Net monetary return = Gross monetary return - Total cost cultivation

3.4.6.3 B: C Ratio

B:C ratio is the ratio of gross monetary return to the total cost of cultivation and it was calculated for each treatment.

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

3.4.7 Statistical analysis

The data obtained from field experiments was subjected to statistical analysis using WASP software. The data after statistical analysis were used for comparison and interpretation of the results.

Plate. 1. Nursery

Plate. 2. Field layout

Plate. 3. Bund strengthening

Plate. 4. Transplanting

Plate. 5. At panicle initiation stage

Plate. 6. Field visit

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Plate. 7. General view of the plot after transpalnting

Plate. 8. General view of the plot at harvest stage

RESULTS

4. RESULTS

A field experiment was conducted in farmer's field at Mugu, during the first crop season (*virippu*) of 2017, to study the effect of organic manures along with micronutrient on growth, yield and pest and disease incidence, nutrient uptake and economics of wetland rice. The results of the experiment are presented in this chapter.

4.1 INITIAL SOIL PROPERTIES

Initial soil samples were collected from the field for analyzing the basic physico-chemical properties of the soil. Samples were collected from the depth of 0-15 cm. The soil physico-chemical properties like coarse sand, fine sand, silt, clay, pH, EC, organic carbon and available nutrients like Nitrogen, Phosphorus and Potassium and available secondary nutrients and micronutrients were analyzed and given in Table 5.

The soil was strongly acidic (4.69) in condition. The available N (200.704 kg ha^{-1}) and P (2.29 kg ha^{-1}) were low and the available K (156 kg ha^{-1}) content was medium. With regards to mechanical composition of the soils the percentage of coarse sand, fine sand, silt and clay were 28.45, 29.65, 19.85, 22.05 % respectively and the soil textural class was sandy clay loam. The secondary nutrients *viz*, Ca, Mg and S were in optimum range. The micronutrients (Fe, Mn, Zn and Cu) status of the experimental site was also in optimum range.

Table 5. Initial soil properties

Sl. no	Parameters	Constituent
Mechanical composition		
1	Coarse sand (%)	28.45
2	Fine sand (%)	29.65
3	Silt (%)	19.85
4	Clay (%)	22.05
5	Textural class	Sandy clay loam
Chemical composition		
1	p^H	4.69
2	EC (dsm^{-1})	0.07
3	Organic C (%)	0.9
4	Available Nitrogen (kg ha^{-1})	200.70
5	Available Phosphorus (P_2O_5) (kg ha^{-1})	2.29
6	Available Potassium (K_2O) (kg ha^{-1})	156
7	Calcium (mg kg^{-1})	300.6
8	Magnesium (mg kg^{-1})	133.76
9	Sulphur (kg ha^{-1})	67.2
10	Iron (mg kg^{-1})	122
11	Zn (mg kg^{-1})	11.2
12	Cu (mg kg^{-1})	6.44
13	Mn (mg kg^{-1})	6.52

4.2 GROWTH PARAMETERS

4.2.1 Plant height

The mean plant height data recorded at different growth stages *viz*. maximum tillering , panicle initiation, flowering and harvesting stages were given in Table 6. In general the plant height was rapidly increased in early stages.

At the maximum tillering stage the plant height was ranged from 67.32 cm (T_2–Fertilizer recommendation on STCR basis) to 74.70 cm (T_5). There was significant difference between treatments. Maximum height was recorded in treatment T_5 (T_3 +*Ayar*) and it is on par with treatment T_6 and T_1.

At panicle initiation stage there was significant difference between treatments. The maximum plant height was recorded in T_{10} (T_6+ Si) (93.04 cm) and was on par with T_3, T_6, T_9 and T_{12}. The lowest plant height was recorded by T_7 (T_4 +*Ayar*) (85.16 cm).

At flowering stage there is no significant difference among the treatments. In this stage plant height was ranged from 96.05 cm (T_7) to 102.59 cm (T_{10}).

At harvest stage plant height was maximum in T_{10} (T_6 +Si) (107.79 cm) which was on par withT_9, T_{11}, T_{12}, T_6 and T_2 and minimum in T_5 (101.95 cm). There was significant difference among the treatments. In general, plants supplied with silicon revealed more height than other treatments.

Table 6. Effect of different treatments on plant height at various growth stages

Treatments	Plant height (cm)			
	At maximum tillering	At panical initiation	At flowering	At harvest
T_1 –Farmer's practice	73.20^{ab}	88.10^{bc}	99.60	104.10^{bcd}
T_2–Fertilizer recommendation on STCR basis	67.32^{e}	83.89^{de}	97.79	106.94^{ab}
T_3 –POP Recommendation of KAU	71.44^{abcd}	89.71^{ab}	102.29	104.11^{bcd}
T_4 –FYM+ Neem cake + Groundnut cake	70.42^{bcde}	84.06^{de}	97.83	104.06^{bcd}
T_5– (T_3 +*Ayar*)	74.70^{a}	85.23^{cde}	97.45	101.95^{d}
T_6–(T_3 +*Sampoorna*)	73.61^{ab}	90.32^{ab}	101.21	105.12^{abc}
T_7– (T_4 +*Ayar*)	70.94^{bcde}	83.12^{e}	96.05	102.67^{cd}
T_8–(T_4 +*Sampoorna*)	68.61^{de}	87.56^{bcd}	99.57	104.68^{bcd}
T_9 –(T_5+ Si)	72.72^{abc}	89.66^{ab}	102.40	105.94^{ab}
T_{10}–(T_6+ Si)	72.65^{abc}	93.04^{a}	102.59	107.79^{a}
T_{11} – (T_7+ Si)	69.26^{cde}	87.06^{bcd}	101.95	106.52^{ab}
T_{12}– (T_8 + Si)	68.58^{de}	89.33^{ab}	100.36	106.26^{ab}
CD (0.05)	**3.740**	**3.743**	**NS**	**3.103**
CV	**3.106**	**2.523**	**2.894**	**1.745**

4.2.2 Number of Tillers Hill^{-1}

Data on total number of tillers hill^{-1} was presented in Table 7. There was significant difference between the treatments at all stages under observation.

At maximum tillering stage, the treatment T_{10} where KAU POP recommendation along with *Sampoorna* and Si were applied recorded the maximum number of tillers hill^{-1} (10.60) and was significantly superior to all other treatments. The treatment T_4 (FYM + Neem cake + Groundnut cake) recorded the lowest number of tillers hill^{-1} followed by T_8 (T_4 + *Sampoorna*) and T_7 (T_4 +*Ayar*).

The same trend was observed at all other stages of observation. At all stages, the treatment T_{10}, where the fertilizers were given as per KAU POP along with *Sampoorna* and silicon recorded maximum number of tillers hill^{-1}, which was on par with T_2, T_6, T_9 and T_{12} at panicle initiation stage and T_3, T_6 and T_{12} at flowering stage. At harvest, T_{10} was on par with T_6 and significantly superior to all other treatments.

Table 7. Effect of different treatments on number of tillers hill^{-1}at various growth stages

Treatments	No of tillers hill^{-1}			
	Maximum tillering stage	Panicle initiation stage	Flowering stage	Harvest stage
T_1 – Farmer's practice	9.40^{b}	11.000^{abcd}	11.60^{bcd}	14.10^{bcd}
T_2 – Fertilizer recommendation on STCR basis	8.80^{bc}	11.200^{ab}	12.10^{abc}	13.50^{cde}
T_3 – POP Recommendation of KAU	8.80^{bc}	10.000^{bcdef}	12.20^{abc}	14.30^{bc}
T_4 – FYM + Neem cake + Groundnut cake	7.40^{e}	9.300^{ef}	10.90^{cde}	11.80^{ef}
T_5 – (T_3 + *Ayar*)	8.50^{bcd}	10.400^{abcde}	11.30^{cd}	14.00^{bcd}
T_6 – (T_3 + *Sampoorna*)	9.00^{bc}	11.200^{ab}	12.20^{abc}	15.80^{ab}
T_7 – (T_4 + *Ayar*)	7.60^{de}	9.600^{cdef}	10.30^{de}	12.40^{def}
T_8 – (T_4 + *Sampoorna*)	7.30^{e}	8.800^{f}	9.40^{e}	11.60^{f}
T_9 – (T_5+ Si)	9.20^{b}	11.200^{ab}	11.80^{abcd}	13.60^{cde}
T_{10} – (T_6+ Si)	10.60^{a}	11.900^{a}	13.40^{a}	16.60^{a}
T_{11} – (T_7+ Si)	8.10^{cde}	9.500^{def}	10.20^{de}	12.30^{def}
T_{12} – (T_8 + Si)	8.70^{bc}	11.100^{abc}	13.20^{ab}	14.10^{bcd}
CD (0.05)	**1.004**	**1.558**	**1.626**	**1.893**
CV	**6.881**	**8.816**	**8.315**	**8.174**

4.3 YIELD AND YIELD ATTRIBUTES

The yield and yield attributes were significantly influenced by different treatments.

4.3.1 Number of panicles hill^{-1}

The data on number of panicles hill^{-1} are given in Table 8. The data showed significant difference between treatments. The treatment T_9 (T_5 +Si) recorded the maximum number of panicles hill^{-1} (10.25) which was on par with T_6, T_{11}, T_{10}, T_{12}, T_5, T_4, T_2 and T_3 and significantly superior to all other treatments.

4.3.2 Panicle length (cm)

Panicle length was significantly influenced by different treatments (Table 8). The highest panicle length was observed in treatment T_5 (21.04 cm) which was on par with T_{12}, T_{11}, T_9 , T_{10} , T_6, T_4, T_2 and T_7 and significantly superior to all other treatments. Lowest panicle length was observed in the treatment T_1 (Farmer's practice) (19.49 cm).

4.3.3 Total grains panicle^{-1}

The data on the effect of different treatments on total grains panicle^{-1} are presented in the Table 8. An appreciable difference was observed among the treatments. Maximum grains panicle^{-1} was recorded in T_9 (95.24) on par with by T_{11} (90.77). Lowest number of grains panicle^{-1} was recorded in treatment T_1 (Farmer's practice) and was 76.60.

4.3.4 Filled grains panicle^{-1}

The data on number of filled grains panicle^{-1} were given in Table 8. Significantly higher number of filled grains were recorded in treatment T_9 (T_5 + Si) followed by T_{11}. The lowest number of filled grains panicle^{-1}was recorded in treatment T_7 (T_4 + *Sampoorna*).

4.3.5 Chaffy grains panicle^{-1}

The data on chaffy grains panicle^{-1} were given in Table 8. There was a significant difference among the treatments. Among the different treatments, significantly lower number of chaffy grains panicle^{-1} was recorded in treatment T_1 which was on par with T_3, T_{11} and T_9 and maximum number of chaffy grains panicle^{-1} was recorded in T_4 where the treatments applied were FYM + Neem cake + Groundnut cake + *Ayar* (16.75).

4.3.6 Test weight

The effect of different treatments on test weight was presented in Table 8. There was a significant difference among the treatments. Significantly higher test weight was recorded in treatment T_9 which was on par with T_5, T_{11} and T_4 and was significantly superior to all other treatments. Significantly lower test weight was recorded in T_7 (26.25 g).

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Table 8. Effect of different treatments on yield attributes.

Treatments	No of panicles $hill^{-1}$	Panicle length (cm)	Total grains $panicle^{-1}$	Filled grains $panicle^{-1}$	Chaffy grains $panicle^{-1}$	Test weight (g)
T_1 – Farmer's practice	8.80^{b}	19.49^{c}	76.60^{f}	66.65^{de}	9.95^{e}	29.33^{abc}
T_2 – Fertilizer recommendation on STCR basis	9.00^{ab}	20.25^{abc}	82.65^{cde}	70.55^{cd}	12.10^{bcde}	29.89^{ab}
T_3 – POP Recommendation of KAU	9.00^{ab}	20.09^{bc}	79.60^{ef}	69.50^{cde}	10.10^{e}	28.05^{c}
T_4 – FYM + Neem cake + Groundnut cake	9.20^{ab}	20.53^{ab}	86.32^{bc}	75.02^{bc}	11.30^{cde}	30.52^{a}
T_5 – (T_3 + *Ayar*)	9.63^{ab}	21.04^{a}	89.82^{b}	75.62^{bc}	14.20^{abc}	30.57^{a}
T_6 – (T_3 + *Sampoorna*)	10.00^{ab}	20.49^{ab}	86.26^{bc}	75.11^{bc}	11.15^{de}	29.46^{abc}
T_7 – (T_4 + *Ayar*)	8.60^{b}	20.37^{ab}	80.65^{def}	63.90^{e}	16.75^{a}	26.25^{d}
T_8 – (T_4 + *Sampoorna*)	7.10^{c}	20.96^{a}	85.51^{bcd}	70.66^{cd}	14.85^{ab}	27.85^{cd}
T_9 – (T_5+ Si)	10.25^{a}	20.87^{ab}	95.24^{a}	84.39^{a}	10.85^{e}	30.63^{a}
T_{10} – (T_6+ Si)	9.70^{ab}	20.76^{ab}	88.45^{b}	74.60^{bc}	13.85^{abcd}	28.08^{c}
T_{11} – (T_7+ Si)	9.83^{ab}	20.81^{ab}	90.77^{ab}	80.32^{ab}	10.45^{e}	30.15^{a}
T_{12} – (T_8 + Si)	9.50^{ab}	20.86^{ab}	88.35^{b}	75.95^{bc}	12.40^{bcde}	28.39^{bc}
CD (0.05)	**1.407**	**0.865**	**5.395**	**6.630**	**2.934**	**1.637**
CV	**9.031**	**2.488**	**3.717**	**5.324**	**14.054**	**3.322**

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4.3.7 Grain yield

Data pertaining to grain yield of rice as influenced by different treatments are presented in Table 9.

Significantly higher grain yield with 5.31 t ha^{-1} was obtained by the treatment T_9 (T_5 + Si) which was on par with T_6 (POP Recommendation of KAU along with *Sampoorna*) (5.25 t ha^{-1}) significantly superior to all other treatments. The lowest grain yield was observed in treatment T_4 (FYM+ Neem cake + Groundnut cake)(4.51 t ha^{-1}).

The percentage increase in grain yield over POP recommendation of KAU was worked out and found that treatment T_9 and T_6 produced 11.92 % and 10.07 % more yield respectively than POP recommendation of KAU. The percentage increase in grain yield over farmer's practice was worked out and found that treatment T_3 with *Sampoorna* produced 1.55 % more yield than farmer's practice and treatment T_9 produced 2.71 % more yield than farmer's practice

4.3.8 Straw Yield

The effect of different treatments on straw yield was given in Table 9.

There was a significant difference among the treatments. The treatment T_5 (T_3 + *Ayar*) significantly produced higher straw yield (5.58 t ha^{-1}) followed by T_6 and T_{10}. The lowest straw yield of 3.91 t ha^{-1} and 3.97 t ha^{-1} was recorded by T_{12} and T_4 respectively.

4.3.8 Harvest Index

The harvest index of rice was significantly influenced by different treatments (Table 9). The higher harvest index of rice was recorded in T_9 (T_5+ Si) on par with T_7, T_{11}, T_{12}, T_1, and T_4 and lower harvest index was observed in T_5 (T_3 + *Ayar*).

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Table 9. Effect of different treatments on grain yield, straw yield and harvest index

Treatments	Grain yield (t ha^{-1})	% increase over POP recommendation of KAU (%)	% increase over farmer's practice (%)	Straw yield (t ha^{-1})	Harvest index
T_1 – Farmer's practice	5.17^{ab}	9.07	-	4.54^{de}	0.54^{a}
T_2 – Fertilizer recommendation on STCR basis	4.97^{abc}	4.85	-3.87	4.51^{de}	0.52^{ab}
T_3 – POP Recommendation of KAU	4.74^{cd}	-	-8.32	4.77^{cd}	0.49^{cd}
T_4 – FYM + Neem cake + Groundnut cake	4.51^{d}	-4.85	-12.77	3.97^{f}	0.54^{a}
T_5 – (T_3 + *Ayar*)	5.06^{abc}	6.75	-2.13	5.58^{a}	0.47^{d}
T_6 – (T_3 + *Sampoorna*)	5.25^{a}	10.07	1.55	5.18^{b}	0.50^{bc}
T_7 – (T_4 + *Ayar*)	4.78^{bcd}	0.79	-7.54	4.19^{ef}	0.54^{a}
T_8 – (T_4 + *Sampoorna*)	5.12^{abc}	7.94	-0.96	4.69^{d}	0.52^{ab}
T_9 – (T_5+ Si)	5.31^{a}	11.92	2.71	4.57^{d}	0.54^{a}
T_{10} – (T_6+ Si)	5.08^{abc}	6.40	-1.74	5.09^{bc}	0.49^{c}
T_{11} – (T_7+ Si)	5.13^{abc}	7.34	-0.77	4.57^{d}	0.52^{a}
T_{12} – (T_8 + Si)	4.53^{d}	-4.09	-12.37	3.91^{f}	0.53^{a}
CD (0.05)	**0.408**	-	-	**4.753**	**0.022**
CV	**4.852**	-	-	**0.373**	**2.757**

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4.4 PHYSICO-CHEMICAL PROPERTIES OF THE SOIL AT HARVEST

4.4.1 Physical properties

4.4.1.1 pH

The effect of application of fertilizers and manures on pH of the soil after harvest is presented in the Table 10. There was no significant difference in soil pH. The lowest (3.67) pH was recorded in the treatment T_2 (Fertilizer recommendation on STCR basis). Application of fertilizers based on POP Recommendation of KAU (T_3) produced the maximum soil pH (3.85) closely followed by treatment T_{10} (3.83). In general, there was a reduction in soil pH was observed after the harvest of crop.

4.4.1.2 EC

The data on soil EC is presented in Table 10. There was no significant difference between the treatments. Treatment T_9 recorded the highest EC (0.097) and lowest EC was recorded in treatment T_3 (POP Recommendation of KAU) and was 0.057.

4.4.2 Chemical properties

4.4.2.1 Available nitrogen in soil (kg ha^{-1})

The effect of different treatments on available nitrogen is given in Table 10. The available N content in soil was significantly influenced by the treatments. Highest available N content was recorded in treatment T_8 (382.59 kg ha^{-1}) followed by T_{10} (319.87 kg ha^{-1}). Lower nitrogen content was recorded in T_1 (119.17 kg ha^{-1}).

4.4.2.2 Available phosphorous in soil (kg ha^{-1})

The data on available phosphorous in soil was presented in Table 10. The available P content in soil was significantly influenced by the treatments. Application of fertilizers based on POP Recommendation of KAU along with *Ayar* (T_5) recorded the higher available phosphorous content in soil (13.97 kg ha^{-1}) followed by the treatment T_6 (T_3 + *Sampoorna*). Among the different treatments T_7 (T_4 +*Ayar*) showed lowest available phosphorous content in soil (7.45 kg ha^{-1}).

4.4.2.3 Available potassium in soil (kg ha^{-1})

The effect of different treatments on available K in soil is recorded in Table 10. Soil available K content was not influenced by different treatments. However, among the different treatment T_4 recorded the highest available K in soil. Lowest available K in soil was noticed in treatment T_6 (T_3 + *Sampoorna*).

Table 10. Effect of different treatments on soil pH, EC and available N, P and K at harvest

Treatments	pH	EC	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1 – Farmer's practice	3.78	0.077	119.17^{g}	8.02^{bc}	93.00
T_2 – Fertilizer recommendation on STCR basis	3.67	0.080	206.98^{def}	9.39^{bc}	96.60
T_3 – POP Recommendation of KAU	3.85	0.057	169.34^{fg}	8.70^{bc}	79.80
T_4 – FYM + Neem cake + Groundnut cake	3.76	0.080	232.06^{cde}	8.24^{bc}	97.80
T_5 – (T_3 + *Ayar*)	3.78	0.080	213.25^{def}	13.97^{a}	86.40
T_6 – (T_3 + *Sampoorna*)	3.75	0.073	244.61^{cde}	10.42^{b}	61.60
T_7 – (T_4 + *Ayar*)	3.72	0.067	200.70^{ef}	7.45^{c}	82.80
T_8 – (T_4 + *Sampoorna*)	3.79	0.070	382.59^{a}	8.36^{bc}	76.20
T_9 – (T_5+ Si)	3.69	0.097	275.97^{bc}	9.74^{bc}	78.60
T_{10} – (T_6+ Si)	3.83	0.080	319.87^{b}	8.77^{bc}	72.60
T_{11} – (T_7+ Si)	3.79	0.077	169.34^{fg}	7.91^{bc}	71.40
T_{12} – (T_8 + Si)	3.77	0.083	263.42^{bcd}	9.28^{bc}	84.60
CD (0.05)	**NS**	**NS**	**62.428**	**2.903**	**NS**
CV	**3.574**	**26.890**	**15.810**	**18.709**	**20.287**

4.5 NUTRIENT CONTENT IN PLANT

4.5.1 Nitrogen

The experimental results with respect to nitrogen content in shoot and root at different growth stages and grain at harvest of rice are given in Table 11.

At maximum tillering stage the nitrogen content in shoot was not significantly influenced by different treatments. However the highest nitrogen content of 1.64 % was recorded by the application of fertilizers based on POP Recommendation of KAU (T_3) and lowest content of nitrogen was noticed in treatment T_4, FYM+ Neem cake + Groundnut cake (0.89 %). In this stage nitrogen content in root was significantly different among the treatments, where highest nitrogen content was observed in treatment T_1 (Farmer's practice) which was on par with the treatment T_{12} (T_8 + Si). However, T_2, T_{10} and T_8 treatments were on par with T_1 and T_{12}. Lowest nitrogen content in root was observed in treatment T_9 (T_5+ Si) which was on par with T_5, T_6 and T_4.

At panicle initiation stage, there was appreciable difference between the treatments in both shoot and root. In shoot application of fertilizers according to POP Recommendation of KAU (T_3) recorded the maximum content of nitrogen (0.80 %) which is on par with T_5, T_9 and T_{11}. Application of FYM + Neem cake + Groundnut cake along with *Ayar* recorded the lowest nitrogen content in shoot at panicle initiation stage. In root maximum nitrogen content (0.73 %) was noticed in T_3 (POP Recommendation of KAU) and lowest nitrogen content (0.41) was noticed in both treatments T_{10} (T_6+ Si) and T_{12} (T_8+ Si).

At harvest stage nitrogen, content in straw was not significantly influenced by different treatments but in root there was significant difference among the treatments. In straw, the lowest nitrogen content (0.29 %) was observed in T_{11} (T_7+ Si) and the maximum nitrogen content (0.59 %) was observed in T_5 (T_3 +*Ayar*) which is closely followed by the treatments T_{12}, T_3 and T_6. In roots application of FYM + Neem cake + Groundnut cake along with *Ayar* and silicon recorded significantly higher nitrogen

Table 11. The effect of different treatments on nitrogen content at different growth stages of rice (%)

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	Straw	Grains
T_1 – Farmer's practice	1.14^{a}	1.27	0.54^{cd}	0.59^{abc}	0.34^{def}	0.49	0.65
T_2 – Fertilizer recommendation on STCR basis	1.03^{ab}	1.38	0.52^{d}	0.62^{abc}	0.45^{abc}	0.43	0.52
T_3 – POP Recommendation of KAU	0.86^{b}	1.64	0.73^{a}	0.80^{a}	0.37^{def}	0.56	0.82
T_4 – FYM+ Neem cake + Groundnut cake	0.47^{c}	0.89	0.50^{de}	0.56^{bc}	0.39^{bcde}	0.41	0.67
T_5 – (T_3 +*Ayar*)	0.43^{c}	1.38	0.49^{def}	0.71^{ab}	0.49^{ab}	0.59	0.62
T_6 – (T_3 +*Sampoorna*)	0.45^{c}	1.23	0.43^{fg}	0.43^{cd}	0.43^{abcd}	0.52	0.80
T_7 – (T_4 +*Ayar*)	0.89^{b}	1.16	0.64^{b}	0.32^{d}	0.37^{cdef}	0.47	0.56
T_8 – (T_4 +*Sampoorna*)	0.95^{ab}	0.97	0.45^{efg}	0.54^{bcd}	0.29^{ef}	0.41	0.58
T_9 – (T_5+ Si)	0.39^{c}	1.08	0.59^{bc}	0.67^{ab}	0.28^{f}	0.39	0.67
T_{10} – (T_6+ Si)	1.03^{ab}	1.33	0.41^{g}	0.39^{cd}	0.37^{cdef}	0.36	0.50
T_{11} – (T_7+ Si)	0.92^{b}	1.19	0.45^{efg}	0.62^{ab}	0.52^{a}	0.29	0.62
T_{12} – (T_8 + Si)	1.12^{a}	1.25	0.41^{g}	0.50^{bcd}	0.41^{bcd}	0.58	0.52
CD (0.05)	**0.198**	**NS**	**0.072**	**0.228**	**0.100**	**NS**	**NS**
CV	**14.539**	**31.968**	**8.278**	**23.951**	**15.170**	**39.381**	**23.469**

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content (0.52 %) and it was statistically on par with treatment T_5 (0.49 %), T_2 (0.45 %) and T_6 (0.43 %) . Significantly lower nitrogen content (0.28 %) was observed in treatment T_9 (T_5+ Si).

In grain maximum nitrogen content (0.82 %) was observed in treatment T_3 (POP Recommendation of KAU) followed by the treatment T_6 (T_3 +*Sampoorna*) (0.80 %). Lowest nitrogen content in grain (0.50 %) was observed in treatment T_{10} (T_6+ Si).

4.5.2 Phosphorous

The data on phosphorous content at different growth stages of rice are presented in Table 12. At maximum tillering stage, in both shoot and root, the phosphorous content was significantly influenced by the treatments. Maximum content of P in shoot was noticed in the treatments T_1, T_2, T_3, T_5, T_6, T_9, T_{10} which was on par with T_{12}. Treatment T_{11} (T_7+ Si) recorded the significantly lower content of phosphorous of 0.34 %. In root, significantly higher phosphorous content was observed in from the treatment T_3 (POP Recommendation of KAU) and lower phosphorous content was observed in treatment T_9 (T_5+ Si).

At panicle initiation stage, no significant difference was observed among treatments in phosphorous content of shoot. Maximum phosphorous content (0.34 %) was recorded in the treatment T_9 (T_5+ Si) and T_{11}(T_7+ Si) and minimum phosphorous content(0.24 %) was recorded in the treatments T_4(FYM+ Neem cake + Groundnut cake). In root, there was significant difference among treatments in phosphorous content. Application of FYM+ Neem cake + Groundnut cake along with *Ayar* recorded the highest phosphorous content (0.127 %) in root and followed by the treatments T_8 (T_4 +*Sampoorna*) and T_9 (T_5+ Si). Treatments T_4, T_{11} and T_{12} recorded the minimum content of phosphorous in roots.

At harvest stage, maximum content of phosphorous in straw was noticed in treatments T_2 and T_{10} which was on par with treatment T_1 and T_3. Minimum content

Table 12. The effect of different treatments on phosphorous content at different growth stages of rice (%)

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	Straw	Grains
T_1 – Farmer's practice	0.33^{e}	0.45^{a}	0.050^{cd}	0.32	0.021^{d}	0.24^{ab}	0.042^{f}
T_2 – Fertilizer recommendation on STCR basis	0.39^{b}	0.44^{a}	0.045^{d}	0.29	0.019^{d}	0.25^{a}	0.053^{de}
T_3 – POP Recommendation of KAU	0.41^{a}	0.44^{a}	0.045^{d}	0.26	0.031^{c}	0.24^{ab}	0.073^{bc}
T_4 – FYM+ Neem cake + Groundnut cake	0.37^{c}	0.37^{bc}	0.021^{e}	0.24	0.023^{d}	0.20^{cd}	0.048^{ef}
T_5 – (T_3 + *Ayar*)	0.37^{c}	0.44^{a}	0.060^{c}	0.28	0.021^{d}	0.20^{cd}	0.087^{a}
T_6 – (T_3 + *Sampoorna*)	0.33^{e}	0.44^{a}	0.062^{c}	0.24	0.021^{d}	0.18^{de}	0.068^{c}
T_7 – (T_4 + *Ayar*)	0.37^{c}	0.38^{bc}	0.127^{a}	0.25	0.044^{b}	0.16^{e}	0.059^{d}
T_8 – (T_4 + *Sampoorna*)	0.35^{d}	0.38^{bc}	0.080^{b}	0.29	0.052^{a}	0.23^{abc}	0.078^{b}
T_9 – (T_5 + Si)	0.29^{f}	0.44^{a}	0.090^{b}	0.34	0.055^{a}	0.21^{cd}	0.042^{f}
T_{10} – (T_6 + Si)	0.36^{cd}	0.44^{a}	0.055^{cd}	0.24	0.044^{b}	0.25^{a}	0.053^{de}
T_{11} – (T_7 + Si)	0.31^{f}	0.34^{c}	0.021^{e}	0.34	0.021^{d}	0.22^{bc}	0.054^{de}
T_{12} – (T_8 + Si)	0.33^{e}	0.40^{ab}	0.022^{e}	0.26	0.028^{c}	0.22^{abc}	0.042^{f}
CD (0.05)	**0.016**	**0.052**	**0.014**	**NS**	**0.004**	**0.029**	**0.007**
CV	**2.765**	**7.451**	**14.751**	**25.395**	**7.622**	**8.038**	**7.452**

of phosphorous (0.16 %) was observed by the application of FYM + Neem cake + Groundnut cake along with *Ayar*. Phosphorous content of root was significantly affected by the different treatments. Treatment T_9 and T_8 recorded maximum phosphorous content in root and was 0.055 % and 0.052 % respectively. In roots minimum amount of phosphorous was recorded in treatments T_2 (0.019 %).

Phosphorous content in grain was significantly influenced by different treatments. Application of fertilizers based on POP recommendation of KAU along with *Ayar* (T_5) recorded maximum P content in grains and was significantly superior to all other treatments. The minimum content was recorded in treatment T_1, T_9 and T_{12} was 0.042 %.

4.5.3 Potassium

The experimental results with respect to potassium content in shoot, root at different growth stages and grains at harvest of rice are given in Table 13.

At maximum tillering stage there was no significant difference between the treatments in K content of both shoot and root. K content of shoot was not influenced by any treatment at all stages of observation where as root K content was influenced by different treatments at panicle initiation stage and at harvest. Significantly higher K content in root at panicle initiation stage was recorded in T_1 (0.83 %) and at harvest stage T_4 (0.57 %) recorded highest K content in root.

Grain K content was also not influenced by any treatments. Highest potassium content (0.35 %) was observed in treatment T_1 (Farmer's practice) and lowest potassium content (0.22 %) was recorded in T_8(T_4 + *Sampoorna*).

4.5.4 Calcium

The data on calcium content in shoot, root and grain in different growth stages of rice is given in Table 14.

Calcium content of shoot at maximum tillering stage and panicle initiation stage were not influenced by different treatments. However, root calcium content at all stages and Ca content of grains and straw at harvest stage were significantly influenced by different treatments.

At maximum tillering stage, highest content of calcium in shoot was recorded by the application of fertilizers based on POP recommendation of KAU along with *Ayar* (12756.67 mg kg^{-1}) and lowest calcium content was noticed by the application of FYM+ Neem cake + Groundnut cake along with *Sampoorna and* silicon (7210.00 mg kg^{-1}). In root, significantly higher calcium content was observed in T_6 (9706.67 mg kg^{-1}) followed by T_2 and T_9. Treatment T_{11} (6166.67 mg kg^{-1}) and T_{12} (6456.67 mg kg^{-1}) recorded the lowest content of calcium in root.

At panicle initiation stage, as in maximum tillering stage shoot calcium content was not affected by treatments. There was significant difference between the treatments in calcium content of root. The treatment T_{10} and T_{12} recorded significantly higher calcium content and T_9 recorded the lowest calcium content (4233.33 mg kg^{-1}) which was followed by T_6, T_3, T_2 and T_9.

At harvest stage, the calcium content recorded in straw was high compared to other growth stages. In straw almost all the treatments were recorded significantly higher concentration of calcium except treatment T_{11} and T_{12}. The treatment T_1 recorded the maximum concentration of calcium (11733.33 mg kg^{-1}) and application FYM+ Neem cake + Groundnut cake recorded the lowest concentration of calcium in root.

In grain, significantly higher concentration of calcium was recorded by the application of fertilizers based on POP recommendations of KAU along with *Ayar* and silicon, which was on par with treatment T_{11} (T_7+ Si). Lowest calcium content was noticed in treatment with POP recommendation of KAU (T_3).

Table 13. The effect of different treatments on potassium content at different growth stages of rice (%)

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	Straw	Grains
T_1 – Farmer's practice	0.70	2.76	0.83^{a}	1.55	0.43^{b}	1.70	0.35
T_2 – Fertilizer recommendation on STCR basis	0.63	2.76	0.45^{cd}	1.72	0.40^{bc}	1.75	0.25
T_3 – POP Recommendation of KAU	0.62	2.77	0.57^{bc}	1.72	0.35^{bc}	2.07	0.28
T_4 – FYM+ Neem cake + Groundnut cake	0.70	2.67	0.43^{cd}	1.55	0.57^{a}	1.53	0.30
T_5 – (T_3 + *Ayar*)	0.67	2.66	0.65^{b}	1.87	0.37^{bc}	2.10	0.28
T_6 – (T_3 + *Sampoorna*)	0.53	2.82	0.53^{bcd}	1.62	0.40^{bc}	2.08	0.23
T_7 – (T_4 + *Ayar*)	0.55	2.34	0.65^{b}	1.63	0.30^{c}	1.50	0.27
T_8 – (T_4 + *Sampoorna*)	0.58	2.48	0.63^{b}	1.60	0.35^{bc}	2.03	0.22
T_9 – (T_5 + Si)	0.62	2.77	0.65^{b}	1.80	0.32^{c}	1.83	0.25
T_{10} – (T_6 + Si)	0.62	2.75	0.68^{ab}	2.07	0.30^{c}	1.78	0.30
T_{11} – (T_7 + Si)	0.73	2.48	0.38^{d}	1.48	0.33^{bc}	1.75	0.27
T_{12} – (T_8 + Si)	0.78	2.81	0.43^{cd}	1.68	0.33^{bc}	1.68	0.23
CD (0.05)	NS	**NS**	**0.174**	NS	**0.111**	NS	NS
CV	**19.00**	**10.825**	**17.895**	**21.489**	**17.603**	**16.282**	**19.627**

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Table 14. The effect of different treatments on calcium content at different growth stages of rice (mg kg^{-1})

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	Straw	Grains
T_1 – Farmer's practice	7066.67^{f}	9786.67	6533.33^{e}	6936.67	11733.33^{a}	18146.67^{a}	2930.00^{cde}
T_2 – Fertilizer recommendation on STCR basis	9190.00^{b}	7593.33	4688.33^{f}	4843.33	6100.00^{i}	15980.00^{a}	2645.00^{de}
T_3 – POP Recommendation of KAU	7276.67^{ef}	9646.67	4553.33^{f}	4810.00	7116.67^{g}	19740.00^{a}	2085.00^{e}
T_4 –FYM+ Neem cake + Groundnut cake	7563.33^{de}	11673.33	10783.33^{c}	5746.67	5966.67^{i}	17236.67^{a}	2656.67^{de}
T_5– (T_3 +*Ayar*)	8660.00^{c}	12756.67	7900.00^{de}	5863.33	6083.33^{i}	17706.67^{a}	2456.67^{de}
T_6–(T_3 +*Sampoorna*)	9706.67^{a}	9320.00	4290.00^{f}	5740.00	7900.00^{f}	17906.67^{a}	2800.00^{cde}
T_7– (T_4 +*Ayar*)	7816.67^{d}	7433.33	8116.67^{d}	5460.00	6783.33^{h}	18340.00^{a}	4050.00^{cde}
T_8–(T_4 +*Sampoorna*)	7270.00^{ef}	8473.33	18083.33^{b}	6263.33	7150.00^{g}	18033.33^{a}	3388.33^{cde}
T_9 –(T_5+ Si)	9123.33^{b}	8800.00	4233.33^{f}	5350.00	9700.00^{c}	17533.33^{a}	6865.00^{a}
T_{10}–(T_6+ Si)	7133.33^{f}	8136.67	21733.33^{a}	7293.33	8666.67^{e}	17983.33^{a}	4321.67^{bcd}
T_{11} – (T_7+ Si)	6166.67^{g}	8573.33	4915.00^{f}	7833.33	10116.67^{b}	9646.67^{b}	6390.00^{ab}
T_{12}– (T_8 + Si)	6456.67^{g}	7210.00	22150.00^{a}	6830.00	9200.00^{d}	9723.33^{b}	4781.67^{bc}
CD (0.05)	**294.612**	NS	**1492.200**	NS	**291.326**	**4867.491**	**2074.811**
CV	**2.235**	**28.987**	**8.963**	**19.585**	**2.139**	**17.422**	**32.406**

4.5.5 Magnesium

The data pertaining to Mg content is furnished in Table 15. Magnesium content was not influenced by the treatments at all stages except shoot calcium content at panicle initiation stage and root calcium content.

At maximum tillering stage there was no significant difference among the treatments in both shoot and root for their Mg content. In shoot highest Mg content (869.33 mg kg $^{-1}$) was obtained by the application of nutrients based on farmers practice (T_1). Application of FYM + Neem cake + Groundnut cake along with *Sampoorna* and silicon recorded the lowest Mg content (796.00 mg kg $^{-1}$) in rice shoot. But in roots application of nutrients based on farmers practice (T_1) recorded reduced level of Mg content and application of FYM + Neem cake + Groundnut cake along with *Ayar* and silicon recorded highest Mg content (720.67 mg kg $^{-1}$).

At panicle initiation stage, there was a significant difference among the treatments in rice shoot calcium content. Application of FYM + Neem cake + Groundnut cake along with *Ayar* and silicon (T_{12}) recorded significantly higher Mg content (749.33 mg kg $^{-1}$) which was on par with all the treatments except T_4, T_7 and T_8. Application of FYM + Neem cake + Groundnut cake (T_4) recorded significantly lower Mg content in rice shoot. There was no significant difference among the treatments with regard to root calcium content. However, Mg content in root was ranged from 175.67 mg kg $^{-1}$(T_{10}) to 1776.33 mg kg $^{-1}$ (T_2).

At harvest stage there was no appreciable difference between the treatments in rice straw Mg content. Highest Mg content (742.00 mg kg $^{-1}$) was noticed in treatment T_3 (POP Recommendation of KAU) followed by treatment T_9 (T_5+ Si) and lowest Mg content was observed in treatment T_7 (T_4 + *Ayar*)(617.33 mg kg $^{-1}$). There was a significant difference between treatments in root Mg content. Highest Mg content in roots found in treatment T_1 (Farmer's practice) and T_{11} (T_7+ Si) followed

Table 15. The effect of different treatments on magnesium content at different growth stages of rice (mg kg^{-1})

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	Straw	Grains
T_1 –Farmer's practice	572.67	869.33	636.67	715.33^{abc}	550.00^{a}	636.00	523.67
T_2–Fertilizer recommendation on STCR basis	668.67	834.67	1776.33	708.67^{abc}	312.33^{d}	660.67	564.00
T_3 –POP Recommendation of KAU	675.33	830.00	249.33	690.67^{abc}	327.00^{d}	742.00	796.17
T_4 –FYM+ Neem cake + Groundnut cake	670.67	816.67	575.00	581.33^{d}	194.00^{f}	671.33	565.17
T_5– (T_3 +*Ayar*)	624.67	851.33	570.00	696.67^{abc}	125.00^{g}	679.33	945.00
T_6–(T_3 +*Sampoorna*)	689.33	839.33	210.00	675.33^{abc}	482.83^{b}	633.33	561.67
T_7– (T_4 +*Ayar*)	645.33	862.67	1726.00	642.00^{cd}	322.17^{d}	617.33	633.33
T_8–(T_4 +*Sampoorna*)	669.33	857.33	1406.67	659.33^{bcd}	258.83^{e}	640.00	563.33
T_9 –(T_5+ Si)	621.33	848.67	477.83	722.67^{abc}	432.00^{c}	704.00	726.67
T_{10}–(T_6+ Si)	662.00	844.00	175.67	708.00^{abc}	281.00^{e}	634.00	665.00
T_{11} – (T_7+ Si)	720.67	855.33	239.67	749.33^{a}	526.33^{a}	636.00	698.33
T_{12}– (T_8 + Si)	676.67	796.00	1306.67	744.00^{ab}	417.83^{c}	653.33	596.67
CD (0.05)	**NS**	**NS**	**NS**	**89.979**	**24.847**	**NS**	**NS**
CV	**8.245**	**3.286**	**94.049**	**7.688**	**4.163**	**6.512**	**27.540**

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by treatment T_6 (T_3 +*Sampoorna*). Significantly lower Mg content (194.00 mg kg $^{-1}$) was observed in treatment T_4 (FYM+ Neem cake + Groundnut cake).

4.5.6 Sulphur

The data on Sulphur content at different growth stages of rice was given in Table 16. The treatment influence on sulphur content of shoot and root all stages and grain at harvest were significant.

At maximum tillering stage, almost all treatments recorded significantly higher sulphur content in shoot except T_8 and T_7. In root, T_4 (FYM+ Neem cake + Groundnut cake) recorded higher concentration of S (0.58 %) which was on par with treatments T_{10}, T_{12}, T_7, T_{11} and T_1. Application of FYM+ Neem cake + Groundnut cake along with *Sampoorna* recorded lower concentration of S (0.22 %).

At panicle initiation stage in both shoot and root the sulphur content was found to be significant. In shoot application of fertilizers based on POP recommendation of KAU along with *Ayar* recorded higher concentration of S and it was on par with T_2, T_3 and T_{10}. Lower concentration of S was recorded in T_{11} (T_7+ Si). In root, treatment T_7 (0.45 %) and T_{12} (0.44 %) were recorded higher concentration of S and T_1 (0.08 %) recorded lower concentration of S.

At harvest stage, the S concentration of straw and root was reduced. In straw significantly higher concentration of S (0.078 %) was recorded in treatment T_2 (Fertilizer recommendation on STCR basis) and it is followed by treatment T_1 (Farmer's practice). Application of fertilizers based on POP Recommendation of KAU along with *Ayar* was noticed lowest concentration of S (0.007 %). In root T_1 (0.16 %) and T_4 (0.16 %) recorded higher concentration of sulphur closely followed by treatment T_{12} (0.13 %). Lower content of S noticed in treatment T_9 (T_5+ Si) (0.03%).

Table 16. The effect of different treatments on sulphur content at different growth stages of rice (%)

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	Straw	Grains
T_1 –Farmer's practice	0.45^{ab}	0.31^{a}	0.08^{f}	0.32^{de}	0.16^{a}	0.068^{b}	0.33^{a}
T_2–Fertilizer recommendation on STCR basis	0.26^{cd}	0.32^{a}	0.18^{e}	0.43^{ab}	0.09^{c}	0.078^{a}	0.22^{abc}
T_3 –POP Recommendation of KAU	0.33^{bcd}	0.29^{a}	0.36^{b}	0.38^{abcd}	0.06^{f}	0.014^{def}	0.20^{bc}
T_4 –FYM+ Neem cake + Groundnut cake	0.58^{a}	0.29^{a}	0.18^{e}	0.36^{cd}	0.16^{a}	0.008^{ef}	0.19^{bc}
T_5– (T_3 +*Ayar*)	0.39^{bc}	0.28^{ab}	0.34^{b}	0.45^{a}	0.04^{hi}	0.007^{f}	0.15^{c}
T_6–(T_3 +*Sampoorna*)	0.38^{bc}	0.30^{a}	0.17^{e}	0.36^{bcd}	0.07^{e}	0.011^{def}	0.23^{abc}
T_7– (T_4 +*Ayar*)	0.46^{ab}	0.23^{b}	0.45^{a}	0.34^{cde}	0.08^{d}	0.016^{de}	0.18^{bc}
T_8–(T_4 +*Sampoorna*)	0.22^{d}	0.16^{c}	0.28^{c}	0.38^{bcd}	0.07^{e}	0.012^{def}	0.21^{abc}
T_9 –(T_5+ Si)	0.43^{b}	0.31^{a}	0.19^{de}	0.37^{bcd}	0.03^{i}	0.009^{def}	0.18^{bc}
T_{10}–(T_6+ Si)	0.47^{ab}	0.30^{a}	0.22^{d}	0.39^{abc}	0.045^{gh}	0.053^{c}	0.29^{ab}
T_{11} – (T_7+ Si)	0.45^{ab}	0.29^{a}	0.36^{b}	0.28^{e}	0.048^{g}	0.014^{def}	0.33^{a}
T_{12}– (T_8 + Si)	0.46^{ab}	0.28^{ab}	0.44^{a}	0.32^{de}	0.13^{b}	0.016^{d}	0.15^{c}
CD (0.05)	**0.149**	**0.064**	**0.033**	**0.070**	**0.007**	**0.008**	**0.116**
CV	**21.643**	**13.572**	**7.308**	**11.317**	**5.144**	**18.229**	**31.111**

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In grains treatments found to be significant. T_1 and T_{11} recorded higher concentration of S (0.33 %) and it was on par with T_{10}, T_6, T_2 and T_8. Lower concentration of S was recorded by T_5 and T_{12}.

4.5.7 Iron

The experimental results with respect to iron content in shoot, root and grains in different growth stages of rice is given in Table 17. At maximum tillering stage Fe content was significantly different among the treatments in both shoot and roots of rice. Enhanced Fe content was noticed in both shoot and roots at maximum tillering stage and decreased content was observed afterwards. In shoot maximum Fe content (7146.67 mg kg $^{-1}$) was recorded by the application of FYM + Neem cake + Groundnut cake along with *Ayar* (T_7) followed by T_8 (T_4 + *Sampoorna*) and T_5 (T_3 + *Ayar*). Application of FYM+ Neem cake + Groundnut cake (T_4) and application of fertilizers based on POP recommendation of KAU along with *Sampoorna* recorded lowest Fe content. In root, application of FYM+ Neem cake + Groundnut cake along with *Ayar* (T_7) and application of FYM+ Neem cake + Groundnut cake along *Sampoorna* (T_8) recorded significantly higher Fe content was 14253.33 mg kg $^{-1}$ and 14080 mg kg $^{-1}$ respectively and it is on par with treatments T_{12}, T_5 and T_6 . Lowest Fe content was recorded in treatment T_9 (12280.00 mg kg $^{-1}$) and T_3 (12346.67 mg kg^{-1}).

The Fe content was gradually decreased at panicle initiation stage compared to maximum tillering stage. In both shoot and root, the Fe content was significantly different between the treatments. In shoot, maximum content of Fe was recorded in treatment T_4 (3142.67 mg kg $^{-1}$) and which was on par with T_{10} (2860.00 mg kg $^{-1}$) and T_9 (2780 mg kg $^{-1}$). Lowest Fe content was noticed in treatments T_1 (1722 mg kg $^{-1}$), T_7 (1739.33 mg kg $^{-1}$) and T_6 (1803.33 mg kg $^{-1}$). In root, significantly higher Fe content was recorded in treatments T_1 (10813.33 mg kg $^{-1}$), T_2 (10706.67 mg kg $^{-1}$) and T_{12} (10700.00 mg kg $^{-1}$). The lowest Fe content was noticed in T_8 (7340.00 mg kg^{-1}).

Table 17. The effect of different treatments on iron content at different growth stages of rice (mg kg^{-1})

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	straw	Grains
T_1 –Farmer's practice	12673.33^{cd}	4233.33^{bc}	10813.33^{a}	1722.00^{e}	10033.33^{c}	1160.67^{cdef}	291.33
T_2–Fertilizer recommendation on STCR basis	12920.00^{bcd}	3686.67^{bc}	10706.67^{a}	2293.33^{bcde}	11860.00^{a}	1048.00^{def}	251.33
T_3 –POP Recommendation of KAU	12346.67^{d}	4126.67^{bc}	10266.67^{c}	1882.67^{de}	9920.00^{c}	2273.33^{a}	233.67
T_4 –FYM+ Neem cake + Groundnut cake	12533.33^{cd}	2846.67^{c}	8760.00^{f}	3142.67^{a}	10800.00^{b}	1304.00^{bcdef}	274.67
T_5– (T_3 +*Ayar*)	13720.00^{ab}	4786.67^{b}	8706.67^{f}	2620.00^{abcd}	8080.00^{d}	1640.67^{b}	394.00
T_6–(T_3 +*Sampoorna*)	13660.000^{ab}	2906.67^{c}	10506.67^{b}	1803.33^{e}	10366.67^{bc}	914.67^{f}	312.00
T_7– (T_4 +*Ayar*)	14253.33^{a}	7146.67^{a}	10186.67^{c}	1739.33^{e}	11600.00^{a}	1362.00^{bcde}	322.67
T_8–(T_4 +*Sampoorna*)	14080.00^{a}	4966.67^{b}	7340.00^{g}	2620.00^{abcd}	10360.00^{bc}	1478.00^{bcd}	322.67
T_9 –(T_5+ Si)	12280.00^{d}	4613.33^{bc}	9106.67^{e}	2780.00^{abc}	10020.00^{c}	1248.00^{bcdef}	418.00
T_{10}–(T_6+ Si)	13386.67^{abc}	4400.00^{bc}	10453.33^{b}	2860.00^{ab}	8460.00^{d}	1494.67^{bc}	392.67
T_{11} – (T_7+ Si)	13033.33^{bcd}	3593.33^{bc}	9266.67^{d}	2355.33^{bcde}	9906.67^{c}	943.33^{ef}	350.67
T_{12}– (T_8 + Si)	13880.00^{ab}	4480.00^{bc}	10700.00^{a}	2024.67^{cde}	11673.33^{a}	988.67^{ef}	216.47
CD (0.05)	**973.791**	**1770.362**	**117.828**	**777.703**	**662.284**	**445.940**	**NS**
CV	**4.346**	**24.225**	**0.715**	**19.793**	**3.813**	**19.930**	**27.267**

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At harvest stage, there was appreciable difference between the treatments in both straw and root on Fe content. In straw, significantly higher Fe content was recorded by T_3 (2273.33 mg kg $^{-1}$) and the lowest Fe content was noticed in T_6 (914.67 mg kg $^{-1}$). In root, significantly higher Fe content was observed in treatments T_2 (11860.00 mg kg $^{-1}$), T_{12} (11673.33 mg kg $^{-1}$) and T_7 (11600.00 mg kg $^{-1}$). The treatment T_{10} and T_5 recorded the lowest Fe content in root at harvest stage.

In grains, the Fe content ranged from 216.47 mg kg $^{-1}$ (T_{12}) to 418.00 mg kg $^{-1}$ (T_9) while there was no significant difference between the treatments.

4.5.8 Manganese

The experimental results with respect to manganese content in shoot, root and grains in different growth stages of rice is given in Table 18.

The effect of different treatments on content of manganese in roots and shoots of rice at maximum tillering stage and panicle initiation stage was significant. In shoot significantly higher Mn content was recorded by the application of fertilizers based POP Recommendation of KAU along with *Ayar* and silicon (757.33 mg kg $^{-1}$) and which was on par with T_{12} (723.33 mg kg $^{-1}$). The treatment POP Recommendation of KAU recorded the lowest Mn content in shoot. The treatments T_9, T_5 and T_{12} were recorded significantly highest Mn content and the lowest Mn content was recorded by the application of fertilizer based on STCR in root.

In shoot significantly higher Mn content was observed in T_9 (T_5+ Si) (526.67 mg kg $^{-1}$) which was on par with T_{12} and T_7. Lower Mn content was observed in treatment T_2, T_3 and T_4. In root significantly higher Mn content was observed in T_5, T_1, T_2 and T_9 and lower content of Mn was noticed in T_{10} and T_{11}.

At harvest stage, the Mn content both in straw and root was significantly affected by the treatments. In straw application of fertilizers based on POP Recommendation of KAU along with *Ayar* and silicon recorded higher Mn content

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(513.33 mg kg $^{-1}$). Which was on par with treatment T_{11} (430.00 mg kg $^{-1}$). Application of FYM + Neem cake + Groundnut cake along with *Ayar* (T_7) recorded significantly lowest Mn content in straw. In root, application of FYM+ Neem cake + Groundnut cake recorded the highest Mn content (310.40 mg kg $^{-1}$) followed by the treatments T_{12}, T_6 and T_1. The lowest Mn content was noticed in treatment T_2, T_{11} and T_5.

In grains effect of different treatments on manganese content was found to be significant. Maximum Mn content was noticed in the treatment T_8, T_{12}, T_9 and T_{11} and values were 88.40 mg kg $^{-1}$, 87. 0 mg kg $^{-1}$, 85.67 mg kg $^{-1}$ and 84.47 mg kg $^{-1}$ respectively. The lowest content of Mn (42.27 %) was recorded in T_6.

4.5.9 Zinc

The experimental results with respect to manganese content in shoot, root and grains in different growth stages of rice is given in Table 19.

At maximum tillering stage, the effect of treatments at on Zn content of rice shoot was significant. The treatments, T_5 (86.80 mg kg $^{-1}$), T_{11} (84.87 mg kg $^{-1}$) and T_9 (84.27 mg kg $^{-1}$) recorded the maximum content of Zn which was on par with T_8 and T_7. Lower content of Zn was observed in treatments T_3, T_4, T_6, T_{12} and T_2. In root, there was no significant difference between the treatments, however it was ranged from 48.8 mg kg $^{-1}$ (T_1) to 118.2 mg kg $^{-1}$ (T_{11}).

At panicle initiation stage, the effect of treatments was found to be non-significant with regard to Zn content of rice shoot. However, Zn content ranged from 32.47 mg kg $^{-1}$ (T_5) to 63.13 mg kg $^{-1}$(T_9). In root, the treatment POP Recommendation of KAU along with *Ayar* (T_5) recorded significantly highest concentration of Zn which was on par with T_8 and T_9. Significantly lower content of Zn was noticed in T_3 (22.80 mg kg $^{-1}$) and T_6 (20.93 mg kg $^{-1}$).

Table 18. The effect of different treatments on manganese content at different growth stages of rice (mg kg^{-1})

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	straw	Grains
T_1 –Farmer's practice	136.67^{cd}	306.00^{cd}	224.33^{a}	151.87^{bc}	204.73^{b}	252.67^{de}	64.40^{d}
T_2–Fertilizer recommendation on STCR basis	28.27^{e}	358.00^{cd}	209.80^{a}	105.87^{c}	84.87^{d}	202.00^{ef}	64.60^{cd}
T_3 –POP Recommendation of KAU	65.87^{de}	248.67^{d}	110.07^{b}	121.33^{c}	116.60^{cd}	238.00^{e}	74.67^{b}
T_4 –FYM+ Neem cake + Groundnut cake	47.07^{de}	295.33^{cd}	129.67^{b}	119.80^{c}	310.40^{a}	412.00^{bc}	70.87^{bc}
T_5– (T_3 +*Ayar*)	362.00^{a}	593.60^{abc}	248.00^{a}	256.67^{bc}	67.87^{d}	152.73^{fg}	72.80^{b}
T_6–(T_3 +*Sampoorna*)	122.13^{cde}	421.33^{bcd}	112.40^{b}	238.53^{bc}	215.07^{b}	229.33^{ef}	42.27^{e}
T_7– (T_4 +*Ayar*)	240.60^{b}	474.00^{abcd}	111.40^{b}	318.67^{abc}	106.07^{cd}	37.33^{h}	72.73^{b}
T_8–(T_4 +*Sampoorna*)	210.00^{bc}	512.47^{abcd}	49.13^{c}	$191.80b^{c}$	165.87^{bc}	96.93^{gh}	88.40^{a}
T_9–(T_5+ Si)	416.00^{a}	757.33^{a}	201.73^{a}	526.67^{a}	146.67^{bcd}	513.33^{a}	85.67^{a}
T_{10}–(T_6+ Si)	114.67^{cde}	486.67^{acd}	51.47^{c}	181.07^{bc}	178.40^{bc}	197.73^{ef}	64.40^{d}
T_{11} – (T_7+ Si)	90.40^{de}	344.00^{cd}	55.33^{c}	291.33^{bc}	70.00^{d}	430.00^{ab}	84.47^{a}
T_{12}– (T_8 + Si)	360.00^{a}	723.33^{ab}	138.40^{b}	354.00^{ab}	215.73^{b}	333.33^{cd}	87.20^{a}
CD (0.05)	**99.079**	**309.772**	**49.114**	**213.044**	**80.531**	**83.689**	**6.424**
CV	**32.006**	**39.762**	**21.199**	**52.831**	**30.318**	**19.159**	**5.217**

Table 19. The effect of different treatments on zinc content at different growth stages of rice (mg kg^{-1})

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	straw	Grains
T_1 –Farmer's practice	48.80	53.67^{bc}	33.47^{cdef}	45.60	92.40^{bc}	37.53^{j}	23.53^{cde}
T_2–Fertilizer recommendation on STCR basis	78.27	50.53^{c}	37.47^{bcd}	42.53	85.80^{bcd}	97.33^{b}	20.27^{e}
T_3 –POP Recommendation of KAU	79.93	44.93^{c}	22.80^{g}	50.53	50.00^{f}	74.47^{e}	27.87^{abcd}
T_4 –FYM+ Neem cake + Groundnut cake	98.73	45.73^{c}	25.40^{fg}	33.07	82.47^{bcde}	66.80^{fg}	19.53^{e}
T_5– (T_3 +*Ayar*)	104.47	86.80^{a}	49.73^{a}	32.47	104.27^{b}	62.27^{g}	23.20^{de}
T_6–(T_3 +*Sampoorna*)	61.27	49.80^{6}	20.93^{g}	35.67	61.67^{ef}	80.67^{d}	31.47^{ab}
T_7– (T_4 +*Ayar*)	71.73	70.60^{abc}	27.13^{defg}	48.73	63.47^{ef}	45.67^{i}	22.67^{de}
T_8–(T_4 +*Sampoorna*)	48.93	82.13^{ab}	44.60^{ab}	38.20	64.80^{def}	88.13^{c}	27.00^{abcd}
T_9–(T_5+ Si)	84.47	84.27^{a}	43.07^{abc}	63.13	69.27^{def}	136.13^{a}	26.80^{bcd}
T_{10}–(T_6+ Si)	73.87	54.33^{bc}	25.67^{efg}	52.27	78.40^{cde}	71.27^{ef}	26.53^{bcd}
T_{11} – (T_7+ Si)	118.20	84.87^{a}	36.00^{bcde}	58.00	147.20^{a}	53.07^{h}	32.87^{a}
T_{12}– (T_8 + Si)	81.13	50.20^{c}	25.20^{fg}	55.93	54.20^{f}	49.60^{hi}	29.33^{abc}
CD (0.05)	**NS**	**29.453**	**10.466**	**NS**	**22.108**	**5.722**	**5.962**
CV	**31.755**	**27.540**	**18.945**	**30.768**	**16.423**	**4.699**	**13.581**

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At harvest stage, effect of treatment was found to be significant in case of zinc content of rice shoot and root. Application of fertilizers based on POP Recommendation of KAU along with *Ayar* and silicon (T_9) recorded maximum content of Zn (136.13 mg kg $^{-1}$) and application of fertilizers based on farmer's practice (T_1) recorded the lowest concentration of Zn (37.53 mg kg $^{-1}$) in straw. In root application of FYM+ Neem cake + Groundnut cake along with *Ayar* and silicon recorded the highest concentration of Zn (147.20 mg kg $^{-1}$) followed by T_5 (104.27 mg kg $^{-1}$). Less concentration of Zn was noticed in T_3 and T_{12} was 50.00 mg kg $^{-1}$ and 54.20 mg kg $^{-1}$ respectively.

In grains treatments were found to be significant. Maximum content of Zn was observed in treatment T_{11} (32.87 mg kg $^{-1}$) which was on par with T_3, T_8, T_6 and T_{12}. The lowest concentration of Zn was noticed in T_4 and T_2 was 19.53 mg kg $^{-1}$ and 20.27 mg kg $^{-1}$ respectively.

4.5.9 Copper

The experimental results with respect to copper content in shoot, root and grains in different growth stages of rice is given in Table 20.

At maximum tillering stage, the effect of treatment was found to be significant in case of copper content in shoot and root of rice. Application of FYM+ Neem cake + Groundnut cake along with *Ayar* was recorded the maximum content of Cu (56.60 mg kg $^{-1}$) in shoot and which was on par with T_{11} (T_7 + Si). The next treatment recorded maximum content of Cu was 36.73 mg kg $^{-1}$ (T_9). Other treatments recorded less content of Cu ranged from 2.65 mg kg $^{-1}$ to 10.20 mg kg $^{-1}$. In root, T_{10} (37.93 mg kg $^{-1}$) recorded the maximum content of Cu and next treatment which recorded maximum content of Cu was T_1 (30.93 mg kg $^{-1}$).

At panicle initiation stage, the effect of treatment application was found to be significant in case of copper content in shoot and root of rice. In shoot T_5 (T_3 +*Ayar*) recorded significantly higher content of Cu which is on par with T_9. The lowest content of Cu was observed in treatments T_1 (Farmer's practice) and T_3 (POP Recommendation of KAU) was 2.35 mg kg $^{-1}$and 4.39 mg kg $^{-1}$ respectively. In root, T_5 (T_3 +*Ayar*) recorded significantly higher content of Cu followed by T_6 (T_3 + *Sampoorna*). Application of FYM+ Neem cake + Groundnut cake recorded the minimum amount of Cu in root.

At harvest stage, the effect of treatment was found to be significant in case of copper content in straw and root of rice. Treatment T_{10} and T_9 recorded maximum content of Cu in straw 33.67 mg kg $^{-1}$ and 30.73 mg kg $^{-1}$ respectively. T_3 and T_{11} recorded the minimum content of Cu 2.91 mg kg $^{-1}$ and 3.33 mg kg $^{-1}$ respectively. In root T_6 (T_3 +*Sampoorna*) (154.53 mg kg $^{-1}$) recorded maximum Cu content which was on par with T_{11} and T_7. Lowest concentration of Cu was noticed in treatment T_8, T_{10}, T_9, T_4, and T_1.

In grains, there was no significant difference between the treatments. The Cu content ranged from 10.38 mg kg $^{-1}$ (T_6) to 37.67 mg kg $^{-1}$ (T_8).

4.5.10 Silicon

The experimental results with respect to Si content in shoot, root and grains in different growth stages of rice is given in Table 21.

At maximum tillering stage in shoot significantly higher concentration of Si was recorded by the application of POP recommendation of KAU along with *Sampoorna* and silicon (8.62 %) which was on par with treatment T_9. Application of FYM+ Neem cake + Groundnut cake recorded the lowest Si concentration in shoot.

Table 20. The effect of different treatments on copper content at different growth stages of rice (mg kg^{-1})

Treatments	Maximum tillering		Panicle initiation		Harvest		
	Root	Shoot	Root	Shoot	Root	Straw	Grains
T_1 –Farmer's practice	30.93^{ab}	6.26^{c}	70.67^{g}	2.35^{c}	75.07^{c}	23.40^{bc}	21.87
T_2–Fertilizer recommendation on STCR basis	18.81^{bcd}	4.49^{c}	92.27^{c}	4.99^{bc}	120.67^{b}	23.07^{bc}	13.96
T_3 –POP Recommendation of KAU	5.75^{de}	4.57^{c}	75.53^{f}	4.39^{c}	121.47^{b}	2.91^{e}	10.52
T_4 –FYM+ Neem cake + Groundnut cake	2.70^{e}	4.67^{c}	35.67^{k}	10.41^{bc}	71.40^{c}	23.53^{bc}	10.67
T_5– (T_3 +*Ayar*)	22.66^{abc}	10.20^{c}	153.60^{a}	26.90^{a}	112.07^{b}	25.07^{b}	14.19
T_6–(T_3 +*Sampoorna*)	11.32^{cde}	3.06^{c}	106.73^{b}	12.04^{bc}	154.53^{a}	12.20^{d}	10.38
T_7– (T_4 +*Ayar*)	6.21^{de}	56.60^{a}	62.07^{i}	6.75^{bc}	134.53^{ab}	21.27^{c}	11.69
T_8–(T_4 +*Sampoorna*)	26.93^{ab}	5.89^{c}	67.60^{h}	12.67^{bc}	61.20^{c}	23.00^{bc}	37.67
T_9–(T_5+ Si)	21.11^{bcd}	36.73^{b}	84.13^{d}	16.00^{ab}	74.79^{c}	30.73^{a}	14.60
T_{10}–(T_6+ Si)	37.93^{a}	3.47^{c}	75.07^{f}	10.78^{bc}	68.07^{c}	33.67^{a}	15.37
T_{11}– (T_7+ Si)	24.83^{abc}	47.33^{ab}	78.53^{e}	8.53^{bc}	136.60^{ab}	3.33^{e}	12.57
T_{12}– (T_8 + Si)	19.95^{bcd}	2.65^{c}	57.60^{j}	10.79^{bc}	117.80^{b}	13.69^{d}	15.79
CD (0.05)	**15.547**	**13.324**	**2.666**	**11.350**	**30.333**	**3.013**	**NS**
CV	**48.073**	**50.786**	**1.969**	**63.535**	**17.221**	**9.052**	**74.566**

Table 21. The effect of different treatments on silicon content in shoot and grains in different growth stages of rice (%)

Treatments	Si content in shoot (%)			Si content in grains (%)
	Maximum tillering	Panicle initiation	Harvest	
T_1 –Farmer's practice	6.76^{def}	5.52^{f}	4.32^{h}	3.24^{h}
T_2–Fertilizer recommendation on STCR basis	6.64^{fg}	6.28^{d}	4.66^{g}	3.62^{ef}
T_3 –POP Recommendation of KAU	6.52^{g}	5.92^{e}	4.20^{h}	3.38^{gh}
T_4 –FYM+ Neem cake + Groundnut cake	6.36^{h}	4.98^{g}	3.88^{i}	2.88^{i}
T_5– (T_3 +*Ayar*)	6.82^{de}	6.3^{d}	5.54^{d}	3.68^{de}
T_6–(T_3 +*Sampoorna*)	6.78^{def}	5.72^{ef}	5.32^{e}	3.78^{d}
T_7– (T_4 +*Ayar*)	6.90^{d}	5.60^{f}	5.20^{ef}	3.52^{fg}
T_8–(T_4 +*Sampoorna*)	6.72^{ef}	6.42^{d}	5.06^{f}	3.28^{h}
T_9–(T_5+ Si)	8.42^{b}	7.74^{ab}	6.64^{b}	4.46^{a}
T_{10}–(T_6+ Si)	8.62^{a}	7.94^{a}	6.96^{a}	4.48^{a}
T_{11}– (T_7+ Si)	7.88^{c}	7.36^{c}	6.26^{c}	4.24^{b}
T_{12}– (T_8 + Si)	8.02^{c}	7.54^{bc}	6.16^{c}	4.04^{c}
CD (0.05)	**0.151**	**0.262**	**0.219**	**0.160**
CV	**1.263**	**2.44**	**2.324**	**2.559**

At panicle initiation stage, application of fertilizer based on POP recommendation of KAU along with *Sampoorna* and silicon was recorded the maximum concentration of Si (7.94 %) followed by treatment T_9.

At harvest stage Si content was gradually decreased. Lower concentration of Si was noticed in treatment T_3 and T_4. Higher concentration of Si was observed in T_{10} and followed by T_9.

In grains treatments found to be significant. Higher silicon content was recorded in T_{10} and T_9. Lower concentration of Si was noticed in the treatment T_4.

4.6 EFFECT OF DIFFERENT TREATMENTS ON NUTRIENT UPTAKE

Effect of different treatments on total nutrient uptake was presented in Table 22.

There was no significant difference between total uptake of N, however the highest total N uptake was recorded in T_6 (68.655 kg ha^{-1}) and the lowest N uptake was recorded in T_{10} (44.15 kg ha^{-1}). P uptake showed significant difference among the treatments. Highest uptake of P was recorded in treatment T_{10} (15.480 kg ha^{-1}) and it was on par with T_8, T_5, T_2 and T_3. Significantly lower uptake of P was recorded in treatment T_7. Total K uptake was maximum in T_5 (122.224[a] kg ha^{-1}) and it was closely followed T_6, T_8, T_{10}, T_3, T_9, T_1, T_2 and T_{11}. Significantly lower K uptake was recorded in T_4 and T_7.

Among the secondary nutrients, all the three nutrients viz, Ca, Mg and S uptake showed significant difference between treatments. Total uptake of Ca was significantly higher in treatment T_9 (131.082 kg ha^{-1}) and it was on par with T_{10} and lower Ca uptake was recorded in treatment T_{12} (64.457 kg ha^{-1}). Significantly higher Mg uptake was recorded in treatment T_5 (8.39 kg ha^{-1}) and it is on par with T_3 and T_9. Lower Mg uptake was recorded in T_4 (5.29 kg ha^{-1}). Total S uptake was significantly higher in T_1 (19.928[a] kg ha^{-1}) and was on par with T_{11} and T_{10}.

Table 22. Effect of different treatments on total nutrient uptake (Kg ha^{-1})

Treatments	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu	Si
T_1 –Farmer's practice	56.416	13.21^{bcd}	98.23^{abc}	95.71^{bcd}	5.67^{bcd}	19.928^{a}	6.91^{def}	0.29^{g}	1.51^{de}	0.22^{abc}	369.97^{fg}
T_2–Fertilizer recommendation on STCR basis	46.318	14.78^{ab}	99.57^{abc}	90.07^{bcd}	6.04^{bcd}	14.80^{abc}	6.39^{ef}	0.58^{b}	1.32^{ef}	0.18^{bcd}	409.89^{ef}
T_3 –POP Recommendation of KAU	65.425	14.63^{abc}	109.66^{ab}	98.58^{bcd}	7.25^{ab}	10.28^{cd}	11.71^{a}	0.48^{d}	1.47^{de}	0.06^{e}	357.27^{g}
T_4 –FYM+ Neem cake + Groundnut cake	47.061	10.49^{fg}	77.46^{c}	79.25^{e}	5.29^{d}	8.66^{cd}	6.57^{ef}	0.36^{fg}	2.03^{bc}	0.14^{cde}	290.05^{h}
T_5– (T_3 +*Ayar*)	62.452	15.06^{ab}	122.22^{a}	100.90^{bc}	8.39^{a}	8.09^{d}	10.66^{ab}	0.44^{de}	1.16^{ef}	0.20^{abcd}	478.86^{cd}
T_6–(T_3 +*Sampoorna*)	68.655	12.69^{cde}	117.56^{a}	98.59^{bcd}	6.16^{bcd}	12.32^{bcd}	6.26^{ef}	0.57^{b}	1.38^{de}	0.11^{de}	468.72^{cd}
T_7– (T_4 +*Ayar*)	46.286	9.42^{g}	76.60^{c}	94.91^{bcd}	5.63^{bcd}	9.25^{cd}	7.29^{de}	0.30^{g}	0.50^{g}	0.14^{cde}	388.18^{fg}
T_8–(T_4 +*Sampoorna*)	48.939	15.04^{ab}	111.82^{a}	101.19^{bc}	5.97^{bcd}	11.52^{bcd}	8.79^{bcd}	0.56^{bc}	0.93^{f}	0.30^{a}	413.66^{ef}
T_9 –(T_5+ Si)	53.567	11.67^{def}	97.31^{abc}	131.08^{a}	7.07^{abc}	9.69^{cd}	7.94^{cde}	0.76^{a}	2.80^{a}	0.21^{abc}	541.27^{b}
T_{10}–(T_6+ Si)	44.145	15.48^{a}	109.54^{ab}	113.61^{b}	6.68^{abcd}	17.27^{ab}	9.77^{abc}	0.50^{cd}	1.35^{e}	0.25^{ab}	590.59a
T_{11} – (T_7+ Si)	45.155	12.72^{cde}	94.58^{abc}	89.60^{bcd}	6.50^{bcd}	17.42^{ab}	6.15^{ef}	0.41^{ef}	2.41^{ab}	0.08^{e}	505.69^{bc}
T_{12}– (T_8 + Si)	49.188	11.24^{efg}	83.38^{bc}	64.45^{f}	5.42^{cd}	7.22^{d}	5.15^{f}	0.34^{g}	1.79^{cd}	0.12^{cde}	441.47^{de}
CD (0.05)	**NS**	**1.948**	**27.667**	**13.732**	**1.724**	**6.244**	**2.080**	**0.066**	**0.421**	**0.10**	**47.347**
CV	**19.678**	**8.807**	**16.366**	**24.954**	**16.040**	**30.208**	**15.770**	**8.252**	**16.102**	**36.646**	**6.388**

Regard to micronutrients, total Fe uptake was significantly influenced by different treatments. Significantly higher Fe uptake was recorded in treatment T_3 (11.711 kg ha^{-1}) and was on par with T_5 (10.664 kg ha^{-1}) and the lowest Fe uptake was recorded in T_{12} (5.153 kg ha^{-1}). Total uptake of Zn was significantly higher in T_9 (0.763 kg ha^{-1}) and was on par with T_6 and T_2. Higher Mn uptake was noticed in T_9 (2.808 kg ha^{-1}) and was on par with T_{11}. Significantly lower Mn uptake was noticed in T_7 (0.505 kg ha^{-1}). Total Cu uptake was significantly higher in T_8 (0.305 kg ha^{-1}) and was on par with T_{10}, T_9 and T_1.

With regard to silicon total uptake was significantly influenced by different treatments. Significantly higher Si uptake was recorded in treatment T_{10} (590.59 kg ha^{-1}) and was on par with T_9 (541.27 kg ha^{-1}) and lowest Si uptake was recorded in T_4 (290.05 kg ha^{-1}).

4.7 CORRELATION STUDIES

4.7.1. Correlation between plant nutrients and yield

The relationship between plant nutrients content and yield at different growth stages were worked out by correlation studies and presented in Table 22 to 29.

At maximum tillering stage root phosphorus content showed a negative correlation with yield and was highly significant. Root Ca content showed a positive relationship with yield. Shoot Mg, Zn and Si content had a positive relationship with yield though the effect was not statistically significant.

At panicle initiation stage, root Cu content was significantly correlated with yield and the relationship was positive. Root S content was negatively correlated with yield. In the shoot, yield was significantly correlated with P content and was positive. The same trend was observed with root P and K content, though the effect was not significant. Si content had a positive relationship with yield though the effect was not statistically significant.

The results at harvest stage revealed no significant correlation between nutrient content of straw and yield. In straw Si content had a positive relationship with yield though the effect was not statistically significant. Root Ca and Mg had significant positive relation between yield and the effect was statistically significant with regard to Ca. The effect of Fe and S content of root was negative with yield.

In grains there was a significant correlation of Si with yield.

4.7.2 Inter relationship between plant nutrient content at different growth stages and at harvest

Inter relation between plant nutrients were recorded at critical growth stages of rice. At maximum tillering stage, in shoot a positive and significant correlation found between K and N (0.344), K and P (0.543), Zn and Mg (0.528), Zn and Fe (0.346), Mn and Fe (0.4006), Cu and Fe (0.483), Mn and Zn (0.379), Cu and Zn (0.359) and Si and Mn (0.373) while, negative and significant correlation was observed between Cu and P (-0.363) and Mn and Ca (-0.373). In root, a positive and significant correlation between Zn and Mg (0.385) and Zn and S (0.399). However, negative and significant correlation were found between Ca and N (-0.605) and Mn and P (-0.382).

At panicle initiation stage, in shoot, a positive and significant correlation exist between S and K (0.492), Ca and Mg (0.422), Zn and Mg (0.356), Mn and Mg (0.436), Mn and Zn (0.513), Cu and S (0.377), Si and Zn (0.410) and Si and Mn (0.3792). However, there was a negative and significant correlation between Ca and S. In the case of root, a positive and significant correlation was found between K and P (0.438), Cu and Zn (0.433) and Cu and Mn (0.445) while, negative and significant correlation found between Ca and N (-0.513), Zn and Fe (-0.537), Mn and Ca (-0.406) and Cu and Ca (-0.342).

Table 23. Correlation coefficient of root nutrient content at maximum tillering stage with yield

	Yield	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu
Yield	1										
N	-0.066	1									
P	**-0.439****	0.130	1								
K	-0.193	0.147	-0.044	1							
Ca	0.317	**-0.605****	0.058	-0.318	1						
Mg	-0.153	0.066	0.051	-0.005	-0.141	1					
S	-0.222	-0.103	-0.163	-0.110	-0.167	0.250	1				
Fe	-0.071	0.177	0.0157	0.151	-0.0454	0.172	-0.059	1			
Zn	-0.110	-0.203	-0.038	0.246	-0.111	**0.385***	**0.399***	-0.120	1		
Mn	0.100	-0.230	**-0.382***	-0.079	0.117	-0.222	0.177	0.179	-0.033	1	
Cu	0.278	0.315	-0.130	0.0330	-0.198	-0.060	-0.223	0.201	-0.313	0.0643	1

Table 24. Correlation coefficient of shoot nutrient content at maximum tillering stage with yield

	Yield	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu	Si
Yield	1											
N	-0.110	1										
P	0.175	0.188	1									
K	-0.033	**0.344***	**0.543****	1								
Ca	0.0258	-0.0180	0.0297	0.306	1							
Mg	0.326	0.239	-0.110	-0.313	-0.193	1						
S	0.0328	0.253	0.162	0.174	0.117	-0.0424	1					
Fe	-0.0282	-0.0115	-0.124	-0.192	-0.269	0.370	-0.320	1				
Zn	0.292	-0.0445	-0.267	-0.276	0.129	**0.528****	-0.210	**0.346***	1			
Mn	-0.0031	0.129	-0.060	-0.147	**-0.373***	0.298	0.0515	**0.4006***	**0.379***	1		
Cu	0.161	-0.139	**-0.363***	-0.313	-0.202	0.280	-0.166	**0.483***	**0.359***	0.117	1	
Si	0.224	-0.0176	0.0514	0.0951	-0.243	-0.0266	0.181	0.0812	0.196	**0.373****	0.253	1

**Correlation is significant at 0.01 level (2-tailed) ; *Correlation is significant at 0.05 level

Table 25. Correlation coefficient of root nutrient content at panicle initiation stage with yield

	Yield	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu
Yield	1										
N	-0.0843	1									
P	0.295	0.320	1								
K	0.235	0.198	**0.438****	1							
Ca	-0.255	**-0.513****	-0.121	0.001	1						
Mg	-0.310	0.0437	0.147	-0.055	0.129	1					
S	**-0.338***	0.103	0.139	-0.282	0.247	0.176	1				
Fe	-0.100	0.110	-0.138	0.0269	-0.105	-0.004	-0.080	1			
Zn	0.244	-0.005	0.173	0.215	-0.104	0.157	-0.104	**-0.537****	1		
Mn	0.123	0.239	0.015	0.275	**-0.406***	0.102	-0.294	0.183	0.320	1	
Cu	**0.427****	-0.089	0.131	0.152	**-0.342***	-0.128	-0.012	-0.050	**0.433****	**0.445****	1

Table 26. Correlation coefficient of shoot nutrient content at panicle initiation stage with yield

	Yield	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu	Si
Yield	1											
N	-0.029	1										
P	**0.358***	-0.003	1									
K	-0.025	-0.285	0.274	1								
Ca	0.0967	-0.262	0.181	0.039	1							
Mg	0.188	-0.009	0.232	0.282	**0.422***	1						
S	0.133	0.108	0.105	**0.492****	**-0.410***	-0.159	1					
Fe	-0.070	0.077	0.056	0.254	0.129	0.0933	0.258	1				
Zn	0.044	-0.045	0.018	0.064	-0.0321	**0.356***	-0.188	-0.033	1			
Mn	0.0650	-0.109	0.078	0.067	0.189	**0.436****	-0.237	0.0873	**0.513****	1		
Cu	0.233	0.0154	0.017	0.088	0.0184	-0.133	**0.377***	0.191	-0.167	0.0423	1	
Si	0.266	-0.025	0.214	0.254	0.283	0.505	-0.023	0.218	**0.4100****	**0.3792****	0.236	1

**Correlation is significant at 0.01 level (2-tailed) ; *Correlation is significant at 0.05 level

Table 27. Correlation coefficient of root nutrient content at harvest with yield

	Yield	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu
Yield	1										
N	-0.005	1									
P	0.110	**-0.608****	1								
K	-0.232	0.137	**-0.427****	1							
Ca	**0.330***	-0.116	0.0256	-0.173	1						
Mg	0.296	-0.022	-0.150	-0.144	**0.825****	1					
S	**-0.444****	-0.046	**-0.404***	0.574	0.108	0.121	1				
Fe	**-0.336***	-0.103	-0.066	0.0686	-0.117	0.2258	**0.496****	1			
Zn	0.208	**0.529****	**-0.395***	0.0561	0.227	0.153	-0.117	-0.298	1		
Mn	-0.242	-0.285	-0.0032	**0.490****	0.088	0.0313	**0.600****	0.131	**-0.336***	1	
Cu	-0.055	**0.527****	**-0.429****	-0.1055	-0.122	0.251	-0.159	0.241	0.0559	-0.288	1

Table 28. Correlation coefficient of straw nutrient content at harvest with yield

	Yield	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu	Si
Yield	1											
N	-0.206	1										
P	0.0579	-0.098	1									
K	0.121	0.121	0.284	1								
Ca	0.125	-0.283	0.188	**0.367***	1							
Mg	-0.169	**0.332***	-0.0039	-0.192	**-0.387***	1						
S	0.1406	-0.110	**0.492****	-0.079	0.0344	-0.149	1					
Fe	-0.241	0.181	0.182	0.218	0.256	**0.343***	-0.184	1				
Zn	**0.320***	-0.118	0.0876	0.101	0.104	0.302	-0.081	0.0490	1			
Mn	0.0156	-0.147	0.138	-0.090	-0.180	0.207	-0.190	-0.323	0.300	1		
Cu	0.198	-0.120	0.0285	-0.105	0.206	-0.118	0.305	-0.058	0.313	-0.110	1	
Si	**0.316***	-0.131	0.0104	0.063	-0.174	-0.140	-0.127	-0.240	0.221	0.225	0.224	1

**Correlation is significant at 0.01 level (2-tailed) ; *Correlation is significant at 0.05 level

Table 29. Correlation coefficient of grain nutrient content with yield

	Yield	N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu	Si
Yield	1											
N	0.0961	1										
P	0.163	0.163	1									
K	0.008	-0.0008	-0.0942	1								
Ca	0.066	-0.128	**-0.399***	-0.252	1							
Mg	0.0327	0.099	**0.384***	0.176	0.2098	1						
S	0.303	0.019	-0.173	-0.005	0.265	-0.0012	1					
Fe	0.323	-0.060	0.0581	0.035	0.263	0.289	0.044	1				
Zn	0.236	0.123	0.073	-0.273	0.202	-0.047	0.010	0.0095	1			
Mn	-0.150	-0.104	-0.075	-0.121	**0.418***	0.156	-0.169	0.027	0.113	1		
Cu	0.151	-0.098	0.141	0.051	0.0006	-0.096	0.136	-0.068	-0.121	0.258	1	
Si	**0.33637***	-0.184	-0.237	-0.144	**0.6674****	0.20124	0.09466	**0.36850****	**0.4107****	0.143	-0.099	1

**Correlation is significant at 0.01 level (2-tailed) ; *Correlation is significant at 0.05 level

At harvest stage, in shoot a positive and significant correlation found between N and Mg (0.332), S and P (0.492), Ca and K (0.367) and Fe and Mg (0.343), While, there was negative and significant correlation between Mg and Ca (-0.387). In root there was a positive and significant correlation between Zn and N (0.529), Cu and N (0.527), Mn and K (0.490), Mg and Ca (0.825), Fe and S (0.496) and Mn and S (0.600). Whereas, negative and significant correlation was found between P and N (-0.608), K and P (-0.427), S and P (-0.404), Zn and P (-0.395), Cu and P (-0.429) and Mn and Zn (-0.336).

In grains a positive and significant correlations found between Mg and P (0.384), Mn and Ca (0.418), Si and Ca (0.66743), Si and Fe (0.3685) and Si and Zn (0.4107) whereas, a negative and significant correlation was found between Ca and P (-0.399).

4.8 INCIDENCE OF PEST AND DISEASES

The major pests observed in the field were rice stem borer, leaf roller, rice bug. Rice bug was observed in all the plots but comparatively less in treatment T_{11} (T_7+ Si). Leaf roller was observed in early stage of growth. In each plot, 2-3 tillers were affected by stem borer comparatively less in silicon applied plots. The important diseases observed were lakshmi disease and blast. The incidence of pest and disease never reached threshold level.

4.9 ECONOMICS

The data on economics of cultivation are presented in Table 30. Gross income was significantly influenced by the treatments. Maximum gross income was registered by T_6 where the fertilizers were applied as per KAU POP recommendation along with *Sampoorna* (168430.13 ₹ ha^{-1}) which was on par with T_5 and T_9 where fertilizers were applied as per KAU POP recommendation along with Ayar and Ayar + silicon respectively. The treatment with organics alone (T_4) recorded the lowest gross income followed by T_{12} where in addition to organics, silicon also given. Net income as well as B:C ratio was maximum in the treatment which received fertilizer as per KAU POP recommendation along with *Sampoorna*(T_6). This treatment was significantly superior to all other treatments with regard to net income and on par with T_3 (KAU POP recommendation) with respect to B:C ratio. The lowest benefit-cost ratio was recorded in treatment T_7 followed by T_4, T_{11} and T_{12} where organics alone or in combination with micronutrients mixture + silicon were applied.

Table 30. Effect of different treatments on gross income, net income and B:C ratio

Treatments	Cost of cultivation (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
T_1 – Farmer's practice	102730.33^{h}	157312.17^{bc}	54582.17^{de}	1.53^{c}
T_2 – Fertilizer recommendation on STCR basis	92201.53^{k}	148950.60^{de}	56749.06^{cd}	1.61^{b}
T_3 – POP Recommendation of KAU	88690.33^{l}	155074.77^{cd}	66384.75^{b}	1.74^{a}
T_4 – FYM + Neem cake + Groundnut cake	124930.33^{e}	137823.47^{f}	12893.47^{h}	1.09^{f}
T_5 – (T_3 + *Ayar*)	114340.66^{g}	163542.30^{ab}	49202.26^{ef}	1.43^{d}
T_6 – (T_3 + *Sampoorna*)	92990.33^{j}	168430.13^{a}	75440.14^{a}	1.81^{a}
T_7 – (T_4 + *Ayar*)	150580.66^{b}	143042.00^{ef}	-7538.02^{j}	0.95^{h}
T_8 – (T_4 + *Sampoorna*)	129230.33^{d}	157087.43^{bc}	27857.42^{g}	1.21^{e}
T_9 – (T_5+ Si)	115340.33^{f}	161572.70^{abc}	46232.74^{f}	1.39^{d}
T_{10} – (T_6+ Si)	93990.33^{i}	157604.93^{bc}	63614.92^{bc}	1.67^{b}
T_{11} – (T_7+ Si)	151580.66^{a}	156167.33^{bcd}	4587.34^{i}	1.03^{g}
T_{12} – (T_8 + Si)	130230.66^{k}	138714.80^{f}	8484.77^{hi}	1.06^{fg}
CD (0.05)	**1.094**	**7438.817**	**7438.80**	**0.070**
CV	**0.005**	**2.856**	**11.49**	**3.176**

Cost of inputs: Urea - ₹ 8 kg^{-1}, Factomphos - ₹ 20 kg^{-1}, MOP - ₹ 14 kg^{-1}, 18:18:18 - ₹ 20 kg^{-1}, FYM - ₹ 3 kg^{-1}, Neemcake - ₹ 30 kg^{-1}, Groundnut cake - ₹ 38 kg^{-1}, Ayar - ₹ 50 kg^{-1} and Sampoorna - ₹ 200 kg^{-1}

Cost of outputs: Grain - ₹ 23.5 kg^{-1}, Straw - ₹ 8 kg^{-1}

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DISCUSSION

5. DISCUSSION

The results obtained on the investigation on "Integrated nutrient approach on productivity enhancement of rice in oxyaquic fluent soils of Northern Kerala" are briefly discussed below.

5.1 INITIAL SOIL PROPERTIES

The soil was strongly acidic (4.69) in reaction. In soil the available N (200.704 kg ha^{-1}) and P (2.29 kg ha^{-1}) content were low and the available K (156 kg ha^{-1}) content was medium. With regards to mechanical composition the percentage of coarse sand, fine sand, silt and clay were 28.45, 29.65, 19.85, 22.05 % respectively. Availability of secondary and micronutrients were sufficient in soil. The initial status of Fe was more than that of the laterite paddy soils. Similar observations were reported by Bridgit, (1999).

5.1 GROWTH PARAMETERS

5.1.1 Effect of different treatments on plant height and number of tillers $hill^{-1}$

The mean plant height data recorded at different growth stages *viz.* maximum tillering, panicle initiation, flowering and harvesting stages were shown in Table 6 and fig. 3. In general the plant height was rapidly increased in early stages. Effect of treatment was significant on plant height at maximum tillering, panicle initiation and at harvesting stage. At flowering stage there was no significant difference between the treatments. At maximum tillering stage application of fertilizers based on POP recommendation of KAU along with *Ayar* (T_5) recorded the maximum plant height but in other two stages of growth, application of fertilizers based on POP recommendation of KAU along with *Sampoorna* and silicon (T_{10}) recorded the maximum plant height. The number of tillers $hill^{-1}$ at different growth stages were given in Table 7 and fig. 4 and significantly higher number of tillers $hill^{-1}$ were recorded in T_{10} where KAU POP + *Sampoorna* + Si was given. The increased plant height and tillers $hill^{-1}$ might be due to better availability of all the nutrients at the initial growth stages of the crop. Das (1986) reported that application of $ZnSO_4$ @ 25 kg ha^{-1} significantly enhanced the plant height and number of tillers in lateritic soil. Nagula *et al.* (2015) reported that Silicon and boron fertilization through soil and foliar application was recorded the highest plant height and number of tillers. Ravent (1983) recorded that the plant height will be increased by using materials consisting silicon. Gholami and Falah (2013) reported that the plant height, number of tillers $plant^{-1}$ and number of productive tillers were improved by the application of Si fertilizers in rice crop. Mohapatra (2003) reported that application of S + Zn + B along with RFD @ 120-60-60 N-P-K kg ha^{-1} resulted in vigorous crop growth at all phases of growth. Singh and Mandal (1997) reported that application of sufficient nutrients encourage the supply of assimilates from source to sink which would have resulted in improved plant height and number of tillers $hill^{-1}$.

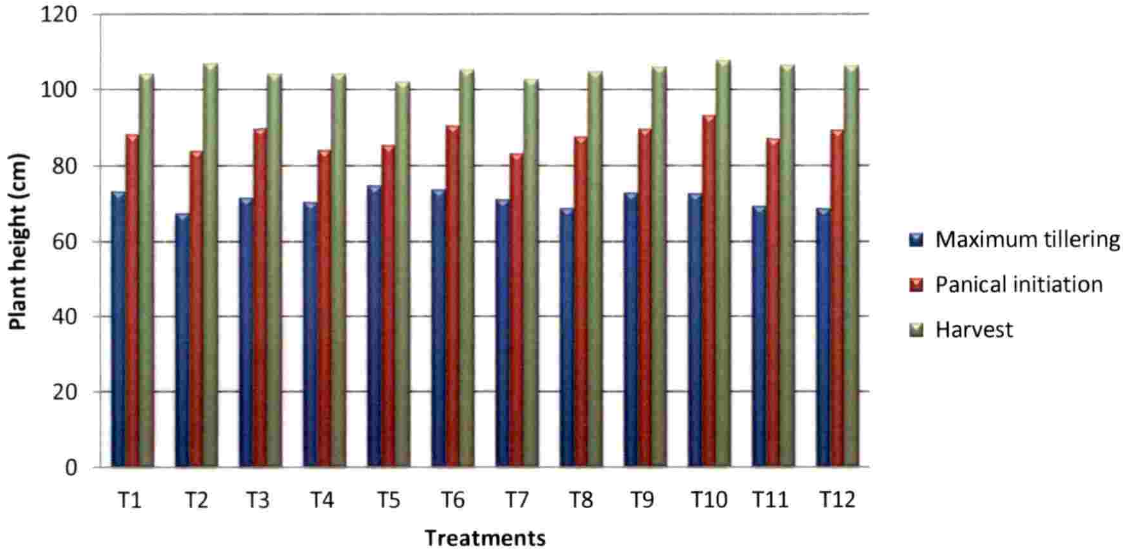

Fig. 3. Effect of treatments on plant height at different growth stages

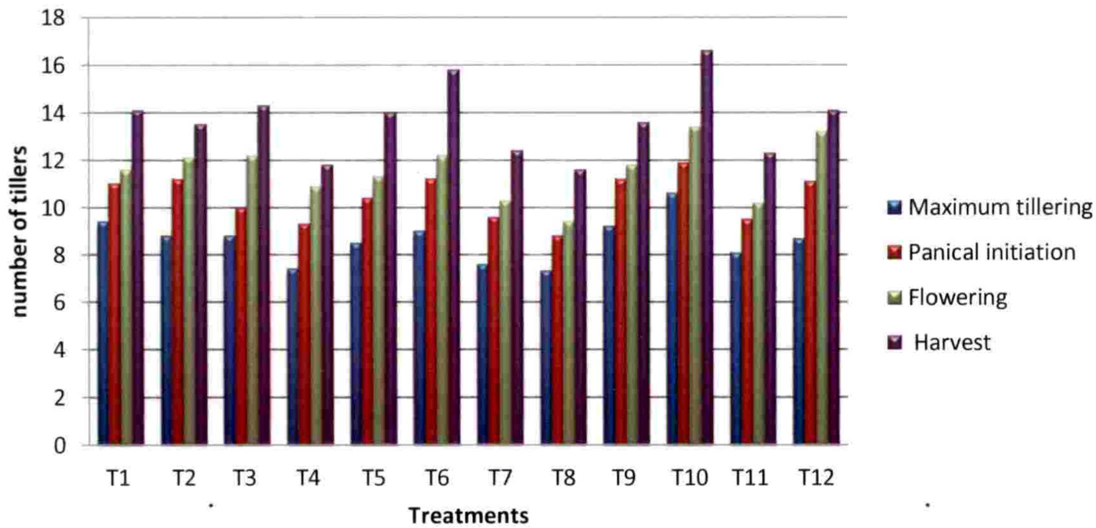

Fig. 4. Effect of treatments on number of tillers at different growth stages`

5.2 YIELD AND YIELD ATTRIBUTES

5.2.1 Effect of different treatments on Yield attributes

Yield attributes like No of panicles hill^{-1}, Panicle length, Total grains panicle^{-1}, Filled grains panicle^{-1}, Chaffy grains panicle^{-1} and Test weight were significantly influenced by different treatments. Maximum number of panicles hill^{-1} was recorded by the treatment T_9 (T_5 +Si) and it was on par with other calcium silicate applied treatments (T_{10}, T_{11} and T_{12}), T_6 and T_5. Maximum panicle length was observed in treatment T_5 and T_8. It is on par with treatment T_6, T_7, T_9, T_{10}, T_{11} and T_{12}. Total grains panicle^{-1} was higher in treatment T_5 and were on par with other calcium silicate applied treatments and organic applied treatments. Maximum Number of filled grains panicles^{-1} was observed in treatments where fertilizers were applied based on POP recommendation of KAU along with *Ayar* and silicon which was on par with T_{11}. Significantly lower number of chaffy grains panicle^{-1} was observed in treatment T_1, T_3, T_9 and T_{11}. Maximum 1000 grain weight was recorded in treatments T_9 which was on par with T_{11}, T_5 and T_4. Application of inorganics alone significantly reduced the yield attributes like test weight, total grains panicle^{-1} etc. The treatments with silicon and micronutrient mixture along with organics or combinations of organics + inorganics produced higher yield attributes and yield. Adequate supply of primary, secondary and micronutrients along with silica improved the growth attributes of rice in oxyaquic fluent soils of northern Kerala. Related works reported by Mathew (2002) in lateritic soils of humid tropics and stated that integrated use of nutrients will increase the yield. Sunilkumar and Geethakumari (2002) recorded higher number of spikelets panicle^{-1} filled grains panicle^{-1} and panicle weight by the silica application. This might be due to the better transaction of photosynthesis product to the grains. Miyoshi and Ishii (1960) also observed that application of silica helps to better translocation of photosynthates from straw to ear head. Vijayakumar (1977) reported that application of silica increased the thousand-grain weight and also observed the better filling of grains. Nagula (2015) recorded that there was a significant influence of silicon and boron on yield attributes like panicle weight plant^{-1} and thousand grain weight. Combined soil application of $ZnSO_4$ and $FeSO_4$ each @ 25 kg ha^{-1} and foliar spray of $ZnSO_4$ and $FeSO_4$ each @ 0.5 % significantly improved the yield attributing characters like productive tillers per meter row length and number of filled grains panicle^{-1} (Suresh and Salakinkop, 2016). The application of Zn at 1 kg ha^{-1} and Cu at 2 kg ha^{-1} with NPKS fertilizers shows potential combination for improving the growth and yield of rice (Siddika *et al.,* 2016).

5.2.1 Effect of different treatments on Yield and Harvest index

Data pertaining to grain yield, straw yield and harvest index of rice as influenced by different treatments is presented in Table 9, fig. 7 and fig. 8. Significantly higher grain yield with 5.31 t ha^{-1} was obtained by the treatment T_9 (T_5 + Si) which was on par with T_6 (POP Recommendation of KAU along with *Sampoorna*) (5.25 t ha^{-1}). The lowest grain yield was observed in treatment T_4 (FYM+ Neem cake + Groundnut cake). The treatment T_5 (T_3 + *Ayar*) significantly produced higher straw yield (5.58 t ha^{-1}). The lowest straw yield of 3.91 t ha^{-1} and 3.97 t ha^{-1} was recorded by T_{12} and T_4 respectively. The higher harvest index of rice was recorded in T_9 (T_5+ Si) followed by T_7, T_{11}, T_{12}, T_1, and T_4 and lower harvest index was observed in T_5 (T_3 + *Ayar*). Lowest grain yield and straw yield was noticed under treatment T_4 (FYM + Neem cake + Groundnut cake). This may be due to the non availability of nutrients in organics alone treated plots. Similar result was reported by Mathew (2002) where the treatment without any inorganic fertilizers recorded the lowest yield during all the seasons. Maximum grain yield was obtained by the application of fertilizers based on POP Recommendation of KAU along with *Ayar* and silicon and closely followed by the application of fertilizers based on POP Recommendation of KAU along with *Sampoorna*. Foliar application of micronutrient mixture along with POP Recommendation of KAU supplied adequate nutrients for increasing yield and also silicon fertilization along with secondary nutrient mixture through soil increased the grain yield in oxyaquic soils. Adequate supply of nutrients increases the grain and straw yield by supplying food from source to sink. Micronutrient mixture application will helps to increase the enzymatic reactions and hormone productions in plants, which helps to increase the yield. Prasad (2015) reported that application of $ZnSO_4$+ B along with RFD significantly improved the grain yield. Bridgit and potty (2007) revealed that 120 kg ha^{-1} potassium, 100 kg ha^{-1} silica and 150 kg ha^{-1} lime increased the grain yield in lateritic soil. Lekshmi (2016) reported that application of fertilizer based on POP recommendation of KAU along with calcium silicate increased the grain yield upto 6.90 t ha^{-1}. Combination of Mg and Si was influenced the early ripening of grain which resulted in increased 1000 grain weight and also significantly increased grain and straw yield (Padmaja and Verghese, 1965). Varghese and Money (1964) revealed that application of fertilizers(40: 40: 40) with calcium and magnesium increased the grain yield. Koruth *et al.* (1995) concluded that grain yield of rice increased by the adequate supply of different micronutrients. Liew *et al.* (2010) showed that the application of a special fertilizer formulated from 29.9 kg of K, 4 kg of Cu, 4 kg of Zn, 3.6 kg of Mn, 2.43 kg of Mg and 2.25 kg of B could increase the rice yield. The application of Zn at 1 kg ha^{-1} and Cu at 2 kg ha^{-1} with NPKS fertilizers shows potential combination for improving the growth and yield of rice (Siddika *et al.,* 2016). Mathew (2002) reported that application of recommended dose of NPK fertilizers along with application of 250 kg ha^{-1} silica and soil application of $ZnS0_4$ 20 kg ha^{-1} , $MgS0_4$ 20 kg ha^{-1} and $CuS0_4$ 12.5 kg ha^{-1} increased the grain yield.

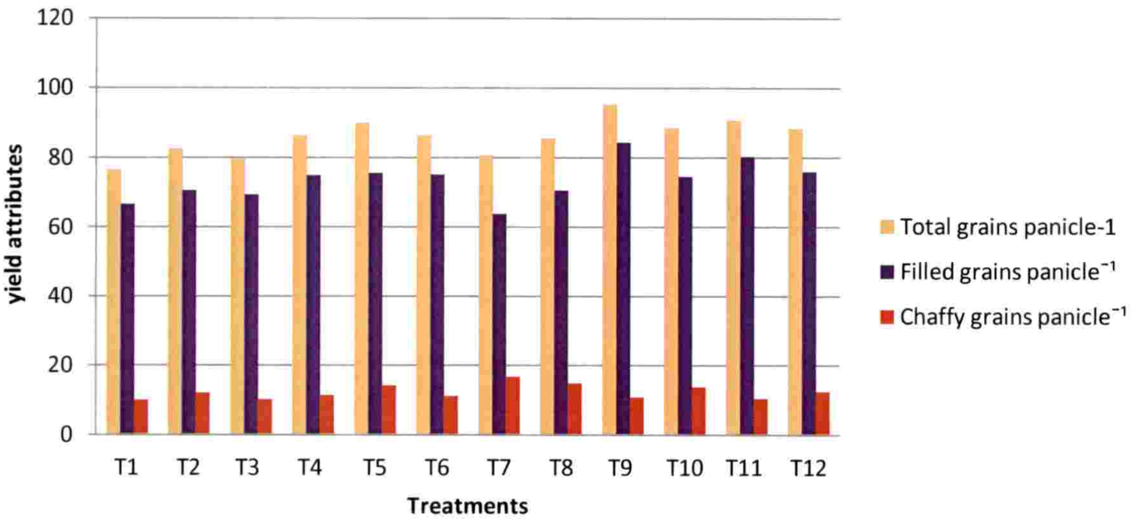

Fig. 5. Effect of different treatments on total grains panicle^{-1}, filled grains panicle^{-1} and chaffy grains panicle^{-1}

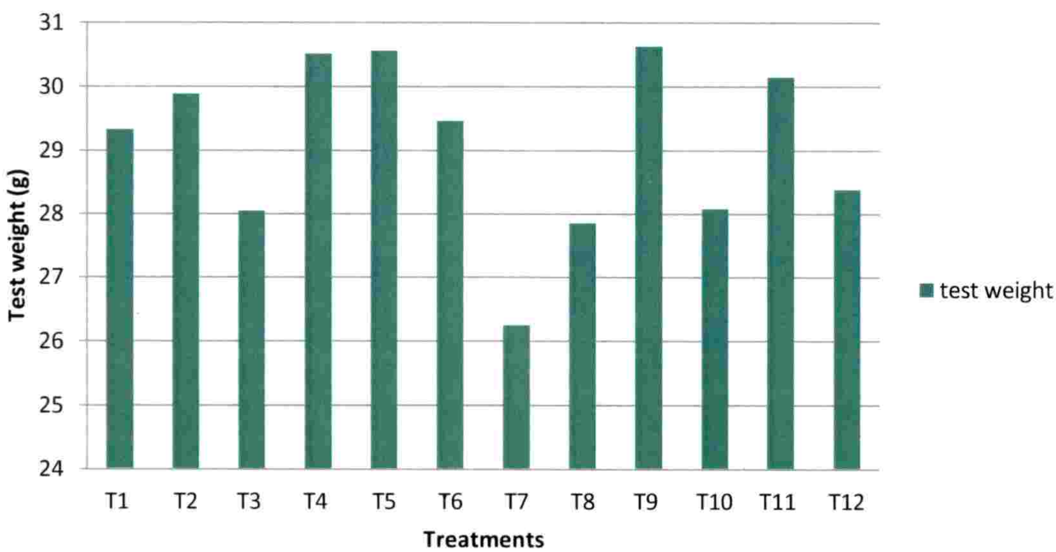

Fig. 6. Effect of different treatments on test weight

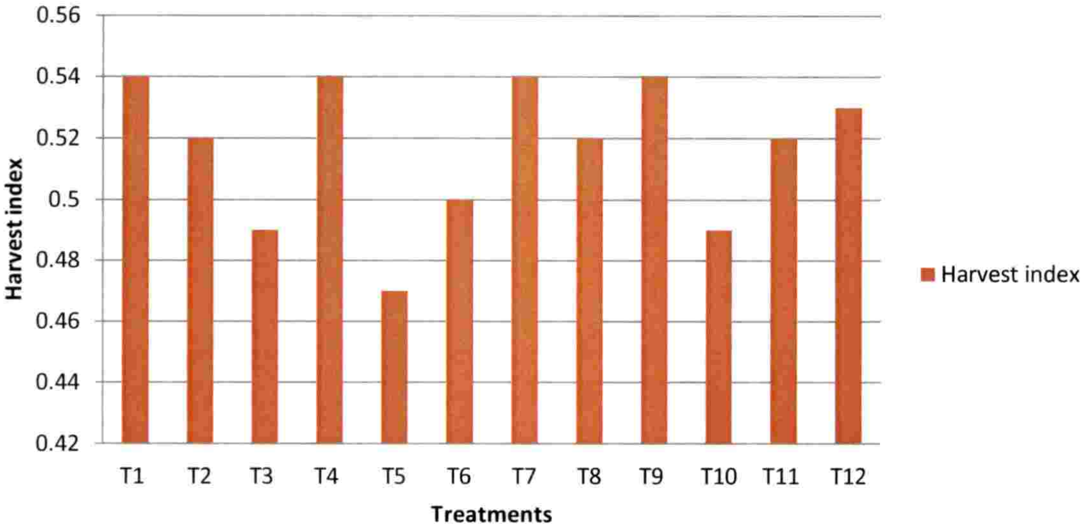

Fig. 7. Effect of different treatments on harvest index

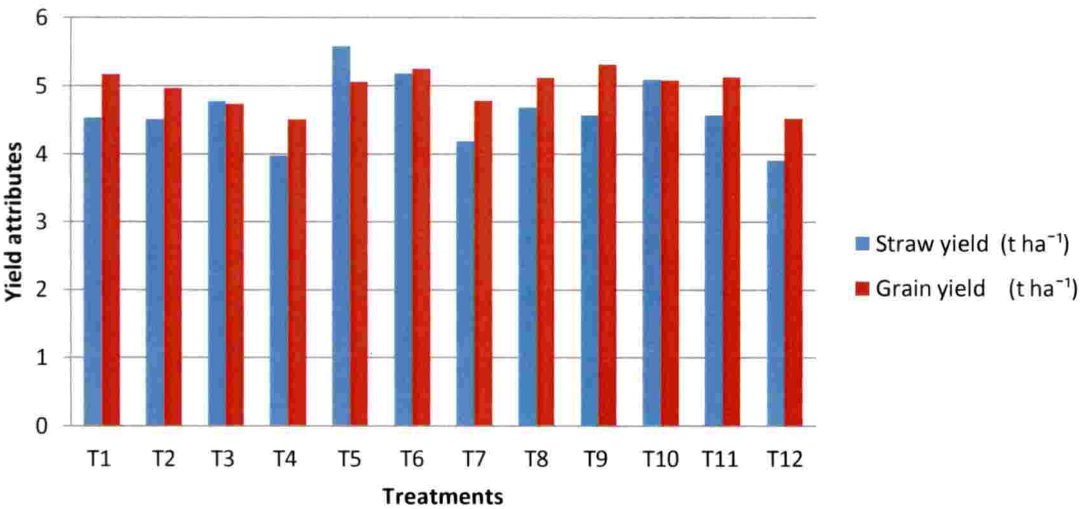

Fig. 8. Effect of different treatments on grain yield and straw yield

5.3 NUTRIENT CONTENT IN SOIL

5.3.1 Effect of different treatments on nutrient content of soil at harvest stage.

The effect of different treatments on available N, available P, available K, pH and EC was given in table 10, fig. 9 and fig. 10. The effect of different treatment on soil chemical properties and nutrient status were found to be non significant with regards to pH, EC and available K content of the soil. In soil, pH was reduced over the initial soil status. However, available N and P content were found to be significant. Significantly higher available N content in soil was recorded by T_8 (T_4 + *Sampoorna*) and T_5 (T_3 + *Ayar*) recorded the higher available P content in soil. The available N and P content in soil were increased under different treatment compared to initial nutrient status of the soil. Application of organic nutrient and fertilizer under different treatments favored mineralization and improved the physical condition of soil which in turn resulted in increased status of available N and available P. similar result was also recorded by Gupta *et al.* (2006), Das *et al.* (2009) and Dekate (2011) due to application of organic, inorganic and integrated sources of nutrient management.

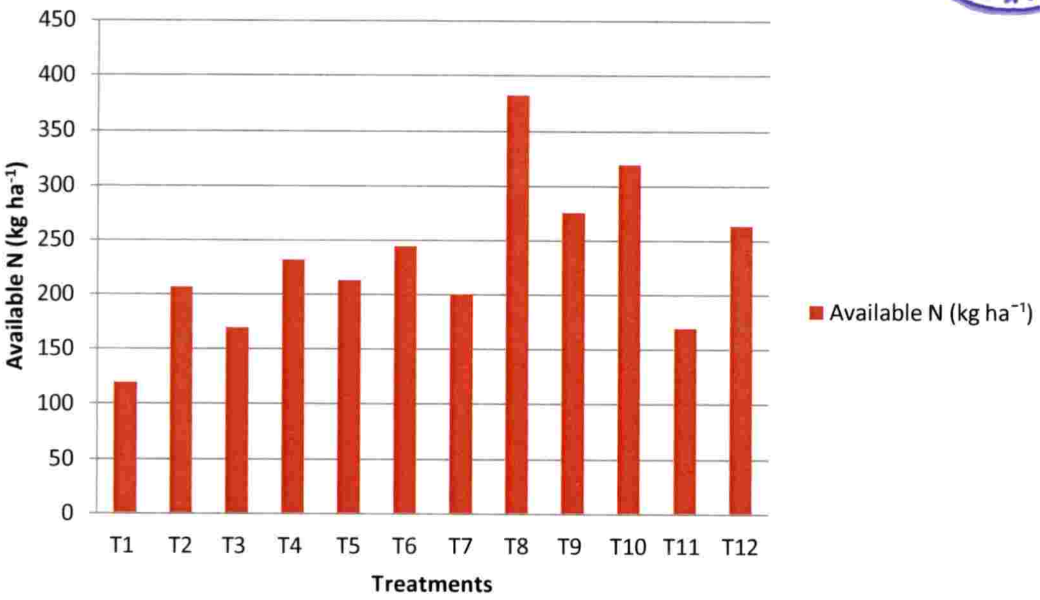

Fig. 9. Effect of different treatments on available N kg ha^{-1}

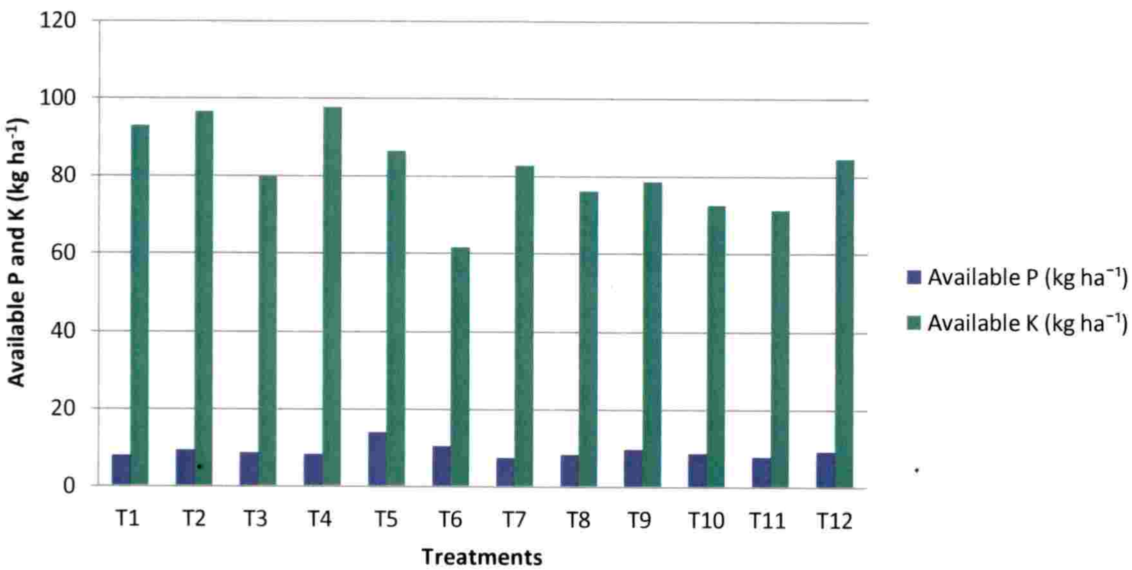

Fig. 10. Effect of different treatments on available P kg ha^{-1} and available K kg ha^{-1}

5.4 NUTRIENT CONTENT IN PLANT

5.4.1 Effect of different treatments on nutrient content in rice root, shoot, grain, straw and total uptake at different crop growth stages

Application of fertilizers and manures increased the primary, secondary and micronutrients content in rice shoot, root and grains. In general Integrated fertilizer application increased the nutrient content in plants.

5.4.1.1 Nitrogen

The nitrogen content was decreased from maximum tillering stage to harvest in both shoot and root. In shoot, the nutrient content was not significantly influenced by treatments at maximum tillering stage and at harvest stage but at panicle initiation stage significantly higher nitrogen content was recorded in treatment T_3. Similar results were reported by Murali and Setty (2001), N uptake significantly increased by the application of NPK up to 150-75-75 kg ha^{-1} in rice. In root, at maximum tillering stage the nitrogen content was higher in treatment T_1 and T_{12}. At panicle initiation stage T_3 recorded higher N content and at harvest stage T_{11} recorded the higher N content. Application of organic manures along with micronutrient and secondary nutrients increased the nitrogen content in root.

5.4.1.2 Phosphorus

The phosphorus content of the plant showed the same trend as in the case of nitrogen. The nutrient content was gradually decreased from maximum tillering stage to harvest stage. Nitrogen and phosphorus were required at the early stages of growth. P given as chemical fertilizers and also along with secondary nutrients recorded the higher P content in plants. The total P nutrient uptake was significantly higher in the treatment given as POP recommendation of KAU along with *Sampoorna* and silicon and it is closely followed by T_8, T_5 and T_2. At panicle initiation stage P showed a positive and significant correlation between yield and nutrient content. At maximum tillering stage shoot and at panicle initiation stage root showed a positive correlation between the P and K. P showed a negative and significant correlation between micronutrients like Mn, Zn and Cu at different growth stages. Correlation studies with yield showed a positive trend at all the stages except at maximum tillering stage with root P content. This may be due to the low initial P status of the soil Mathew (2002) reported that during *kharif* season higher P uptake was noticed in silica applied plots in lateritic soil.

5.4.1.2 Potassium

Potassium content at harvest stage slightly increased than the panicle initiation stage. Potassium content was less in treatment in which organic manure alone was given. Silicon applied treatments also showed a reduced K content in shoot and root. The reduced K uptake with application of silica has been recorded by Islam and Saha (1969). Potassium uptake was also reduced in the treatment where application of FYM+ Neem cake + Groundnut cake along with *Ayar* was given. The results showed that the uptake of K was decreased due to K-Mg antagonism. The same result was reported by many workers (Varughese and Jose, 1994: Muralidharan and Jose, 1994 a). K content in shoot showed a positive and significant correlation between S and K during panicle initiation stage and Ca and K during harvest stage. However application of fertilizers along with *Sampoorna* increased the K content. This might be due to higher K content in *Sampoorna* multi nutrient mixture and was applied as foliar spray.

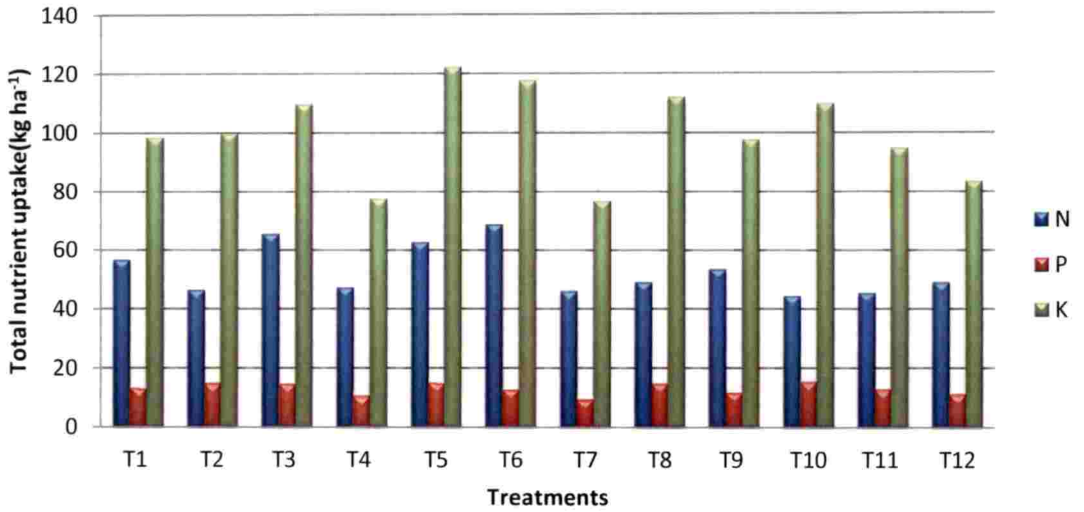

Fig. 11. Effect of different treatments on total nutrient uptake of N, P and K

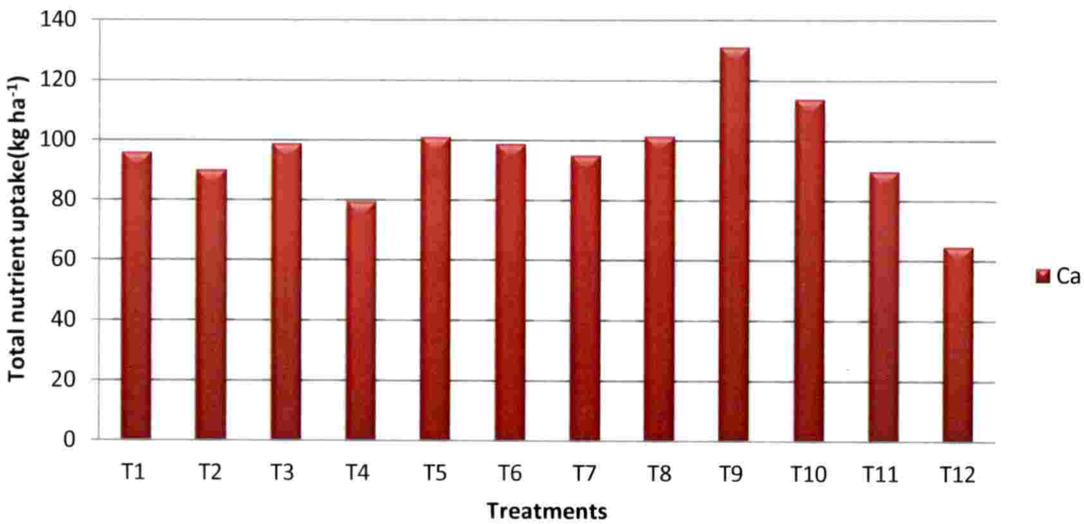

Fig. 12. Effect of different treatments on total nutrient uptake Ca

5.4.1.3 Secondary nutrients

Ca content was increased in straw and grains at harvest stage. Total Ca uptake was maximum in treatment with POP recommendation of KAU along with *Ayar* and silicon, where the yield was maximum in the field study. Similar finding was recorded by Mathew (2002) where application of silica and higher K dose increased the Ca uptake during *kharif* in lateritic soil. Ca showing a positive and significant correlation between Ca and Mg (0.422) at panicle initiation stage in shoot but at harvest stage positive correlation found in root.

Application of organic and inorganic fertilizers along with silicon produced higher Mg content. Higher Mg uptake was observed under POP recommendation of KAU along with *Ayar* and *Sampoorna*. This might be due to the increased availability of this nutrient supplied through *Ayar* and *Sampoorna*. Similar result was obtained by Kobayashi *et al*., (2005), Mg content of shoots and roots, and the potassium and chloride contents of roots were increased with the excess Mg treatment. Mg showed a positive and significant relation with micronutrients like Fe, Mn and Zn.

S content was gradually decreased from maximum tillering stage to harvest stage. During maximum tillering stage both in shoot and root the S content was high in the silicon treated plot. Farmer's practice recorded higher total S uptake and it was on par with T_{10} and T_{11}. S content in root at panicle initiation stage cause a negative and significant correlation with the yield. Prasad (2015) reported that application of Zn-EDTA + S + B recorded higher uptake of N, P, K, S, Zn and B in comparison to their sole application.

5.4.1.3 Micronutrients

The content of iron in straw, grain and uptake of iron were significantly influenced by different treatments. In root the Fe content was above the toxicity level due to high content in the soil. Fe content was gradually decreased from maximum tillering stage to harvest stage. Significantly higher Fe uptake was recorded in treatment T_3 (11.711 kg ha^{-1}) and it was on par with T_5 (10.664 kg ha^{-1}) and significantly lower Fe uptake was recorded in T_{12} (5.153 kg ha^{-1}). Fe uptake was decreased with the application of silicon fertilizers. Similar result was recorded by Bridgit (1999) and Mathew (2002) in laterite soil. There was a negative and significant correlation between Fe and yield at harvest stage.

Application of fertilizers based on POP recommendation of KAU along with secondary and micronutrients and Si recorded the higher Mn content in shoot and root and grains. Similar results was recorded by Nagula *et al.* (2015). Application of calcium silicate @ 100 kg ha^{-1} along with Borax spray recorded higher Mn content shoot and grains. Higher total Mn uptake was recorded in T_9 (2.808 kg ha^{-1}) and it was on par with T_{11}. Initial stages of growth Mn showed negative correlation with Ca content. But in grains it showed a positive and significant correlation with Ca.

Higher Zn content was recorded in treatments applied with *Ayar* and *Sampoorna*. This might be due to the Zn content in both *Ayar* and *Sampoorna*. Total Zn uptake significantly higher in T_9 (0.763 kg ha^{-1}) and it is on par with T_6 and T_2. The data (Table 24, 25,26, 27, 28,29) on correlation of Zn with yield at all the stages showed a positive relation with yield and the higher uptake of Zn might be the reason for higher yield in these treatments T_9 and T_6. Mathew (2002) reported that in laterite soil the application of $ZnSO_4$ through soil and foliar increased the Zn content. At maximum tillering in shoot Zn showed a positive and significant correlation with Mg and Fe.

Similar trend as that of Zn was observed in the case of Cu also. Cu showed a positive and significant correlation with yield and also with nutrients like N, S, Fe, Mn and Zn.

5.4.1.3 Silicon

The experimental results with respect to Si content in shoot, root and grains in different growth stages of rice is given in Table 21.

Application of POP recommendation of KAU along with *Sampoorna* and silicon (T_{10}) recorded the maximum content of silicon and Si nutrient uptake and it was on par with T_9. Similar result was recorded by Mathew (2002) and reported that supply of silicon significantly increase the silicon content and uptake in rice. Si is the major nutrient required for the healthy growth and development of rice. Soil application of calcium silicate increased the total uptake of silicon. In T_{10} application of Si increased the uptake of P by reducing the uptake of Mn. According to Ma and Takahashi (1990), application of Silicon improves the accessibility of P by inhibiting excessive Mn uptake, which can antagonize P. In correlation study at harvest stage, application of Si showed positive correlation with yield and Si content in straw and grains significant with grain Si content.

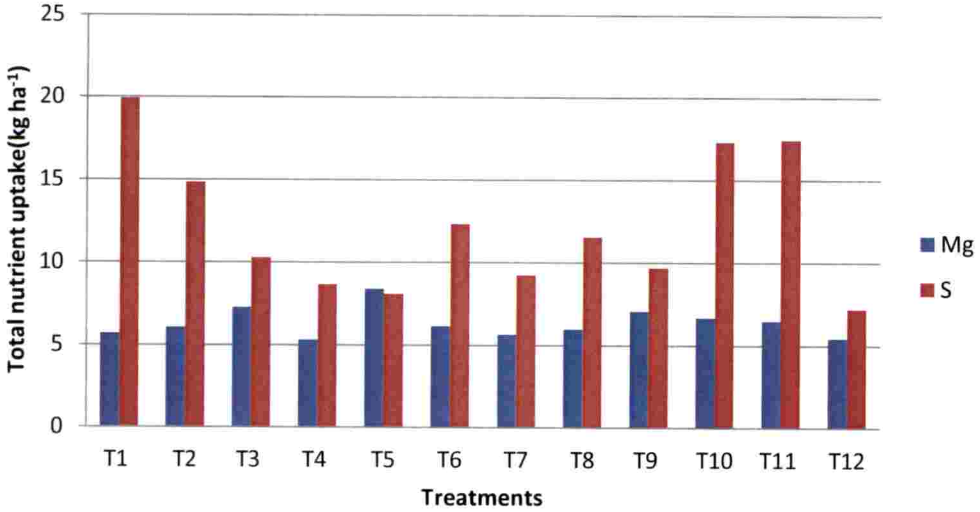

Fig. 13. Effect of different treatments on total nutrient uptake of Mg and S

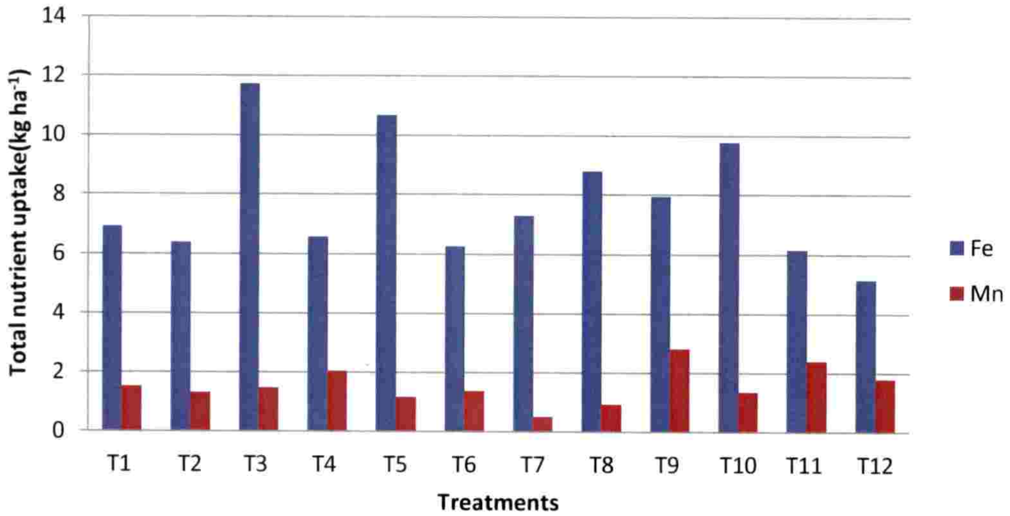

Fig. 14. Effect of different treatments on total nutrient uptake of Fe and Mn

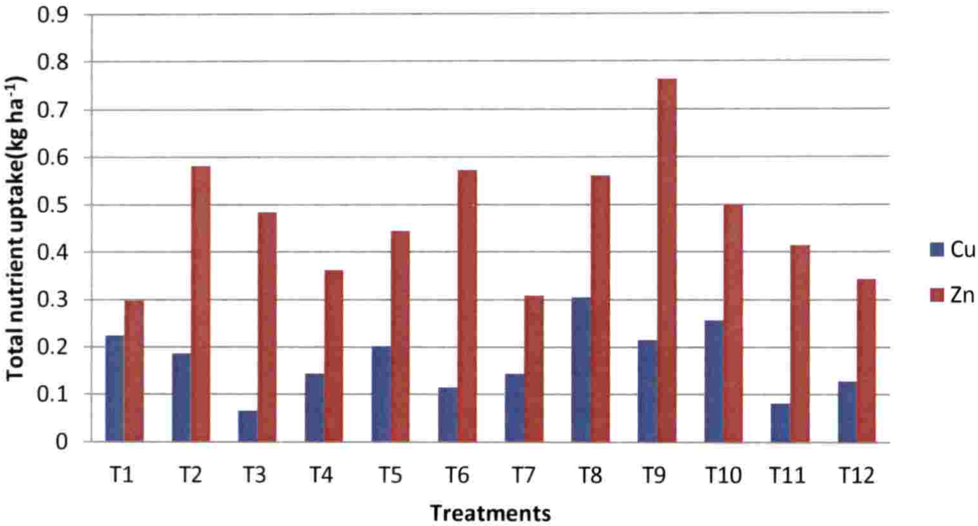

Fig. 15. Effect of different treatments on total nutrient uptake of Cu and Zn

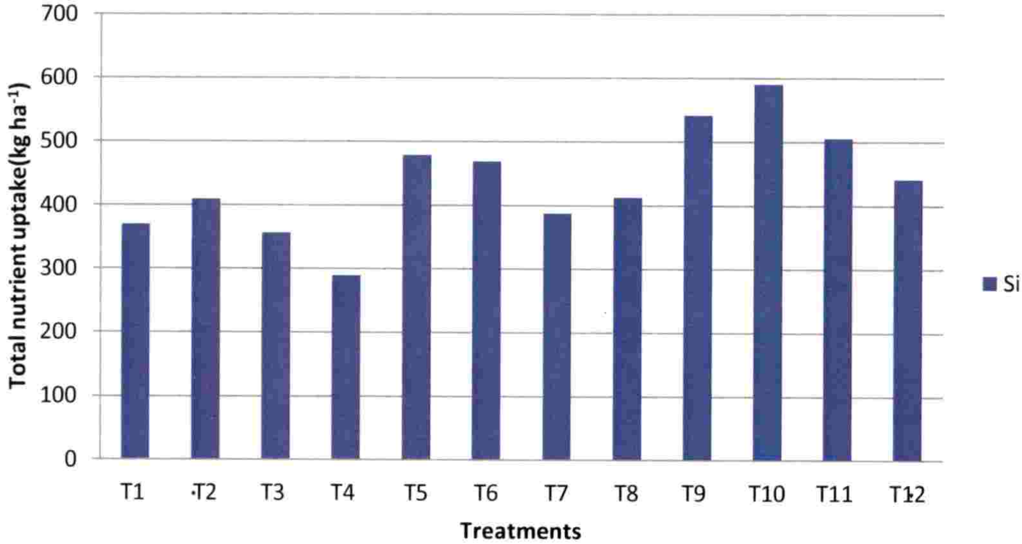

Fig. 16. Effect of different treatments on total nutrient uptake of Si

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5.5 EFFECT OF DIFFERENT TREATMENTS ON ECONOMICS

The data on economics of cultivation presented in Table 30 and fig. 17 and 18 revealed that gross income was significantly influenced by the treatments. Maximum gross income was registered by the application of fertilizers based on KAU POP recommendation along with *Sampoorna* (168430.13 Rs ha^{-1}) which was on par with T_5 and T_9. Significantly higher net income and benefit-cost ratio was recorded in treatment T_6 (T_3+ *Sampoorna*). Micronutrient given as foliar spray recorded higher gross return, net return and benefic cost ratio. Similar result was recorded by Baishya *et al.* (2015) and reported that micronutrient fortification enhanced gross and net returns of the rice. Organic manures treated plots recorded lower B: C ratio because the higher cost of organic manures compared to inorganic fertilizers. Application of *Ayar* along with KAU POP and silicon recorded maximum yield and gross income. But the net income and B: C ratio were lower due to high cost of the chemical, as well as the quantity required. By modifying the combination in this micronutrient mixture and including silica the quantity required per hectare can be reduced. Because of the easiness in application the farmers will accept if it is available at a lower price. In general application of KAU POP along with micronutrient mixtures and silica gave a better income compared to other treatments. By improving the content and quality and reduced quantity of micronutrient mixtures can have a better acceptance among farmers for improving the productivity of rice.

5.6 INCIDENCE OF PEST AND DISEASES

The major pests observed in the field were rice stem borer, leaf roller, rice bug. Rice bug was observed in all the plots and comparatively less in treatment T_{11} (T_7+ Si). Leaf roller was observed in early stage of growth. In each plot 2-3 tillers were affected by stem borer and was comparatively less in silicon applied plots. The important diseases observed were lakshmi disease and blast. The incidence of pest and disease never reached threshold level. Application of FYM+ Neem cake +

Groundnut cake along with Ayar and Silicon showed less pest and disease attack. Jayant *et al.* (2015) reported that application of Si @ 400 kg ha^{-1} through rice husk ash helps to reduce the borer infestation in rice. Higher content and uptake of K and Si might be the reason for low incidence of pest and diseases. Buck *et al.* (2008) reported that foliar application of potassium silicate reduced the blast incidence in rice.

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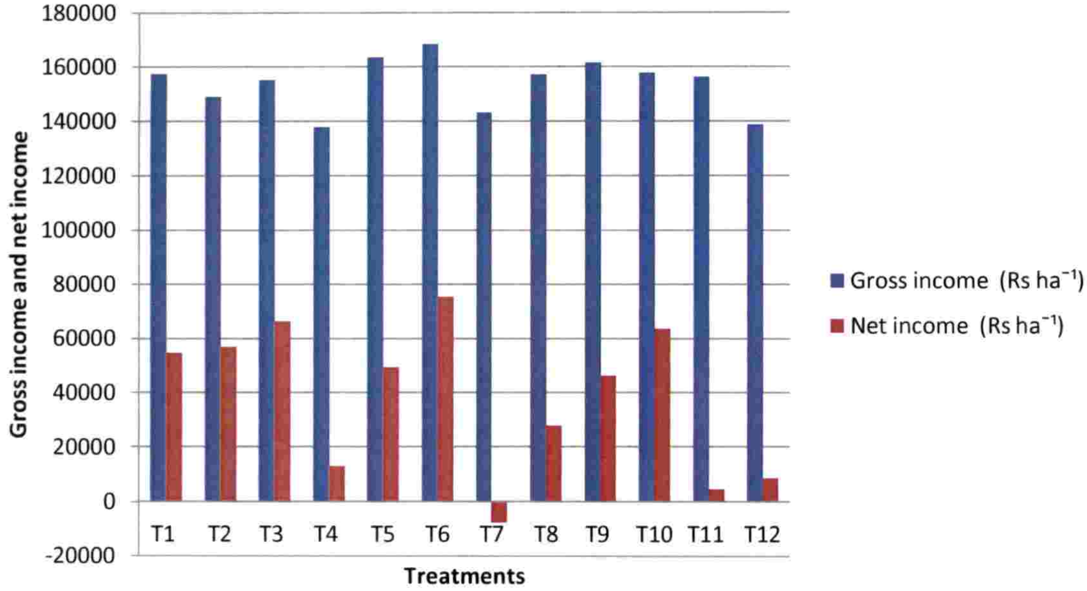

Fig. 17. Effect of different treatments on gross income and net income

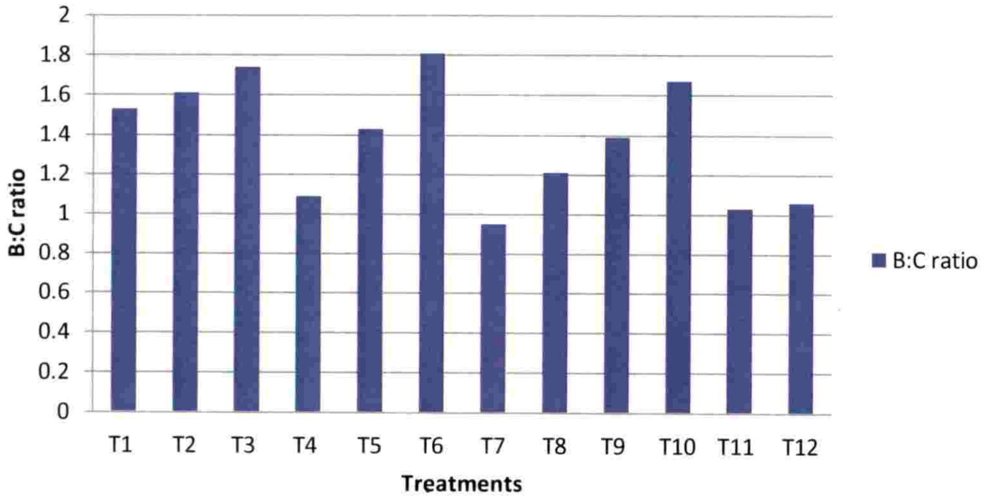

Fig. 18. Effect of different treatments on B:C ratio

SUMMARY

6. SUMMARY

The salient findings derived from the field experiments conducted to study "Integrated nutrient approach on productivity enhancement of rice in oxyaquic fluent soils of Northern Kerala" are compiled in this chapter.

This field experiment was conducted to study the effect of organic manures along with micronutrient mixtures on growth, yield, pest and disease incidence, nutrient uptake and economics of wetland rice in farmer's field during *virippu* season 2017. The experiment was laid out in randomized block design with 12 treatments and 3 replications. The treatments were T_1 - Farmer's practice (FYM 5 t ha^{-1} + 18:18:18), T_2 - Fertilizer recommendation on the STCR basis (75.6: 57.6: 37.35 kg ha^{-1} NPK), T_3 - POP Recommendation of KAU (90:45:45 kg ha^{-1} NPK), T_4 - FYM (5 t ha^{-1}) + Neem cake (400 kg ha^{-1}) + Groundnut cake (400 kg ha^{-1}), T_5 - T_3 + *Ayar* (500 kg ha^{-1} as basal dose), T_6 - T_3 + *Sampoorna* (5g l^{-1} at 1-2 days before transplanting and 10 g l^{-1} at 50 DAT as foliar spray respectively), T_7 - T_4 + *Ayar* (500 kg ha^{-1} as basal dose), T_8 - T_4 + *Sampoorna* (5g l^{-1} at 1- 2 days before transplanting and 10 g l^{-1} and at 50 DAT as foliar spray respectively), T_9 - T_5 + Si (100 kg ha^{-1} calcium silicate as basal dose), T_{10} - T_6 + Si (100 kg ha^{-1} as calcium silicate), T_{11} - T_7 + Si (100 kg ha^{-1} as calcium silicate) and T_{12} - T_8 + Si (100 kg ha^{-1} as calcium silicate).

Farmyard manure was applied @ 5t ha^{-1} to each experimental plot as per the treatments. Full dose of P and half the dose of N and K fertilizers were applied as basal and the remaining N and K were applied at panicle initiation stage. Neem cake and ground cake were applied in two equal doses, first as basal and second at panicle initiation stage. *Ayar* was applied as a single dose @ 500 kg ha^{-1} as basal. *Sampoorna* was applied two times, first at 1-2 days before transplanting @ 5g l^{-1} and second at 45 DAT @ 10 g l^{-1} as foliar spray respectively. Si was applied as 100 kg ha^{-1}calcium silicate as basal dose.For calculating the fertilizer requirement in STCR treatments, soil samples were collected from the experimental plot and analyzed for major nutrients. Based on the nutrient contents of the soil sample, nutrient requirement for the treatments were worked out and fertilizers were applied accordingly. All other cultural practices were adopted as per the package of practices recommendations of KAU (KAU, 2016).

Observations were recorded on growth parameters and growth attributes such as plant height and number of tillers hill^{-1} at maximum tillering stage, panicle initiation stage, flowering stage and at harvest stage, no. of panicles hill^{-1}, total grains panicle^{-1}, filled grains panicle^{-1}, test weight, grain and straw yield were recorded at the time of harvest and harvest index was computed.

Plant analysis were done separately for shoot, root and grains for nutrients such as N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and Si at maximum tillering, panicle initiation and at harvest stage. The total nutrient uptake was also recorded after harvest. Soil nutrient status for major nutrients was analyzed for initial nutrient status and after harvest. Simple correlation co-efficient was worked out for plant and grain nutrient with yield. Pest and disease incidents were recorded during the crop period. Economics were computed after harvest based on the local market price of inputs and output. The data were statistically analyzed and results of this field experiment are presented here.

At maximum tillering stage, application of fertilizers based on POP recommendation of KAU along with *Ayar* (T_5) recorded the maximum plant height but in other two stages of growth, application of fertilizers based on POP recommendation of KAU along with *Sampoorna* and silicon (T_{10}) recorded the highest plant height. Significantly higher number of tillers hill^{-1} in different growth stages were recorded in T_{10} (T_6+ Si).

Maximum number of panicles hill^{-1} was recorded in the treatment T_9 (T_5 +Si) and it was on par with other calcium silicate applied treatments (T_{10}, T_{11} and T_{12}) and T_6 and T_5. Comparable panicle length was observed in all the treatments except T_1, T_2, T_3, T_4 and T_8. Maximum total grains panicle^{-1} was recorded in treatment T_5 and

T_{11}. Maximum Number of filled grains panicles^{-1} was observed by the application of fertilizers based on POP recommendation of KAU along with *Ayar* and silicon which was on par with T_{11}. Significantly lower number of chaffy grains panicle^{-1} was observed in treatment T_1, T_3, T_9 and T_{11}. Higher comparable test weight was recorded in treatments T_9, T_{11}, T_5 and T_4.

Significantly higher grain yield with 5.31 t ha^{-1} was obtained by the treatment T_9 (T_5 + Si) which was on par with T_6 (POP Recommendation of KAU along with *Sampoorna*) (5.25 t ha^{-1}). The lowest grain yield was observed in treatment T_4 (FYM + Neem cake + Groundnut cake). The treatment T_5 (T_3 + *Ayar*) significantly produced higher straw yield (5.58 t ha^{-1}). The lowest straw yield of 3.91 t ha^{-1} and 3.97 t ha^{-1} was recorded by T_{12} and T_4 respectively. The higher harvest index of rice was recorded in T_{12} (T_8+ Si). The higher harvest index of rice was recorded in T_9 (T_5+ Si) followed by T_7, T_{11}, T_{12}, T_1, and T_4 and lower harvest index was observed in T_5 (T_3 + *Ayar*).

The effect of different treatment application on soil nutrient status was found to be non significant with regards to pH, EC and available K content of the soil. Significantly higher available N and P were recorded in T_8 (T_4 + *Sampoorna*) and T_5 (T_3 + *Ayar*) respectively. Compared to initial values, available N and P status in soil were increased in all the treatments.

There was no significant difference in nitrogen content of straw at maximum tillering and harvest stage but significantly higher nitrogen content was recorded in T_3 at panicle initiation stage. In root at maximum tillering stage the nitrogen content was higher in treatment T_1 and T_{12}. At panicle initiation stage T_3 recorded higher N content while, T_{11} recorded higher value at harvest.

The total P nutrient uptake was significantly higher in the treatment given as POP recommendation of KAU along with *Sampoorna* and silicon and it was closely followed by the T_8, T_5 and T_2. At panicle initiation stage P showed a positive and significant correlation between yield and nutrient content. At maximum tillering stage

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shoot and at panicle initiation stage root showed a positive correlation between the P and K. P showed a negative and significant correlation between micronutrients like Mn, Zn and Cu at different growth stages.

Silicon applied treatments also showed a reduced K content in shoot and root. Potassium uptake was lowered by the application of FYM + Neem cake + Groundnut cake along with *Ayar*. But K content in shoot showed a positive and significant correlation with S during panicle initiation stage and Ca during harvest stage. However application of fertilizers along with *Sampoorna* increased the K content.

Ca content was increased in straw and grains at harvest stage and total Ca uptake in treatment with POP recommendation of KAU along with *Ayar* and silicon. Ca showed a positive and significant correlation between Ca and Mg (0.422) at panicle initiation stage in shoot but at harvest stage positive correlation found in root.

Higher Mg uptake was observed under POP recommendation of KAU along with *Ayar* and also through *Sampoorna*. Mg showed a positive and significant relation with micronutrients like Fe, Mn and Zn.

S content was gradually decreased from maximum tillering stage to harvest stage. Shoot and root recorded higher S content during maximum tillering stage in silicon treated plot. Farmer's practice recorded higher total S uptake and it was on par with T_{10} and T_{11}. S content in root at panicle initiation stage cause a negative and significant correlation with the yield.

The content of iron in straw, grain and uptake of iron were significantly influenced by different treatments. In root the Fe content was above the toxicity level due to the Fe toxicity in the initial soil. Fe content was gradually decreased from maximum tillering stage to harvest stage. Significantly higher Fe uptake was recorded in treatment T_3 (11.711 kg ha^{-1}) and it was on par with T_5 (10.664 kg ha^{-1}) and significantly lower Fe uptake was recorded in T_{12} (5.153 kg ha^{-1}). Fe uptake was decreased with the application of silicon fertilizers. There was a negative and significant correlation between Fe and yield at harvest stage.

Application of fertilizers based on POP recommendation of KAU along with secondary nutrients and micronutrients and Si recorded higher Mn content in shoot, root and grains. Higher total Mn uptake was recorded in T_9 (2.808 kg ha^{-1}) and it was on par with T_{11}.

Higher Zn content was recorded in treatment which was applied with *Ayar* and *Sampoorna*. This might be due to the Zn content in both *Ayar* and *Sampoorna*. Total Zn uptake significantly higher in T_9 (0.763 kg ha^{-1}) and it was on par with T_6 and T_2,

Similar trend as that of Zn was followed for Cu. Cu showed a positive and significant correlation with yield and also with nutrients like N, S, Fe, Mn and Zn.

Application of POP recommendation of KAU along with *Sampoorna* and silicon (T_{10}) recorded the maximum content of silicon and Si nutrient uptake and it was on par with T_9

Soil application of calcium silicate increased the total uptake of silicon. In T_{10} application of Si increased the uptake of P by reducing the uptake of Mn. In correlation study in straw at harvest stage, in straw Si showing a positive correlation with yield and in grains it showing a positive and significant correlation with yield.

Maximum gross income, net income and B:C ratio were registered by the application of fertilizers based on KAU POP recommendation along with *Sampoorna*.

The major pests observed in the field were rice stem borer, leaf roller, rice bug. Rice bug was observed in all the plots and was comparatively less in treatment T_{11} (T_7+ Si). Leaf roller was observed in early stage of growth. In each plot 2-3 tillers were affected by stem borer which was comparatively less in silicon applied plots. The important diseases observed were lakshmi disease and blast. The incidence of pest and disease never reached threshold level.

The overall study of this field experiment results concluded that application of fertilizers based on POP recommendation of KAU along with *Sampoorna* can be recommended for higher yield and profit for oxyaquic fluent soils of northern Kerala and application of POP recommendation of KAU along with *Ayar* and silicon were also equally good with yield.

Future line of work

- For recommending *Ayar* to rice crop more works has to be done to standardize the nutrient combination
- The scope of organic manures along with STCR must be evaluated
- The suitability of POP recommendation along with Sampoorna should be studied in other rice growing tracts of Kerala

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ABSTRACT

INTEGRATED NUTRIENT APPROACH ON PRODUCTIVITY ENHANCEMENT OF RICE IN OXYAQUIC FLUENT SOILS OF NORTHERN KERALA

By

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(2016-11-038)

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, KASARAGOD 671314

KERALA, INDIA

2018

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ABSTRACT

The experiment entitled "Integrated nutrient approach on productivity enhancement of rice in oxyaquic fluent soils of Northern Kerala" was conducted to study the effect of organic manures along with micronutrient mixtures on growth, yield, pest and disease incidence, nutrient uptake and economics of wetland rice in farmer's field during *virippu* season 2017. The experiment was laid out in randomized block design with 12 treatments and 3 replications. The treatments were T_1 - Farmer's practice (FYM 5 t ha^{-1} + 18:18:18), T_2 - Fertilizer recommendation on the STCR basis (75.6: 57.6: 37.35 kg ha^{-1} NPK), T_3 - POP Recommendation of KAU (90:45:45 kg ha^{-1} NPK), T_4 - FYM (5t ha^{-1}) + Neem cake (400 kg ha^{-1}) + Groundnut cake (400 kg ha^{-1}), T_5 - T_3 + *Ayar* (500 kg ha^{-1} as basal dose), T_6 - T_3 + *Sampoorna* (5g l^{-1} at 1-2 days before transplanting and 10 g l^{-1} at 50 DAT as foliar spray respectively), T_7 - T_4 + *Ayar* (500 kg ha^{-1} as basal dose), T_8 - T_4 + *Sampoorna* (5g l^{-1} at 1-2 days before transplanting and 10 g l^{-1} and at 50 DAT as foliar spray respectively), T_9 - T_5 + Si (100 kg ha^{-1} as calcium silicate), T_{10} - T_6 + Si (100 kg ha^{-1} as calcium silicate), T_{11} - T_7 + Si (100 kg ha^{-1} as calcium silicate) and T_{12} - T_8 + Si (100 kg ha^{-1} as calcium silicate). The available N, P and K status of the experimental field ranged from low to medium and the secondary and micronutrients were in the sufficiency level. All the treatments were applied as per the technical programme.

The results of the experiment showed that the growth and yield attributes such as plant height and number of tillers hill^{-1}, number of panicles hill^{-1}, filled grains panicle^{-1}, test weight and lowest number of chaffy grains were significantly influenced by application of POP recommendation of KAU along with micronutrient mixtures *viz. Sampoorna* and *Ayar*. The treatment T_9 (T_5 + Si) recorded maximum grain yield which was on par with T_6 (T_3 + *Sampoorna*). Straw yield was maximum in T_5 (T_3 + *Ayar*) and was on par with T_6. Higher harvest index was recorded in treatment T_9 (T_5 + Si).

At harvest, the available N and P status of the soil were increased whereas the available K was decreased when compared to the initial soil nutrient status. Application of FYM + Neem cake + Groundnut cake along with *Sampoorna*

recorded higher soil available N and application of fertilizers based on POP recommendation of KAU along with *Ayar* recorded maximum soil available P content. Plant nutrient content *viz*. N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and Si of both shoot and root were analyzed at maximum tillering, PI stage and at harvest. In the shoot, all the nutrients showed a declining trend from maximum tillering to PI except sulphur. The content of Fe showed sharp decrease from maximum tillering to harvest stage. The total uptake of nutrients showed a significant difference among treatments. Phosphorus uptake was maximum in treatment T_{10} and T_6 recorded maximum K uptake. The treatment T_9 recorded maximum uptake of nutrients such as Ca, Zn and Mn. T_5 recorded maximum Mg uptake. Application of FYM + Neem cake + Groundnut cake along with *Sampoorna* and silicon reduced the uptake of Fe. Correlation study revealed that plant nutrient content such as P, Ca, Mg, Cu and Si showed a positive relationship with yield at different critical growth stages.

The treatment with POP Recommendation of KAU along with *Sampoorna* (T_6) recorded maximum yield, gross return, net return and B:C ratio whereas, application of POP Recommendation of KAU along with *Ayar* and Si were also equally good with yield and ease of application.

In general, the integrated use of organic and inorganic sources of nutrients along with secondary, micronutrients and Si not only increase the growth parameters and yield attributes but also increase the soil nutrient level and economics of wetland rice cultivation.

APPENDIX

Appendix 1. Weather parameters during the standard weeks from 26th to 43rd

	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
	Maximum	Minimum			
26 (June 25 - July 1)	28.94	23.37	87.855	289.2	2.2
27 (July 2 - 8)	29.28	23.52	83.71	227	1.85
28 (July 9 - 15)	28.3	23.28	84.925	218.7	2.17
29 (July 16 - 22)	28.57	24.21	82.425	141.4	2.12
30 (July 23 - 29)	30.64	24.21	80.995	60.1	2.42
31 (July 30 - Aug 5)	30.42	24	80.495	129	1.9
32 (Aug 6 - 12)	29.5	24.11	83.355	88.6	2.23
33 (Aug 13 - 19)	29.61	24.14	82.5	123.6	2.04
34 (Aug 20 - 26)	29.1	23.16	85.43	181	1.77
35 (Aug 27 - Sep 2)	27.94	23.37	83.785	212.8	2.1
36 (Sep 3- 9)	30.61	24.36	81.355	10.4	2.8
37 (Sep 10- 16)	30.56	23.96	81.715	59.6	2.44
38 (Sep 17- 23)	29.01	23.79	84.575	145.4	2.1
39 (Sep 24- 30)	30.1	23.64	80.855	52.8	2.8
40 (Oct 1 - 7)	30.15	24.17	81.145	40.4	2.53
41 (Oct 8 - 14)	30.81	24.09	80.355	8.6	2.97
42 (Oct 15 - 21)	29.69	23.77	80.575	38.6	2.36
43 (Oct 22 – 28)	31.5	22.86	69.575	0	2.76