IMPACT OF LONG TERM INTEGRATED NUTRIENT SUPPLY SYSTEM ON SOIL HEALTH AND RICE PRODUCTIVITY

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DECLARATION

I hereby declare that this thesis entitled "**Impact of long term integrated nutrient supply system on soil health and rice productivity**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title of any other University or Society.

Vellayani
19-03 - 2007

Raji. S. Prasad
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CERTIFICATE

Certified that this thesis entitled " **Impact of Long term Integrated nutrient supply system on soil health and rice productivity**" is a record of research work done independently by Mrs. Raji.S.Prasad under my guidance and supervision and that it has not previously formed the basis for the award of any degree , fellowship or associate ship to her.

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LIST OF ABBREVIATIONS

AICRP	All India Coordinated Research Project
BD	Bulk Density
CD	Critical difference
CEC	Cation exchange capacity
cm	Centimeter
cm^{-2}	Centimeter square
CSRC	Cropping System Research Centre
c.c	Cubic centimetre
DAS	Days after sowing
DAT	Days after transplanting
DMP	Dry matter production
e.g.	For example
EC	Electrical conductivity
et al.	And others
Fig.	Figure
FYM	Farmyard manure
g^{-1}	Per gram
GM	Green manure
ha^{-1}	Per hactare
INM	Integrated nutrient management
K	Potassium
K_2O	Potassium

kg^{-1}	per kilo gram
km	Kilometer
m^{-2}	per meter square
mg	milligram
mm	milli meter
N	Nitrogen
No.	Number
NS	Non significant
°C	degree celsius
$p = 0.05$	probability at 5 per cent level
P_2O_5	Phosphorus
$plant^{-1}$	per plant
RD	Recommended dose
RDF	Recommended dose of fertilizers
S	Sulphur
$S.E_D$	Standard error difference
$t\ ha^{-1}$	tonnes per hectare
viz.,	namely
WHC	Water Holding Capacity
Zn	Zinc

LIST OF SYMBOLS

&	And
@	at the rate of
%	per cent
per	otherwise, or, per

INTRODUCTION

INTRODUCTION

Rice is the staple food for about 50% of the world's population that resides in Asia. India, with the maximum area under rice in Asia, has 29.4 % of the global rice area (Tiwari, 2004) .Contributing consistently to around 47% of the India's cereal production , rice hold the key to sustained food sufficiency in the country. To sustain the current level of sufficiency the minimum production and productivity required to rice has been estimated to be 100mt and 2454 $kgha^{-1}$ respectively against the present 93 mt and 2086 $kgha^{-1}$ (Tiwari, 2004) . By 2020 India needs about 122 mt rice for domestic consumption alone. Since land is the limiting factor and rice areas getting stabilized the future rice production targets should be through progressive yield growth by means of judicious fertilizer , water , nutrient weed , pest disease as well as crop management. It is in this context that Integrated Nutrient Management becomes an inevitable topic of research.

Rice – rice cropping system, with the introduction of high yielding, fertilizer responsive varieties, have become highly intensive. Among the different rice based cropping sequences, energy input and energy out put was maximum for rice – rice CS.(Parihar *et al* ., 1999). Hence the system needs large amounts of nutrients to sustain yield potential. In India about 40% of the total plant nutrients are consumed only by rice and environmental pollution through excessive improper and imbalanced application of inorganic fertilizers have added new dimensions to their use in rice nutrition (Ravi sankar *et al* , 2002) . The prolonged and over usage of chemicals has resulted in human and soil health hazards, pesticide toxicity, environment pollution and tunneled the prospects of sustainability of agricultural production. The present hike in fertilizer prices and energy crisis often make farmers omit certain nutrient management practices deviating from the balanced way. Long term application of NPK fertilizers alone with out the use of any organic amendments has resulted in secondary and micronutrient deficiencies which seriously impair the response to applied fertilizer and reduce the yield potential considerably. Again the results of long term fertilizer experiment conducted with rice based cropping system at several stations at all India level, confirm sub optimal status of optimum fertilizer recommendations.

Organic sources are the store houses of secondary and micro nutrients and efficiently conserve the inherent physico chemical and biological properties of soil. Addition of organic manure causes soil life to flourish. Organic manures are available in the form of green and dry plant residues, fresh animal wastes, decomposed materials of plant and animal origin and biologically active preparations. The crop production efficiency of FYM is about 30% that of fertilizer nutrients and FYM can be absorbed by rice plants during one crop season and the accumulated nutrients from the continuous application of these manures are gradually mineralized and utilized by the successive crops which sustain high productivity. Green manuring benefits a number of crops particularly rice based cropping systems. Sun hemp, *Sesbania rostrata* , *Sesbania aculeate* ,Kolinji etc are important green manures. Green manure is a good source of N, P, K, secondary and trace elements and fertilizer response of rice found to increase when the crop was preceded by a GM crop. The potential benefits of crop residue incorporation include water conservation, soil erosion control and maintenance or enhancement of soil organic manure, improving soil environment. Residues may cause several fold increase in available Fe, Mn,Cu and P. Rice straw contains almost all the K and about 1/3 N, P and sulphur removed from the soil by a rice crop.

Most of the organic sources are bulky and needed in large amounts to satisfy the nutrient requirement, so judicious use of chemical fertilizers becomes in evitable and balanced use of in organics is essential for sustained high yields and system productivity. Hence need for Integrated Nutrient Management (INM) is becoming highly essential for sustained production and productivity.

INM involves the judicious use of chemical fertilizers in combination with organic manures required to improve the soil health as well as to achieve sustainable production (Khanda *et al* , 2005) . Organic manure is indeed not a practical substitution for organic fertilizers and vice versa. But integrated nutrient supply system leads to soil and crop productivity due to balanced application of nutrients , as these supply micro nutrients to meet the crop needs which is also a prerequisite to increase fertilizer use efficiency (Singh *et al* , 1999). Organic sources of nutrient applied to the preceding crop benefit the succeeding crop to a great extent. (Hegde, 1998).

A permanent plot experiment on Integrated Plant Nutrient Supply system in the rice rice crop sequence was started at Cropping system Research Centre, Karamana under AICRP in 1985-86. There are 12 sets of treatments .One set will be completed only after testing both *kharif* and *rabi* seasons. The system productivity of 14 years data (1985- 86 to 1998-99) clearly revealed that 50% substitution of RD of NPK as FYM during *kharif* and full dose of fertilizers during *rabi* season profoundly increased the grain yields. The permanent manurial experiments conducted all over India have shown that neither the organic manures alone nor the mineral N,P and K fertilizers could achieve the yield sustainability at a higher order under the intensive farming where the nutrient turn over in soil plant system was quite high. The integrated application of 100% NPK along with FYM 10 t/ha recorded the highest yield in all the cropping cycles (Santhy *et al* ., 2000)

Permanent plot experiments become more useful when periodical soil analysis and critical analysis of soil test data are made. Main objective is to have an idea on correlation, residual effects, nutrient imbalances due to continuous use of manures and fertilizers either alone or in combination. It is well known that the organic matter has got beneficial effects on soil physical, chemical and biological properties. The effects of prolonged application of FYM, green manure, and crop residues along with chemical fertilizers on physico chemical, biological properties of soil, weed population, pest disease incidence has not been studied under in the climatic conditions of southern Kerala. Hence the present study is proposed to analyze the various parameter which were responsible for the above results

The present study aims

- To determine the individual effect of different organics viz., FYM, crop residues and green manure on growth and yield of rice, soil properties, available nutrient status of soil, crop nutrient content and uptake.
- To determine the individual effect of NPK fertilizers and their interactions on growth and yield of rice, soil properties, available nutrient status of soil, crop nutrient content and uptake.
- To study the cumulative effect of the integrated nutrient management system (INMS) involving use of organic manure and NPK fertilizers on growth and yield of rice, soil properties, available nutrient status of soil, crop nutrient content and uptake.
- To evaluate the direct, residual correlation effects in Integrated Plant Nutrient Supply system.
- To evaluate the effects of INM on weed, pest, disease incidence.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Research evidences proved beyond doubt that the integrated nutrient management involving organics, inorganics and biofertilizers can sustain the optimum crop yields and improve soil health. Investigations were carried out at Cropping Systems Research Centre , Karamana , Thiruvananthapuram, Kerala to study the cumulative and synergistic impact of long term integrated nutrient supply system in rice- rice sequential cropping system on yield and growth of rice, physical , chemical and biological properties of soil and pest and disease incidence pattern.

The literature relevant to the investigation is reviewed under the following captions.

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2.2. Effect of organic manure on soil properties.

2.3. Effect of organic manure on soil available nutrients.

2.4. Effect of organic manure on plant nutrient content.

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2.1. EFFECT OF ORGANIC MANURE ON GROWTH AND YIELD OF RICE

2.1.1 EFFECT OF ORGANIC MANURE ON GROWTH

2.1.1.1 Effect of FYM

Application of FYM @10tha^{-1} produced better growth in terms of taller plants, more dry matter accumulation. (Singh *et al.*, 2002). Singh *et al* (2000) reported that application of FYM @ 6.5 t ha^{-1} on dry weight basis increased the root length density significantly over control (No fertilizer). They also opined that the FYM applied plots showed highest root density 5.72 cm cm^{-3} compared with GM. Bridgit and potty (2002) stated that raising FYM levels (0, 5, 10 t ha^{-1}) increased the root number per plant and average root length.

2.1.1.2 Effect of Crop residues

Ravisankar *et al* (2002) reported that growth of rice measured in terms of plant height and dry matter production at different stages showed significant improvement due to incorporation of raw sugar cane trash (10 t ha^{-1}).

2.1.1.3 Effect of Green manures

Application of green manure @ 6.25 t ha^{-1} and neem cake @ 250 kg ha^{-1} basal and 30 days after transplanting increased the plant height and tiller number. (Balasubramaniyan ,2004).

2.1.2 EFFECT OF ORGANIC MANURE ON YIELD ATTRIBUTES AND YIELD OF RICE.

2.1.2.1 Effect of FYM

Kuppuswamy *et al.* (1992) observed that application of FYM @ 10 t ha^{-1} increased the grain yield to 7.33 t ha^{-1} from 6.61 t ha^{-1} and also significantly enhanced straw yield. In order to maintain soil fertility at higher levels and to obtain higher rice and wheat yields, FYM should be applied to rice each year in split rather than a single larger dose (Brar and Dhillon, 1994). There was a linear increase in the yield of rice with the increasing levels of FYM and the maximum obtained at 10 t FYM ha^{-1} (Tiwari *et al* ., 2001).

2.1.2.2 Effect of crop residues

Addition of Crop residues had a favourable effect on overall soil health and fertility status, and therefore increase in yield attributing characters and grain yield of rice occurred. (Parihar ,2004). Surekha and Reddy (2005) reported that grain yields were higher in 100 per cent rice straw incorporation and straw yields were higher in 100 per cent rice straw + green manure incorporation.

2.1.2. 3 Effect of green manure

Green manuring with either *Crotalaria juncea* or *Sesbania rostrata* significantly increased rice grain yield over the control and was statistically on par with fertilizer application (Choudhary and Thakuria, 1996). Shanmugham and Veeraputhran (2000) reported that application of green manure (*Sesbania*) @ 6.25 t ha^{-1} + *Azospirullum* (2kgha^{-1}) took significantly shorter period for 50% flowering (82 and 84 days produced the highest number of productive tillers m^{-2} (436 and 447) and filled grains per panicle (81.10 and 76.26) an panicle length (18.74 and 18.36) in both years. The yield increase in rice under green manured plots with green gram and *Lathyrus* was 16.7 and 20.9 % during *kharif* and *rabi* seasons respectively. (Chettri and Mondal ,2005) .

2.2 EFFECT OF ORGANIC MANURE ON SOIL PROPERTIES

The efficacy of organic manure in improving the soil structure, physical and chemical properties of the soil (Ravikumar and Krishnamoorthy, 1980 and Reddy *et al.*, 1985) was proved.

2.2.1 EFFECT 0N PHYSICAL PROPERTIES

Manickam (1993) opined that decrease in bulk density ,increase in porosity and better water holding capacity of soil mainly due to the action of gum compounds , polysaccharides and fulvic acid compounds of soil organic manure on soil structure. Addition of organic manure to sandy soil increased the available soil moisture to plant and increased the permeability in heavy textured soil; it also increased the water holding capacity which in turn provided protection to the crops against drought (Gaur, 1994). Singh *et al* (2000) found out that OM significantly increased the porosity of both surface and subsurface layers of soil. Sheeba and Kumarasamy (2001) observed a decrease in bulk density with an increase in organic matter content.

2.2.1.1 Effect of FYM

Incorporation of FYM decreased the bulk density and increased the soil porosity and thus increased the water holding capacity of soil.(Parihar ,2004). He added that hydraulic conductivity of soil increased significantly due to the incorporation of FYM and crop residues and opined that organic substances having high CN ratio is known to improve soil physical properties.

2.2.1.2 Effect of crop residues

Badanur and Malabasari (1995) reported that Sorghum stubbles applied @ 5 t ha^{-1} alone or along with Subabul lopping (5 t ha^{-1}) improved the infiltration rate of vertisols significantly over fertilizer application. Mishra and Sharma (1997) reported that addition of crop residues in soil added OM which create favourable environment for increasing the hydraulic conductivity. Application of crop residues around 3 t ha^{-1} contribute towards slow build up of organic matter in rice- rice cropping system leading to increased soil aggregation and reduced bulk density. (Mohanty and Sharma , 2000) . Surekha *et al* (2004) reported a decrease in bulk density and increase in infiltration rate by crop residue (rice straw) incorporation over control or straw burning.

2.2.1.3 Effect of Green manures

Green manuring not only improves the fertility of soils but also improves air-water relationship (Dalvinderjit Singh *et al.*, 1999). Bhardwaj and Bhagat (2005) reported that incorporation of Lantana (*Lantana camara L*) green biomass @ 30 t ha^{-1} in alfisol in rice – wheat cropping system at Palampur , India after 11 years of experiment , saved 18 per cent irrigation water by improved hydraulic conductivity , better moisture retention and soil aggregation.

2.2.2 EFFECT ON CHEMICAL PROPERTIES

Soil organic matter influences the chemical fractions by its ability to interact with metals, metal oxides, hydroxides and clay minerals to form metalloid organic compounds and acts as ion exchanger and store house of nutrients (Maheswarappa *et al* 1999) . Studies by Lal *et al* (2000) reported that initially, basic cat ions were responsible for rise in pH and after that release of organic acids from organic manure played a major role in influencing soil reaction.

2.2.2.1 Effect of FYM

Sharma *et al* (2000) reported that a pronounced decrease in soil pH increase in CEC and organic carbon was observed in FYM treated plots.

2.2.2.2 Effect of Crop residues

Dhiman *et al* (2000) reported that incorporation of crop residues of both paddy and wheat increased the organic carbon content of the soil to 0.66 per cent from the initial 0.52 per cent. Das *et al* (2001) reported that incorporation of crop residues increased the humus content of soil on their decomposition and thus increased the cat ion exchange capacity.

2.2.2.3 Effect of Green manures

Setty and Gowda (1997) reported that the inclusion of green manure or grain legumes in the cropping system increased the soil organic carbon. Gopalaswamy and Kannaiyan (1998) opined that incorporation of *Azolla* hybrids AH-2 reduced the pH and EC of sodic soils from the initial levels and also significant reduction in exchangeable cat ions and increase in CEC from initial soil level was noted when AH- 2 was incorporated. Gopalaswamy and Kannaiyan (1999) found out that *Azolla* hybrids significantly improved the soil organic carbon status. Pattanayak *et al* ., (2001) reported that incorporation of *Azolla* resulted in significantly high organic carbon content of soil (9.2 g kg^{-1})

than *dhaincha* (7.9 g kg^{-1}) and Sunhemp (7.5 g kg^{-1})compared to the initial value (5.1 g kg^{-1}) . Ramesh and Chandrasekaran (2004) reported a gradual build up of organic carbon content when *Sesbania rostrata* was incorporated in situ at flowering stage in rice rice cropping system.

2.2.3 EFFECT ON BIOLOGICAL PROPERTIES

Organic manure contains very large population of bacteria, actinomycetes and fungi. The regulated application of organic manure as a practice will energize the living microorganism involved in biochemical activity of the soil, which improve the soil fertility and plant nutrition; the addition of organic matter profoundly influences the different groups of microorganisms in the rice rhizosphere (Bhattacharya *et al.*, 1996). Maheswarappa *et al* (1999) opined that organic amendments produce more microbial biomass than inorganic fertilizers because they increase the proportion of labile carbon and nitrogen directly stimulating the activity of microorganisms.

Kale *et al* (1992) reported that an increase in the colonization of total microbes and nitrogen fixers in vermicompost applied plots.

During decomposition of *Azolla* in soil , bacterial and fungal populations were low where as actinomycetes , urea hydrolyzing cellulolytic and heterotropic nitrogen fixing bacterial population were increased. (Kannaiyan and Kalidurai ., 1995). Gopalaswamy and Kannaiyan (2000) reported that incorporation of *Azolla* hybrids stimulated the microbial population , total bacterial; , cellulolytic , phosphate solubilising and urea hydrolyzing bacteria , nitrogen fixing *Azospirullum, Azotobacter* , fungi and soil enzymes L-asparaginase, urease , cellulase, dehydrogenase and phosphate activity significantly over prilled urea.. They also reported that the dehydrogenase activity is the indicator of microbial activity in the soil.(Increase in dehydrogenase due to FYM , VC application was mainly attributed to the increase in organic carbon content in turn which enhanced the microbial population).They found that the fungal populations was highest in the FYM and VC applied treatments.

Lal *et al* (2000) reported that the highest number of thiosulphate oxidizers and phosphate solubilising micro organisms were harbored by *Subabul* treated soils . They also reported that in the case of rice straw, *Lantana* tops and *Ipomoea* tops treated soils, the population of phosphate solubilizers increased up to 60 days. Surekha *et al* (2004) reported that residue addition promote a stable supply of carbon and energy for micro organisms and cause an increase in the microbial biomass pool and increase soil respiration rate.

Srinivas *et al* (2004) reported that among the different organic manures like FYM @10 t ha^{-1} treated significantly higher urease activity (UA) (UA 60DAT in rice 27.2) than soils receiving green manure leaves , *Sesbania speciosa* 7.5 t ha^{-1} (UA- 20.4)., *Crotalaria juncea* 7.5 t ha^{-1} (UA-18.1)and *Glyricidia maculata* 7.5 t ha^{-1} (UA – 16.4) which was on par with each other but significantly higher than control.

2.3 EFFECT OF ORGANIC MANURE ON SOIL AVAILABLE NUTRIENTS

Organic manures such as FYM, green manures and crop residues supply secondary and micronutrients and their continued application even in smaller amounts can keep the micronutrient deficencies away. (Rajendra Prasad, 2004)

2.3.1 Effect of FYM

Application of FYM significantly increased the NH^4 – N content in soil up to the first week of incubation and the extent of increase was from 30.1 to 110.1 mg kg^{-1} soil (Duhan *et al* .,2005) . Another report by Yadvinder Singh *et al* (2005) suggested that the lowest amount of K leached was recorded in FYM treatment (1.8 per cent) compared to poultry manure (17.3 per cent), fertilizer K (15.8 per cent)and rice straw (14.4 per cent) thus conserving its availability in soil.

2.3.2 Effect of crop residues

Badanur and Malabasari (1995) reported that significantly higher available P_2O_5 and available K was observed when Subabul in combination with Sorghum (both 5 t ha^{-1}) Stubbles are used. When the straw was added to field after harvest (crop straw returns), the level of soil fertility increases , organic matter content increases from 4.23 per cent from 4.38 per cent and readily available P and K increased from 83 and 6.9 mg kg^{-1} to 110.2 and 11.7 kg ha^{-1} respectively and the net increase of available N was 25.5 mg kg^{-1}.(Hong Chun Lai *et al* ., 2003). Jha *et al* (2004) reported that there was an increase in total nitrogen , available P and K after harvest of wheat over initial status by adding rice crop residue addition irrespective of rice residue management practice , in a rice wheat cropping system.

2.3.3 Effect of green manures

Kannaiyan (1990) reported that *Azolla* incorporation increased the availability of phosphorus, potassium, zinc and iron in rice crop. Application of *Azolla microphylla* could contribute 40-60 kg nitrogen ha^{-1} when inoculated with 500 kg ha^{-1} as dual crop. (Kannaiyan,1995). Gevrek (1999) opined that *Azolla* totally decomposed after 2-3 weeks , increased soil nitrogen by 38-56 % . Kannaiyan and Gopalaswamy (2002) reported that *Azolla* mineralizes rapidly and its nitrogen is made available to rice in a very short period of time.

2.4 EFFECT OF ORGANIC MANURE ON PLANT NUTRIENT CONTENT

Tiwari *et al* (2001) reported that the concentration of N, P,and K in grain and straw increased significantly with the application of FYM and BGA @ 5 t ha^{-1} and 10 kg ha^{-1}.Sahay and Sarkar (2004) reported that

FYM @ 220 q ha^{-1} used continuously had enhanced the grain sulphur content to 0.26 per cent.

2.5 EFFECT OF ORGANIC MANURE ON NUTRIENT UPTAKE

Addition of *S. aculeata* increased N- uptake and nitrogen use efficiency (Panda *et al.*, 1994). Medhi *et al.* (1997) and Sarmah (1997) recorded improvement in P-uptake with green manuring. Sinha and Prasad (1997) noted that increase uptake of micro nutrient cat ions may be due to complexing properties of poultry manure which prevented precipitation and fixation of these nutrients and keep them in soluble form. Mukherjee and Rai (1999) opined that the VAM fungi *Glomus fasciculatum* had a positive influence on P- uptake. The uptake of N,P and K was significantly higher in treatments receiving green manuring – dhaincha, Sunhemp and *Azolla* - compared to those with no green manuring. (Pattanayak *et al* ., 2001). Application of 10 t of FYM ha^{-1} to component *rabi* crops (potato, mustard and wheat) in rice based cropping systems could supplement 25 per cent NPK requirement of all component crops and increased the uptake of N, P and K by the crops (Khanda *et al* .,2005).

2.6. EFFECT OF NPK FERTILIZERS ON GROWTH AND YIELD ATTRIBUTES AND YIELD OF RICE

2.6.1 Effect on growth

Kumari *et al* (2000) reported that taller plants were observed at higher doses of nitrogen application.. Significant increase in the height of rice plants was observed with increased levels of nitrogen. (Anu, 2001).

Singh and Singh (2000) reported that increased dry matter production was obtained under increased nitrogen dose and maximum dry matter accumulation was recorded at 90 kg nitrogen ha^{-1}. Increase in dry matter production with increased levels of nitrogen was recorded upto 60 kg N ha^{-1} by Thomas (2000) and upto 80 kg N ha^{-1} by Anu (2001).

Patil and Sheelavantar (2000) reported that application of 50 kg N ha^{-1} produced superior root length (60.1 cm), root spread (48.4 cm) and root weight $plant^{-1}$(12.4 g). Bhan *et al* (1995) opined that root development increased gradually with the application of nitrogen up to 80 kg ha^{-1}.

Anu (2001) observed that in upland rice incremental doses of nitrogen up to 80 kg ha^{-1} gave significantly higher values of LAI.

Thomas (2000) again reported that tiller number of upland rice increased with higher levels of nitrogen up to 60 kg N ha^{-1}. Singh and Singh (2000) reported that 80 kg N and 40 kg K ha^{-1} produced enhanced number of tillers compared to 120 kg nitrogen alone. Maximum number of tillers $hill^{-1}$ (16.9) was recorded in treatment with 100% NPK.(Lal Bahadur and Bharat Singh ,2003).

But Mahalakshmi *et al* (2001) was of the opinion that highest doses of nitrogen application (800-1200 kg nitrogen ha^{-1}) cause detrimental effect on shoot and root growth in Chilli. They also observed that mortality percentage also increased with increased doses of nitrogen. The lowest per cent of mortality was recorded in 200 kg N ha^{-1}compared to highest plant mortality at 1200 kg N ha^{-1}.

Kumar and Reddy (2003) reported that fertilization with 2 kg P_2O_5 per 100m^2 resulted in greater root length, seedling height and shoot dry weight compared with 0.5 kg P_2O_5 and 1 kg P_2O_5 per 100 m^2.

2.6.2 Effect on Yield Attributes and yield.

Raju *et al* (1999) opined that irrespective of the mode of application K at 60 kg ha^{-1} greatly improved the filled grains/ panicle and effective tillers and improved grain yield significantly, improved harvest Index and reduced the duration of crop. They found that crop without the application of K recorded increased sterile and partially filled spike lets per panicle.

Devendra Singh *et al* (1999b) observed that highest yield of rice was reported at 180 kg K_2Oha^{-1} ,but also found that application of K above 90 kg ha^{-1} did not show any beneficial effect.

Mishra *et al* (1999) reported that effective tillers per plant increased from 10 (with no N) to 17 (with N fertilizers).

Pandian (1999) reported that 120 kg N ha^{-1} produced taller plants and increased yield attributes like panicles m^{-2}, filled grains per panicle and test weight. He also opined that higher levels of P upto 60 kg ha^{-1} result in significantly increased panicles m^{-2}. He added that higher levels of P indicated early tillering and took lesser time for the completion of flowering.

Asif *et al* (1999) opined that the application of 130:67:67 kg NPK ha^{-1} and N in three splits (1/3at transplanting, 1/3 at early tillering, 1/3 at panicle initiation) to Basmathi 385 resulted in higher grain yield with a higher percentage of grain filling and normal kernels due to a considerable reduction in sterility , abortiveness and chalkiness.

Das *et al* (2001) reported that the highest grain and straw yields were recorded under 100% NPK levels followed by 75 , 50 ,and 0 % NPK levels. Singh and Singh (2000) reported that higher panicle bearing tillers, panicle length , grains per panicle , test weight were recorded under 120 kg N and 60 kg K_2O . They also opined that 80 kg N and 40 kg K_2O ha^{-1} enhanced grain and straw yield significantly than 120 kg N alone.

Rasheed *et al* (2003) found that the no : of effective tillers/ hill , spikelets per panicle , normal kernel per panicle and 1000grain weight were improved linearly with an increase in nitrogen and phosphorus up to 100:75 kg ha^{-1}.

Laxmi narayana (2003) reported that grain and straw yields increased significantly with increased doses of nitrogen application up to 80 kg ha^{-1} and showed positive response to higher doses i.e. 120 kg ha^{-1}. He again showed that number of tillershill^{-1}, number of grains per panicle, and test weight positively increased with increased levels of nitrogen.

Singh *et al* (2004) reported that pooled data of three years (1994-95,1995-96,1997-98) indicated that maximum grain yield of rice (5,301 kgha^{-1}) was recorded in treatments where 100 per cent NPK were applied through chemical fertilizers.

How ever, Shalini Pillai and Muraleedharan Nair (1995) found that the application of higher levels of nitrogen (above 50% of the recommended dose of nitrogen) was found to suppress the grain yield.(RD – 70kg ha^{-1}) ,for the extra nitrogen was utilized for straw production rather than grain production. Chopra and Chopra (2000) reported that seed weight per panicle increased significantly up to 80 kg N ha^{-1} and declined at the highest dose. They also opined that panicle length and 1000 seed weight remained unaffected due to nitrogen application.

2.7 . EFFECT OF NPK FERTILIZERS ON SOIL PROPERTIES

2.7.1 Effect on physical properties

Maheswarappa *et al* (1999) opined that there was no variarion in the BD, maximum WHC and porosity of the soil under NPK alone. But Singh (2000) reported that the inorganic fertilizer treatments increased the porosity of subsurface layers with the increase in fertility levels. How ever, Sarkar *et al* (2003) reported that application of inorganic fertilizers alone decreased the stability of micro aggregates and moisture retention capacity and increased the BD values. Dutta and Sharma (2004) opined that in a continuous cropping system of Rice-Linseed for three years there was decrease WHC of soil from the original level of 44.7 per cent to 42.1 per cent in control .(No fertilizer NPK) and 42 per cent in 100 per cent NPK treatments. They also found that lowest micro aggregation and mean weight diameter was seen in 100 per cent NPK treatments.

2.7.2 *Effect on chemical properties*

Selvi *et al* (2003) reported that increase in fertilizer levels from 50-100 per cent of RDF of NPK ha^{-1} gradually increased the CEC of soil. They also pointed out that in plots receiving 100 per cent phosphorus in addition to 100 per cent nitrogen , when compared to plots receiving 100 per cent nitrogen only , showed an increase in CEC. Dutta and Sharma (2004) opined that in a continuous cropping system of Rice-Linseed , continued application of chemical fertilizer alone , decreased the CEC of the soil from that of the original level of 7.1 Cmol (P+)kg^{-1} .

2.7.3 *Effect on Biological properties*

Population of fungi reduced by more than one half by NPK + lime treatment in an All India coordinated long term fertilizer trial conducted on a red loam soil at Ranchi (Nambiar , 1994) , while the same treatment presented a favourable impact on nodular bacteria in Soybean increasing the number of nodules and also their weight per plant. Elevated CO_2 concentration significantly increased the microbial biomass when nitrogen 90 kg ha^{-1} was in sufficient supply (Li Zong *et al* ., 2004) . The application of 100 per cent nitrogen alone and control recorded lower values of microbial population than 100 per cent NPK (Selvi *et al.*, 2004).

2.8 EFFECT OF NPK FERTILIZERS ON SOIL AVAILABLE NUTRIENTS

Hegde and Dwivedi (1992) reported that the results of long term experiments in rice wheat system indicated a small build up in available K in plough layer (0- 20 cm) in plots receiving K fertilizers over the years 1971-1987.

Gupta *et al* (1999) reported that the available P content of the soil increased with the increasing levels of P application at all stages of rice crop.

Chitra and Janaki (1999) opined that the application of different levels of nitrogen 0,50,75, 100 kg ha^{-1} increased the K status of the soil over control. Vyas *et al* (1990) reported that there is synergistic effect between nitrogen and zinc.

Katyal *et al* (2000) reported that the available P was maximum where P_2O_5 was applied @ 90 kg ha^{-1} being 30 per cent more than the initial value of available P in the soil.

Setia and Sharma (2004) reported that continuous use of nitrogen alone resulted in significant increase in the total as well as heat soluble and water soluble sulphur. They also found that combining potassium with nitrogen and Phosphorus significantly decreased the sulphur status of soil, irrespective of the level of N/P addition. Highest potassium depletion was found under control (N0P0K0) followed by $N_{60}P_{40}K_{30}$ treatments.

Kumar and Yadav (2005) reported that continuous cropping with out nitrogen fertilization caused a sharp decrease in the available nitrogen from initial level of 130 to 70 kg ha^{-1}. They also reported that significant reduction in available phosphorus content in soil observed under nitrogen alone and unfertilized control plots.

2.9 EFFECT OF NPK FERTILIZERS ON PLANT NUTRIENT CONTENT

Devendra Singh *et al* (1999b) reported that the application if N increased the content of potassium in rice crop more particularly grain, indicating the synergistic effect and N/K ratios increased markedly in the grain and straw with increasing the levels of N application.

Devendra Singh *et al* (1999a) opined that the potassium concentration in plant tissues increased with increasing levels of K i.e. from 0.54

and 1.75 per cent in control to 0.81 and 2.15 per cent at 180 kg K2O ha^{-1} in rice grain and straw in the first year and 0.52 and 1.71 per cent in control to 0.78 to 2.21 per cent in second year respectively.

While Sharma and Bapat (2000) showed that the reduction of zinc content was prominent in ear head at flowering stage in variation from 4.4 to 18.8 per cent with the application of 40 and 120 kg P_2O_5 ha^{-1} respectively since P is found to inhibit the translocation of zinc from roots to the above ground portions affecting the zinc concentration in plants.

Prom- u- thai and Rerkasem (2003) reported that the increased applicaton of nitrogen from 60- 120 kg N ha^{-1} increased the Fe content of grain from 8.3 to 9.0 and 12.1 to 12.4 (mg Fe kg^{-1}) in brown rice of Basmathi 370. Masthan *et al* (1999) reported that rice fertilized with 26.2 kg P kg^{-1} had low concentration of N and K but more phosphorus in the plant tissue than control.

The increased levels of nitrogen application showed significant increase in K content in grain (Laxminarayana, 2003).

Brahmachari *et al* (2005) reported that when rice crop was fertilized with K along with nitrogen and phosphorus , the K content was higher which influenced the quality of rice grain.

2.10 EFFECT OF NPK FERTILIZERS ON UPTAKE OF NUTRIENTS

Nair and Gupta (1999) reported that highest total K uptake was recorded by 180 kg N ha^{-1} and significantly differed with that recorded by 60 kg N ha^{-1} and remained at par with 120 kg N ha^{-1}.

Chithra and Janaki (1999) was of the opinion that the increase in K uptake consequent to the addition of various levels of N (0,50,75,100 kg N ha^{-1}) over control was significant.

Devendra Singh *et al* (1999b) reported that the uptake of K by grain and straw in rice varied significantly with the increasing doses of K application , but at 90 kg K_2O ha^{-1} and above levels the percentage increase in uptake was not much pronounced. They also opined that the uptake by rice and straw increased significantly over control by the application of both N and K.

Singh and Singh (2000) reported that the highest N and P uptake was observed in the treatment N_{120} K_{60} in both grain and straw of rice.

Suvarnalatha *et al* (2003) reported that the uptake of micro and macro nutrients increased linearly with the increasing levels of fertilizers (0, 50 per cent and 100 per cent RDF) .They added that the uptake of Mn , Cu ,Zn was more at harvest than at maximum tillering stage due to more accumulation of dry matter at harvest and higher concentration of nutrients in the plant at added levels.

Sahay and Sarkar (2004) reported that continuous use of nitrogenous fertilizers resulted in lowest sulphur uptake.(0.75 kg ha^{-1}).

Yadav *et al* (2005) reported that uptake of N and P in wheat was maximum when both rice and wheat were fertilized with 100 per cent NPK in rice– wheat cropping system.

Chettri and Mondal (2005) reported that in the case of sulphur nutrient, uptake was highest when the rice crop was fertilized with 100 per cent RD of sulphur bearing fertilizers (Ammonium sulphate, Diammonium phosphate and Muriate of Potash).

Application of nitrogen even up to 180 kg/ha to rice and 150 kg/ha to wheat resulted in significantly higher total NPK up take by rice – wheat system during 2000-01 and 2001-02 (Patro *et al* ., 2005)

2.11 EFFECT OF INM ON GROWTH AND YIELD ATTRIBUTES AND YIELD OF RICE

2.11.1 EFFECT ON GROWTH

Incorporation of high density of *Sesbania rostrata* and zero per cent nitrogen substitution rate had higher LAI, CGR and LAD leading to higher dry matter production (Halepyati and Sheelavantar, 1993).

Syed Nazeer Peeran and Sree Ramulu (1995) found that application of FYM along with urea gave significantly taller plants than urea alone .

In situ incorporation of intercropped *S. rostrata* in rice increased plant height, LAI and tiller number of semi dry rice (Jayachandran and Veerabadran, 1996).

Integrated application of organic manure, inorganic fertilizers and biofertilizers significantly increased the growth and yield attributes of rice (Jeyabal, 1997).

Hiremath and Patel (1998) reported that growth attributes of summer rice such as LAI, LAD, CGR and NAR were comparable between green manure, *Sesbania aculeata* and *Crotolaria juncea.*

Mukherjee and Rai (1999) reported that *Glomus fasciculatum, G.macrocarpum and Pseudomonas striata* and phosphorus nutrition increased the root biomass significantly than either component separately.

Application of green manure promotes growth of rice by increasing plant height (Bayan, 2000).

Singh *et al* (2000) opined that the combined application of FYM 6.5 t ha^{-1} and RD of NPK (120:60:40 kg N, P_2O_5 and K_2Oha^{-1}) produced almost double the root mass than NPK alone. They also reported that 75 per cent higher root biomass was produced with green manure and recommended NPK than NPK alone.

Patil and Meisheri (2003) indicated that the treatments 1.t FYM ha^{-1} + 25 kg ZnSO4 ha^{-1} (75.96g/pot) and 10t FYM ha^{-1} + 10 kg Zinc chelate ha^{-1} (74.39 g /pot) were significantly superior to other treatments indicating the importance of FYM in dry matter production.

Jha *et al* (2004) opined that the application of inorganic fertilizers of 30:20:15 kg NPK ha^{-1} combination with either cow dung urine (CDU) mix 3t ha^{-1} or 1.5 t of CDU + 5t ha^{-1} of green manure significantly increased the plant height.

2.11.2 EFFECT ON YIELD ATTRIBUTES AND YIELD OF RICE

Budhar and Palaniappan (1997) reported that the partial substitution with green manure recorded similar or comparable yield with that of fully RD through fertilizers.

Singh and Verma (1999) also reported that FYM + 50 per cent recommended N, P, K application gave the highest rice yields

Dubey and Varma (1999) revealed that the grain and straw yields of first and and second season rice crop obtained from the combined application 50 per cent NPK+ 50 per cent poultry manure or FYM were statistically comparable with NPK dose alone.

The results of a long term trial in a rice-rice cropping system in Kerala, Orissa and Andhra Pradesh revealed that application of 25-50 per cent of fertilizers in organic form gave the best yield stability (Katyal and Gangwar, 2000).

Shanmughan and Veeraputhran (2000) reported that the combined application of organic manures like GM (*Sesbania aculeata* 6.25 t ha^{-1}) or FYM 12.5 t ha^{-1} with *Azospirillum (* 2 kg ha^{-1})and application of nitrogen 150 kg ha^{-1}

with25 kg Zn SO4 ha^{-1} maximized the growth and yield attributes and finally the yield of Rabi rice.

Bastia (2002) reported that the number of paniclesm^{-2} was maximum for the treatments FYM 5t ha^{-1} + half the RD of fertilizers (30:15:15 kg NPK ha^{-1}). He also found out that weightpanicle^{-1}, total grainpanicle^{-1}, filled grain panicle^{-1}, test weight and grain yield were higher in the treatment (25 kg seed ha^{-1}) + half the dose of RD.

Singh *et al* (2002) reported that application of Blue green algae @ 16 kg ha^{-1} with 75 per cent RD of inorganic fertilizers increased the grain yield if succeeding wheat by 33 per cent over control in rice – wheat cropping system.

Laxmi narayana (2003) found out that the inoculation with BGA and application of chemical fertilizer nitrogen showed significant increase in grain yield by 5.07 q ha^{-1} (11 per cent) , 4.03 q ha^{-1} (8 per cent) during the first year and 5.47 q ha^{-1} (13 per cent), 5.22 q ha^{-1} (11 per cent) and 3.57 q ha^{-1} (7 per cent) in comparison with the application of 40, 80,120 kg nitrogen ha^{-1} respectively.

Again , Selvi *et al* (2003a) reported that the combination of Rajphos @ 21.82 or 32.73 kg P ha^{-1}, green leaf manuring 6.25 t ha^{-1} and Phosphobacteria 2 kg ha^{-1} resulted in higher grain yield comparable with the sole application of DAP.

Parasuraman *et al* 2003 reported that incorporation of composted coir pith CCP @ 12.5t ha^{-1} along with inorganic fertilizers (150:50:50 kg NPK ha^{-1}) found to record increased values of productive tillers per hill, grains per panicle and test weight.

Chettri and Mondal (2005) reported that in a field experiment conducted at Kalyani , the maximum grain yields of both rainy season (4.66 t ha^{-1}) and winter (5.47 t ha^{-1}) rice were observed in the sequence where green gram and Latyrus were green manured before transplanting of rainy season and winter rice in addition to 75 per cent of RD of nitrogen , P and K through non sulphur bearing fertilizers (urea , Di ammonium phosphate and MOP) along with FYM @ 10t ha^{-1} .

2.12 EFFECT OF INM ON SOIL PROPERTIES

Combination with organic and inorganic has added advantage of improvements in the microbial activity , stabilization of soil structure , enhanced moisture retention capacities and availability of all major nutrients.(Santhy *et al* ., 2000).

2.12.1 EFFECT OF INM ON PHYSICAL PROPERTIES

Singh *et al* (2002) found that lowest BD was with 50 per cent of RD of nitrogen (RDN) through inorganic fertilizers + *Sesbania aculeata* @ 2.5 t ha $^{-1}$ followed by 50 per cent of RDN through in organic fertilizer + press mud 5 t ha^{-1}. Selvi *et al* (2003b) reported that the application of 10 t ha^{-1} of FYM along with 100 per cent NPK recorded significantly low BD. They also got the result that FYM + 100 per cent inorganics increased the hydraulic conductivity , water stable aggregates , porosity and WHC. Dutta and Sharma (2004) opined that the addition of 5 t ha^{-1} of organic fertilizers such as FYM , press mud , biogas slurry or green manures in combination with NPK fertilizers increased the percentage of micro aggregation and there by the mean diameter of the soil.

2.12.2 EFFECT OF INM ON CHEMICAL PROPERTIES

Bastia (2002) reported that the soil pH was reduced from 6.9 to 6.6 in the treatment green manure (6. 25 kg seeds ha^{-1}) + half the RD of NPK and Laxmi narayana (2003) reported that 120 kg N ha^{-1} in combination with BGA has recorded the highest organic carbon content of 0.76 per cent. Selvi *et al* (2003) observed that the highest organic carbon was recorded in plots where fertilizers were incorporated with FYM , continuously. They also got the result that combined application organics and inorganics resulted in significant increase in CEC over control (No fertilizers). Dutta and Sharma (2004) found that the highest organic carbon and CEC was found in the plots receiving 50 per cent NPK + 10 t ha^{-1} biogas slurry in rice-linseed cropping system.

2.12.3 EFFECT OF INM ON BIOLOGICAL PROPERTIES

Tiwari *et al* (2000) reported that the total bacteria count showed the superiority over Azotobacter , Fungi and actinomycetes with the incorporation of wheat straw and biogas slurry at different levels of nitrogen up to the flowering stage of the crop and decreased at harvest. Selvi *et al* (2004) reported that application of FYM @ 10 t ha –1 to finger millet annually along with 100 per cent NPK recorded the highest bacterial counts at the end of rotation followed by 150 per cent NPK. Addition of rice straw and rock phosphate and pyrite at the level equal to poultry droppings brought about a significant increase in the population of non symbiotic nitrogen fixing and ammonifying bacteria. (Debnath *et al.*, 2005).

2.13 EFFECT OF INM ON SOIL AVAILABLE NUTRIENTS

Devarajan and Krishnaswamy (1996) reported the beneficial effect of zinc enriched organic manure on available zinc content in soil after harvest of crop. Dubey and Varma (1999) reported that available N increased to 276 kg ha^{-1} under 50 per cent NPK + 50 per cent poultry manure over the initial value of 220 kg ha^{-1}. Katyal *et al* (2001) showed that application of FYM 5 t ha^{-1} in addition to RD of nitrogen 120 kg ha^{-1} tended to increase the available soil P and K. Patil and Meisheri (2003) pointed out that the application of 10 t FYM ha^{-1} + 25 kg Zn SO4 ha^{-1} and 10 t ha^{-1} FYM + 10 kg Zn chelate ha^{-1} increased significantly the DTPA content in the soil. Selvi *et al* (2003) reported that the total nitrogen content , exchangeable Ca and Mg , available P and available K were increased in plots receiving combined application of 100 per cent NPK (90 : 45 : 17.5 kg ha^{-1})and FYM (10t ha^{-1}). Parasuraman *et al* (2003) opined that the available nutrient status after the harvest of second season rice crop revealed that the available N and K status of soil was improved markedly by CCP (Composted coir pith) 12.5 t ha^{-1} + recommended inorganic fertilizers (RIF) @ 150 : 50: 50 kg NPK ha^{-1}. Jha *et al* (2004) reported that highest potassium solubilisation was observed in the treatments where application of inorganic fertilizer 60: 40: 30 kg NPK ha^{-1} with 5 t ha^{-1} of FYM followed by 20:20: 15 kg NPK ha^{-1} + CDU 1.5 t ha^{-1} + lime 1 q ha^{-1}.

2.14 EFFECT OF INM ON PLANT NUTRIENT CONTENT.

Highest N, P and K content in grain was observed with the combined application 80 and 120 kg N along with BGA inoculums. (Laxmi narayana , 2003). Patel and Meisheri (2003) reported that the combination of FYM with Zinc significantly increased the content in grain and straw over treatments with out FYM.

2.15EFFECT OF INM ON NUTIRENT UPTAKE.

Deepa (1998) proved that highest N and K uptake was recorded when 50 per cent N supplied through FYM and 50 per cent N through inorganic fertilizers and highest P uptake was obtained when 25 per cent of N supplied through crop residue and 75 per cent N through inorganic fertilizers in kharif season. Ranjini (2002) reported that the highest uptake of nitrogen and potassium was registered when 90 kg N ha $^{-1}$ was applied with 25 per cent substitution through VC whereas maximum phosphorus uptake was obtained upon the application of 90 kg ha $^{-1}$ with 50 per cent substitution through VC . Chettri and Mondal (2005) reported that N,P, and K uptake was highest when the rice crop was fertilized with 75 per cent of the RD of N, P and K through non sulphur bearing fertilizers (urea, DAP, and MOP) along with 10 t ha^{-1} FYM applied at both *kharif* and *boro* seasons. The highest N, P and K uptake was recorded with the application of 60 kg nitrogen ha $^{-1}$ + *Azolla* @ 10 t ha $^{-1}$.(Kumarjith Singh *et al.*, 2005)

INM and fertilizer use efficiency.

Thakur *et al* (1999) reported that the field investigation on INM in rice rice cropping system revealed that 25 per cent of the applied nitrogen could be saved and chemical fertilizer use can be reduced up to 50 per cent by using a combination of organic and inorganic fertilizers – FYM 3 t ha^{-1}, crop residues 6t ha^{-1} and *Azolla* 187.5 kg ha^{-1} and 375 kg ha^{-1} for providing 23 per cent and 50 per cent nitrogen respectively. As per Bhagavathiammal and Mahimaraja (1999) the organic acids produced during the decomposition of organic manure supply protons for rock phosphate dissolution. Santi and Selva Kumari (1999) opined that irrespective of the seasons, the critical soil test values of all the three major nutrients were low under IPNS treatments (NPK+ GM, NPK + Phospho bacteria, NPK+ GM+ Phosphobacteria) as compared to NPK alone and resulted in saving of NPK fertilizers. Rajni rani and Srivastava (2001) reported that the incubation studies revealed that when inorganic fertilizer was added in the soil along with organic manures , the availability of nitrogen in the form of NH^{4+}_ H continued to be higher for a longer period of time , showing better compatibility and mutually increasing efficiency of each other. Chakraborthy *et al* (2001) reported maximum NUE when *Sesbania aculeata* (12.5 kg seed ha^{-1}) was fertilized with single super phosphate SSP @ 30 kg P_2O_5 $ha^{-1}$and was incorporated prior to rice transplantation. They added that the agronomic efficiency of P was higher with fertilizers applied @ 30:15:15 kg NPK ha^{-1} to rice after *Sesbania aculeata* incorporation. Combined application of Urea –N , green manure or FYM decreased ammonium volatilization losses in comparison to separate addition of urea- N alone , suggesting that the use of integrated nutrient management could save up to 6 per cent of fertilizer nitrogen.(Yadu vanshi, 2001). Malarkodi and Singaram (2003) reported that the efficiency of rock phosphate was improved by the combined application of water soluble fertilizers , organic manures and bio fertilizers. Laxmi narayana (2003) opined that the efficiency of applied N was significantly improved with the inoculation of N fixing biofertilizer BGA as compared to the application of fertilizer nitrogen alone which is showing an economy of 30- 40 kg ha^{-1}. Lal

Bahadur (2003) reported that NUE (ratio of kg grain per kg N) of rice crop remarkably decreased with increasing levels of nitrogen, showing the deleterious effects of inorganic fertilizers alone. Priyadarshini and Prasad (2003) reported that nitrogen supply at 50 per cent N each through fertilizers and organic sources (FYM+ GM) was instrumental in recording the highest value of NUE which was similar to the combination of 5 per cent N through fertilizers and 25 per cent through organic sources – the lowest value of NUE was observed with 100 per cent N supply through in organic source. Uma Mahesh *et al* (2003) reported that high PUE can be attributed to the integration of P fertilizers SSP (30: 40: 50) and biofertilizer (seed inoculation with phosphate solubilising bacteria) with 25 per cent P through mono ammonium phosphate(12:16: 0) as foliar spray resulting in gradual and continuous availability of both N and P.

CORRELATION STUDIES

Sakal *et al* (1999) reported that there is a significant improvement in boron uptake when it was applied along with sulphur than with out sulphur showing a positive interaction of these nutrients when applied along with recommended NPK. Rajkumar and Veeraraghavaiah (2002) reported that there was a significant improvement in sulphur uptake when sulphur was applied along with NPK in combination with Zn but not in combination with boron showing synergism between sulphur and zinc. A significant positive correlation was observed between org carbon and available N and P , and also organic carbon and available sulphur. The available zinc was significantly and positively correlated with org carbon opined Ramesh *et al* 2003 . Dolui and Banerjee (2004) reported that CEC and organic carbon had significant positve correlation with different forms of extractable sulphur .

RESIDUAL EFFECTS

Singh *et al* (2001) observed that the highest seed yield and highest uptake of N, Pand K in Lentil was recorded in the treatment receiving

50 per cent nitrogen through dhaincha green manuring coupled with 50 per cent nitrogen through prilled urea.in the preceeding rice crop. Residual K in soil was influenced the variation in NPK fertilizers showing high residual potassium under higher NPK. The application of Rajphos @ 32.73 kg P ha $^{-1}$along with green leaf manure 6.25t ha $^{-1}$applied to rice recorded the highest residual black gram yield of 480 kg ha $^{-1}$, reported Selvi *et al* 2003. Dey and Jain (2003) reported that green manures were found to be more beneficial than urea in maintaining the residual effect in Wheat. The treatments combining the application of 10 t FYM ha $^{-1}$+ 25 kg $ZnSO_4$ and 10 t FYM was significantly superior over other treatments indicating the significance of FYM in maintaining the residual effects (Patil and Meisheri , 2003).

ROLE OF OM AND INM IN MAINTAINING SOIL HEALTH

Neher *et al* (2003) reported that decomposition of organic materials is a useful indicator of soil condition because it integrates the collective activities of soil organisms involved in the soil food web.

The use of *Azolla* in rice fields has considerably increased the soil microbial as well as enzyme activity besides playing a vital role in improving soil health or soil quality management in sustainable rice farming (Kannaiyan ,1995) as well as in bioreclammation of sodic soil (Gopalaswamy and Kannaiyan, 1998). It was reported by Baggie and Bah (2001) that the application of 5 t ha^{-1} of partially decomposed rice husk or 5 ha^{-1} *Calapagonium mucunoides* alleviates Fe toxicity and increased the grain yield over control by 76 and 77 per cent respectively and improved the count of effective tillers m^{-2}.

Farmyard manure along with a low dose of benonyl is effective in producing a good harvest of rice in flooded acid soil by way of suppressing the extreme reduced conditions responsible for toxic build up of Fe and Mn in these soils (Bhattacharya *et al.*, 1996).

Dixit and Gupta (2000) reported that BGA plays a vital role in IPNS to achieve sustained crop production and maintain soil health.

Sherin *et al* 2004 reported that application of 10 t coir pith ha^{-1} was an effective ameliorative measure against the saline and alkaline reactions of soil.

EFFECT OF OM ON PESTS

Earlier in 1982, Lyashenko *et al* reported that higher levels of leucoanthocyanins , catachins , and flavanolglycosides and phenol carboxylic acid in plants that received FYM and cause lower pest attack. Chino *et al* (1987) opined that asparagines content of plant phloem sap was significantly lower under organic cultivation there by adversely affecting the feeding activity of BPH. When Azospirillum (2 kg ha^{-1}) and *Azolla* (500kg ha^{-1}) was applied alone the BPH population was 43 and 47 $hill^{-1}$ respectively in first generation and 58and 62 $hill^{-1}$ respectively in second generation compared to bigger population in both generations when synthetic fertilizers are applied alone.(100:50:50 or 120:50:50 kg NPK ha^{-1}). Kajimura *et al* (1995) noted that low densities of BPH and white backed plant hopper in organically farmed fields and those of low nitrogen content. A few workers also observed that application of vermicompost led to higher earthworm population which reduced nematode population (Anon, 1999) and controlled sucking pests of chilies (Verma and Supare, 1997) and groundnut (Ramesh, 2000). Surekha and Arjuna Rao (2001) reported that vermicompost 7.5t ha^{-1} basal was significantly more effective in bringing down the population of aphids followed by FYM (30 t ha^{-1} basal) when compared to NPK straight fertilizers. They reported that the higher levels of polyphenol contents in organic manure (Vermi compost and FYM) treated plots cause low pest build up. Atteri and Nicholls (2003) reported that the crops grown on soils with high OM and active soil organisms tend to be less infested with insect pests.

EFFECT OF INORGANIC NUTRIENTS ON PESTS

Mahalakshmi *et al* (2001) reported that the per cent of borer affected pods in Chilli plant in plots treated with 200 kgN ha^{-1} was 3.5 compared to 5.4 in 1000 kg ha^{-1} and 6.6 in 1200 kg N ha^{-1}.

EFFECT OF INM ON PESTS

J.Alice RP Sujeetha and Venugopal (2003) reported that the combination of inorganic fertilizers (120:50:50 kg NPK ha^{-1}) and Azospirillum (2 kg ha^{-1}) resulted in lowest population of BPH (26.66$hill^{-1}$) in the first generation and (39 $hill^{-1}$) in the second generation respectively compared to 62 and 88.34 $hill^{-1}$ respectively in first and second generation when NPK was applied alone.

NON INSECT PESTS – Effect of in organic sources.

Golden Apple Snail (GAS) population was reduced by 54per cent by the basal application of complete fertilizers 60:40:40 kg NPK ha^{-1} with urea at recommended rate , thus preventing the GAS damage in rice crop during the first two days. (de la Cruz, 2001)

EFFECT OF INORGANIC SOURCES OF NUTRIENTS ON DISEASES

Mahalakshmi *et al* (2001) reported that diseased pods in Chilli was highest in plots treated with 1200 kg N ha^{-1} (23.1) compared to 14.8 in plots treated with 200 kg N ha^{-1} . Girija and Sree Rama Reddy (2002) reported that accumulation of cell wall bound phenols in rice plant may show resistance of rice to blast, and phenol content in rice cell wall is correlated with silicon accumulation in cell wall and such direct relationship may not occur. when there is change in environmental conditions like high soil nitrogen.

EFFECT OF OM ON WEEDS

Sharada *et al* (1999) reported that the average reduction in green weed mass due to green manuring was at the extent of 28 per cent and weed biomass was effectively reduced by Sunhemp to the extent of 38 per cent . Sahoo and Dutta (1999) reported that the compact mass of *Azolla* over the water in field equally checks the growth and emergence of weeds like herbicide and as a result number of tillers $hill^{-1}$ increased by 135 – 137 per cent and grain yield by 60 per cent. Compost treated plots found infested heavily with *Echinochloa* grass and recorded three times more population after 5 years compared with initial value and a marshy weed *Monochoria vaginalis* proliferate 2-3 more times under the straw and green manure applied plots but found absent under compost treated plots. It was noted that green leaf manuring conspicuously reduced the *Echinochloa* population and straw application resulted in complete dissappearence of grasses. (Raju and Reddy , 2000). Kremer and Li (2003) reported that crops grown on soils with high OM and active soil organisms tend to be less infested with weeds.

EFFECT OF IN ORGANIC NUTRIENTS ON WEEDS

Raju and Reddy (2000) reported that the population of *Echinochloa colonum* increases due to chemical nitrogen fertilizer. Roy and Mishra (1999) also reported that weed population and weed dry weight increased with increased levels of nitrogen.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

An investigation was carried out at Cropping Systems Research Centre (CSRC), Karamana to find out the effect of long term integrated nutrient management in rice-rice sequential cropping system on growth and yield of rice, soil physico chemical biological properties, insect, and disease and weed incidence. The experiment was conducted during the *kharif* and *rabi* seasons 2004- 2005 and to study the effects of long term integrated application of organic manure, viz., farmyard manure, green manure and crop residues, and inorganic nutrients in a rice- rice sequential cropping system .The materials used and methods adopted for the investigations are detailed in this chapter.

3.1. Specification of the experimental site

3.1.1. Field location

The experiment was conducted at Cropping Systems Research Centre (CSRC), Karamana of Kerala Agricultural University located 3 km south east of Thiruvananthapuram central railway station, Kerala. The experimental area is geographically located at 11° N latitude and 77° E longitudes at an altitude of 33 m above mean sea level, 16 km away from the coast of Arabian Sea.

3.1. 2. Soil

The soil of the experimental area belongs to the soil type of riverine alluvium. Soil is sandy loam with pH 5.3, low in CEC and available nitrogen, medium in available phosphorus and potassium. A brief description of the physico-chemical properties of soil is given in Table 3.1. The experimental plots were irrigated with the water available from the Karamana River.

3.1.3. Season

The experiment was conducted during *kharif* and *rabi* seasons of the year 2004- 2005 (June 2004-March 2005).

Table 3.1 Physicochemical and biological properties of the experimental site

Sl no	Fractions	Content in soil	Method used
1	Mechanical Composition		International Pipette method (Piper , 1967)
1.1	Sand (%)	72	
1.2	Silt (%)	7.1	
1.3	Clay (%)	20	
1.4	Textural Class	Sandy loam	
2	Available Nitrogen $kgha^{-1}$	266.65	Alkaline permanganate method (Macrokjeldahl method (Subbiah and Asija, 1956)
3	Available Phosphorus $kgha^{-1}$	15.02	Bray and Kurtz Caloriemetric method (Jackson ,1973)
4	Available Potassium $kgha^{-1}$	126.32	Ammonium acetate method (Jackson ,1973)
5	Soil reaction	5.20	1:2.5 soil solution using pH meter with glass electrode (Jackson ,1973)
6	EC (dSm-1)	0.016	Using conductivity meter (Jackson ,1973)
7	CEC (Cmols(+)kg-1)	6.84	Neutral normal Ammonium acetate method (Jackson ,1973)
8	Organic carbon (%)	1.00	Walkley and Black rapid titration method (Jackson , 1973)
9	Microbial count Bacteria ($*10^6$ g^{-1}) Fungi ($*10^4 g^{-1}$) Actinomycetes ($*10^8$ g^{-1})	 23.40 12.80 2.41	Serial dilution plate method (Timonin , 1940)
10	Bulk density	1.3 $Mgcc^{-1}$	Core method (Gupta and Dakshinamoorthy, 1980)

3.1.4. Weather conditions

The mean annual rainfall received was 146.75 mm .The maximum temperature fluctuated between 35°C and 26°C with a mean of 31.2°C. Minimum temperature fluctuated between 27°C and 21°C with a mean of 23.2°C. The relative humidity ranged from 75 to 99 per cent. The meteorological parameters of the cropping period are illustrated in Appendix. 1 and graphically represented in Fig 3.1

3.1.5. Crop sequence and variety

Rice – rice cropping system (Variety. Aiswarya)

3.1.6. Cropping history of the field

The experiment was a part of the ongoing permanent plot experiment project of AICRP at CSRC, Karamana . It was started in the year 1985- 86. The regular sets of treatments had been tested in both *kharif* and *rabi* seasons in all the years .The experiment is being continued.

3.2. EXPERIMENTAL MATERIALS

3.2.1. Seeds

The rice variety selected for the experiment was Aiswarya (Ptb- 52) released from RARS, Pattambi. It is a medium duration variety (120- 125 days) with red , long bold grains ,resistant to blast and blight and to brown plant hopper, suited for both *kharif* and *rabi* seasons.

3.2.2 Manures and Fertilizers

Nitrogen , phosphorus and potassium were applied as urea (46 % N), Mussooriephos (20 % P_2O_5) and Muriate of Potash (60% K_2O). farm yard manure (0.5 %N), crop residues (damaged paddy straw 0.36 % N) and green manure (*Glyricidia* leaves 2.90 % N) were the organic sources of nutrients used in the study.

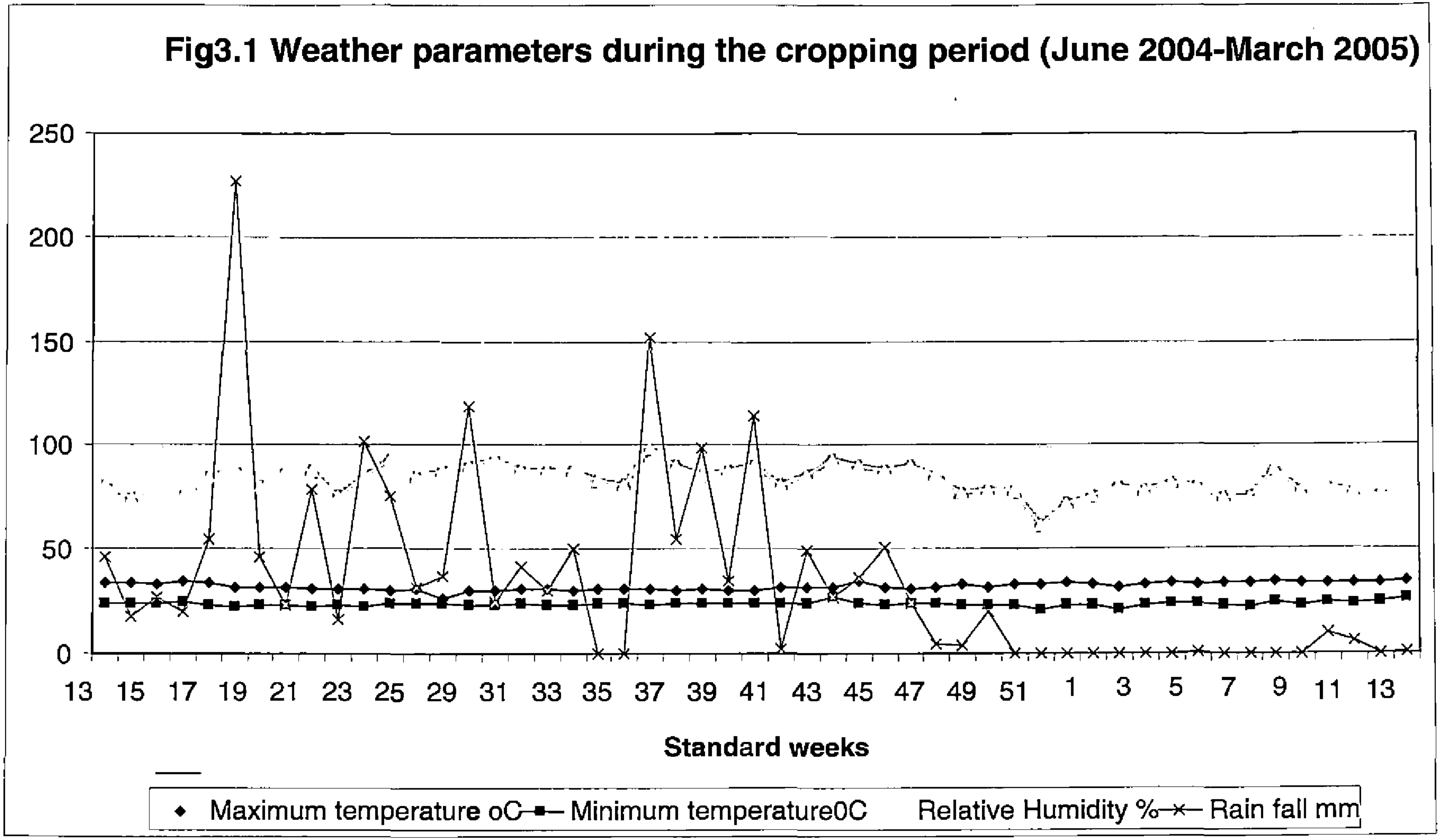


Fig3.1 Weather parameters during the cropping period (June 2004-March 2005)
250
200
150
100
50
0
13 15 17 19 21 23 25 29 31 33 35 37 39 41 43 45 47 49 51 1 3 5 7 9 11 13
Standard weeks
Maximum temperature oC
Minimum temperature0C
Relative Humidity %
Rain fall mm

Fig 3.1

3.3 METHODS

3.3.1 Design and Lay out

The experiment was laid out in Randomised Block Design which omprise of 12 sets of treatment combinations distributed over *kharif* and *rabi* seasons. The treatments were replicated to four times. The treatment details are given in Table. 3.2 The layout plan of the experiment is given in Fig.2. The details of the experiment are given below

Design		:	Randomised Block Design
Treatments		:	12
Replication		:	4
Plot size	Gross	:	16.0 x 6.3 m^2
	Net	:	15.2 x 5.7 m^2 *(Kharif)*
			15.2 x 5.9 m^2 *(Rabi)*
Spacing		:	*Kharif* 20x15cm
			Rabi 20x10 cm
Recommended fertilizer dose		:	90 : 45: 45 $Kgha^{-1}$

3.3.2 Treatments

Table 3.2 Treatment details

Treatments	*Kharif*	*Rabi*
T1	No fertilizers, No organic manure(control)	No fertilizers, No organic manure(control)
T2	50% 0f RDFof NPK through fertilizers	50% 0f RDF of NPK through fertilizers
T3	50% 0f RDF of NPK through fertilizers	100% 0f RDF of NPK through fertilizers
T4	75% 0f RDF of NPK through fertilizers	75% 0f RDF of NPK through fertilizers
T5	100% 0f RDF of NPK through fertilizers	100 %0f RDF of NPK through fertilizers
T6	50% 0f RDF of NPK through fertilizers+ 50% through FYM	100% 0f RDF of NPK through fertilizers
T7	75% 0f RDF of NPK through fertilizers+25% through FYM	75% 0f RDF of NPK through fertilizers
T8	50% 0f RDF of NPK through fertilizers+50% through crop residues	100% 0f RDF of NPK through fertilizers
T9	75% 0f RDF of NPK through fertilizers +25% through crop residues	75% 0f RDF of NPK through fertilizers
T10	50% 0f RDF of NPK through fertilizers+ 50% through green manure	100% 0f RDF of NPK through fertilizers
T11	75% 0f RDF of NPK through fertilizers + 25%through green manure	75 % 0f RDF of NPK through fertilizers
T12	Farmer's Practice 3t FYM +90: 22.5:22.5 kg NPK ha^{-1}.	Farmer's Practice 90: 22.5:22.5 kg NPK ha^{-1}.
RDF recommended dose of Fertilizers 90:45:45 kg NPK/ha		

3.3.3 Cultural Practices

3.3.3.1 Nursery

Wet method is adopted in nursery preparation. The field was ploughed, puddled and leveled, and nursery beds of 1 to 1.5 m wide and 10m length were prepared, with drainage channel between the beds. Applied cattle manure @ 1 kgm^{-2} in the nursery bed and mixed well with soil. Seeds were placed in water, drained and incubated in warm moist place for sprouting. Seeds moistened occasionally and sprouted seeds were sown on third day at the rate of 65 kg ha^{-1}

3.3.3.2 Main field preparation

The experimental plots were puddled and leveled. Weeds and stubbles were removed. After cleaning and thickening the bunds, the plots were again dug and perfectly leveled.

3.3.3.3 Application of Manures and fertilizers

One month before the planting of the crop the respective quantities of organic manures were applied and incorporated in the field .The chemical fertilizers were applied as per the schedule, half dose N and K as basal and the remaining half at panicle initiation, full dose of P as basal.

3.3.3.4 Transplanting

Transplanted with 2-3 seedlings $hill^{-1}$ in the field with a thin film of water and afterwards water level raised to a height of 5cm.

3.3.3.5 Weeding

Hand weeding was given at 20 and 45 days after transplanting (DAT).

Fig : 2 Lay out plan

North ↓

═══ Drainage channels   - - - - - Irrigation channels

48 T 12	47 T 5	46 T 9	45 T 12	44 T 3	43 T 2	42 T 4	41 T 7	40 T 9	39 T 3	38 T 6	37 T 4
25 T 11	26 T 4	27 T 8	28 T 5	29 T 8	30 T 9	31 T 6	32 T 3	33 T 8	34 T 2	35 T 12	36 T 8
24 T 2	23 T 6	22 T 1	21 T 6	20 T 4	19 T 1	18 T 10	17 T 1	16 T 11	15 T 5	14 T 1	13 T 10
1 T 10	2 T 7	3 T 3	4 T 7	5 T 11	6 T 10	7 T 5	8 T 2	9 T 12	10 T 11	11 T 7	12 T 9
	R1			R2			R3			R4	

3.4 OBSERVATIONS

3.4.1 Biometric observations:

3.4.1.1 Number of tillers hill^{-1}

Total number of tillers hill^{-1} was recorded at active tillering, panicle initiation and at harvest stages from four hills selected randomly from the sample area. Tiller number was then expressed as total number of tillers hill^{-1}.

3.4.1.2 Number of roots hill^{-1}

The number of fully developed roots were counted at active tillering, panicle initiation and harvest stages, from the pulled out plants and expressed as total number of roots hill^{-1}

3.4.1.3 Height of the plant

Height of the plant was recorded at active tillering, flowering and maturity stages. Height of plants was measured from the base of the plant to the tip of the longest leaf or the tip of the longest ear heads whichever was taller and expressed in cm.

3.4.1.4 Length of the panicle

Ten panicles were taken from the net plot area and average panicle length was measured and expressed in cm.

3.4.2 Yield and Yield attributes

3.4.2.1 Number of productive tillers hill^{-1}

At harvest the number of productive tillers was recorded from five randomly selected hills in the net plot area and was expressed as number of productive tillers m^{-2}

3.4.2.2 Test weight (Thousand grain weight)

One thousand grains were counted randomly from the cleaned and dried produce from the net plot area of each plot and weight was expressed in grams.

3.4.2.3 Sterility percent

Number of spike lets and unfilled grains panicle^{-1} were counted and expressed as chaff percentage using the following formula.

$$\text{Sterility \%} = \frac{\text{Number of unfilled grains panicle}^{-1}}{\text{Number of filled grains panicle}^{-1}} \times 100$$

3.4.2.4 Grain yield

The grains harvested from each net plot were dried to constant weight of moisture content of 14 %, cleared weighed and expressed in kg ha^{-1}.

3.4.2.5 Straw yield

The straw harvested from each net plot was dried to a constant weight under sun and weight was expressed in kg ha^{-1}.

3.4.3 Plant analysis

Sample plants were collected from each plot at active tillering, panicle initiation and at harvest sun dried oven dried to constant weight, ground, digested and used for nutrient content analysis .The nitrogen content by modified micro kjeldahl's method, phosphorus content by vanadomolybno phosphoric ellow colour method and potassium content by flame photometer method were estimated for plant samples of each plot separately (Jackson ,1973)

3.4.4 Uptake Studies

Uptake of N, P and K by rice crop at active tillering, panicle initiation and at harvest will be calculated as the product of the content of these plant nutrients in the plant sample and the respective dry weight and expressed as kg ha^{-1}.

3.4.5 Soil Analysis

Available N,P,K,Zn,S

Soil collected before and after the experiment , dried in shade , sieved through 2mm sieve and analyzed to determine the available nitrogen content by alkaline permanganate method (Subbaiah and Asija , 1956) , available phosphorus by Bray method (Jackson, 1973), and available potassium by ammonium acetate method ,available micronutrient zinc by Linsar and Norvell (1969) method, using DTPA extract , and available sulphur by Calcium chloride extractable sulphur method (Chesnin and Yien, 1950).

3.4.6 Physical Properties

Soil collected before and after the experiment for calculating the physical properties like bulk density using core sampling method and Water holding capacity using undisturbed core sampling method (Gupta and Dakshinamoorthy, 1980) .

3.4.7 Chemical properties

Organic Carbon content of the soil samples were determined by the wet digestion method by rapid titration method (Walkley 1948).

Cat ion exchange capacity of soil from each plot before and after the experiment was determined by neutral normal acetate method (Amma, 1989).

3.4.9 Biological studies

The count of bacteria, actinomycetes and fungi in soil samples before and after the experiments were determined by the serial dilution plate method (Timonin, 1940).

3.5 ECONOMIC ANALYSIS

3.5. 1 Benefit Cost Ratio (BCR)

The economics of cultivation was worked out considering the total cost of cultivation and prevailing market price of the produce and benefit cost ratio is calculated as follows

$$BCR = \frac{\text{Net Income}}{\text{Total cost of cultivation}}$$

3.6 STATISTICAL ANALYSIS

The data generated, for the characters studied under different treatments were subjected to analysis of variance (Panse and Sukhatme ,1985). Where ever the results were significant, the critical differences were worked out at five or one per cent probability

RESULTS

4. RESULTS

The productivity of rice can be maintained only through a balanced nutrient application. Integrated Nutrient Management, by the judicious mixing of organic and inorganic nutrients is the only way to sustain the productivity in intensive rice- rice sequential cropping. INM which involves the use of chemical fertilizers in conjunction with organic sources (FYM, crop residues, green manure etc), which are complementary and supplementary to each other.

An experiment was carried out at CSRC, Karamana during the *kharif* and *rabi* seasons from June 2004 to March 2005. The objective of study is to find out the effect of INM in rice sequential cropping system on the physical, chemical and biological properties of soil, productivity of rice, and soil health. The results of the experiment are presented below.

4.1 Growth characters

4.1.1 Plant height

The data on plant height recorded at different growth stages are presented on Table 4.1. The statistical analysis of the data revealed that the treatments varied significantly in *kharif* during the active tillering and panicle initiation stages while there was no significant variation among the treatments at harvest. In the *rabi* season, the treatments varied significantly during active tillering stage but showed no variation during panicle initiation and at harvest.

In *kharif* during the active tillering stage the maximum height (56.77cm) was recorded in T7 followed by T6 (55.10 cm) and T11 (54.65 cm). T7 was on par with T6, T11, T9 and T6 while T3 was on par with T12, T8 and T10. During the panicle initiation stage in *kharif*, the maximum height was recorded by T 7 (76.05cm) followed by T6 (74.08cm). The treatments showed significant variation among themselves and T7, T6, T11 and T9 were on par with each other. During harvest stage the treatments showed no significant variations among themselves.

Table 4.1 Effect of treatments on height of the plants at different growth stages (cm)

Treatments	*Kharif*			*Rabi*		
	Active tillering	Panicle initiation	Harvest	Active tillering	Panicle initiation	Harvest
T1	44.75	62.33	89.40	40.70	52.85	84.63
T2	46.95	60.95	92.70	45.75	58.35	82.70
T3	48.85	62.38	93.55	44.68	56. 05	84.30
T4	46.8	65.43	91.10	45.00	61.35	84.30
T5	46.87	64.10	92.85	43.53	57.65	86.10
T6	55.10	74.08	96.45	55.10	68.95	84.30
T7	56.77	76.05	98.20	56.30	69.85	86.90
T8	52.25	69.90	95.05	48.48	61.70	85.80
T9	54.60	67 .10	92.95	50.35	63.70	87.60
T10	52.90	69.83	97.80	53.10	64.55	86.10
T11	54.65	70.33	98.10	49.15	62.05	86.55
T12	50.62	63.78	95.55	44.40	54.85	86.15
F(11,33)	7.0940**	8.3717**	2.0652^{NS}	5.8954*	3.6071^{NS}	2.3991^{NS}
S_{ED}	2.2165	2.3770	2.8084	2.8521	3.9415	1.2794
CD(0.05)	4.2743	4.777	-	5.7327	-	-

* significant at 5% level ** significant at 1% level NS non significant

In *rabi* season, during active tillering phase the maximum height was noted in T7 (56.30cm) followed by T6 (55.10cm). The treatments showed significant variation among themselves only during the active tillering phase. During panicle initiation and harvest stage the treatments were on par with each other.

4.1.2 Number of tillers hill^{-1} at different growth stages

The mean number of tillers hill^{-1} taken at different growth stages during *kharif* and *rabi* are given in Table 4.2. During *kharif* at active tillering stage and at panicle initiation the treatment effects were appreciable. However at harvest there was no significant difference among treatments. From the results it is seen that the plots which received nitrogen from 25 % or 50% substitution of chemicals by organic manures produced more number of tillers hill^{-1} compared to those plots receiving only inorganics during both *kharif* and *rabi* . In *kharif* season during the active tillering stage, T7 recorded the maximum number of tiller count (7.35) while minimum tiller count was by T2 (4.12). During the panicle initiation stage the maximum tiller count was exhibited by T6 followed by T11 and T7 respectively. The minimum tiller count was recorded in T2 plots in both *kharif* and *rabi.* At the harvest of *kharif,* treatments showed no appreciable variation among themselves.

In *rabi* season at the active tillering stage the highest tiller count was recorded in T6 (6.28) followed by T10 while lowest count was observed in T12 (3.45) . During panicle initiation the highest tiller count was in T11 followed by T6 which was on par with T7, T8, T9, T10. During the harvest stage the maximum tiller count was noted in T11 (11.10) followed by T10 and T12 (10.65)

4.1.3 Number of roots hill^{-1}

Number of roots hill^{-1} at different growth stages in both *kharif* and *rabi* seasons were not significant except at active tillering stage during *rabi* season where the maximum root number was seen in plots receiving T6.

Table 4.2 Effect of treatments on the number of tillers hill^{-1} at different growth stages

Treatments	*Kharif*			*Rabi*		
	Active tillering	Panicle initiation	Harvest	Active tillering	Panicle initiation	Harvest
T1	4.55	6.35	10.05	4.18	6.30	10.00
T2	4.12	8.15	11.30	4.30	7.43	10.05
T3	5.00	10.05	10.45	4.10	9.40	9.70
T4	4.70	10.75	10.70	4.35	10.60	9.25
T5	4.75	9.42	11.80	4.00	9.18	9.95
T6	6.60	11.95	11.15	6.28	10.85	9.45
T7	7.35	11.48	11.50	5.23	10.60	10.15
T8	6.03	11.08	11.40	5.05	10.35	10.20
T9	6.73	11.03	11.25	5.13	10.55	9.60
T10	6.73	10.75	11.80	5.40	10.08	10.65
T11	6.25	11.78	10.90	4.75	10.95	11.10
T12	5.45	10.33	11.15	3.45	9.68	10.65
$F_{(11,33)}$	6.5853**	4.9279**	0.4669^{NS}	3.9647**	6.5511**	1.4992*
S_{ED}	0.5595	1.0316	1.0840	0.5468	0.7968	0.6187
CD(0.05)	1.1245	2.0735	-	1.0990	1.6016	1.2436

* significant at 5% level ** significant at 1% level NS non significant

Table 4.3 Effect of treatments on number of roots hill^{-1} at different growth stages

Treatments	*Kharif*			*Rabi*		
	Active tillering	Panicle initiation	Harvest	Active tillering	Panicle initiation	Harvest
T1	78.75	106.25	170.00	70.00	100.00	158.25
T2	83.75	113.75	187.50	80.50	116.25	174.75
T3	93.75	108.00	178.25	90.75	110.00	171.50
T4	121.25	149.50	205.00	113.75	146.25	195.25
T5	135.32	169.80	235.47	133.50	159.25	228.32
T6	157.75	219.75	287.50	155.75	184.50	270.75
T7	156.25	215.75	264.00	153.25	206.25	260.00
T8	154.75	182.75	254.50	149.00	176.75	252.50
T9	152.25	197.25	240.25	150.25	180.75	237.50
T10	153.25	181.25	253.17	145.25	175.00	239.50
T11	143.75	179.00	217.50	133.25	170.50	227.75
T12	86.25	130.00	211.25	83.25	122.50	207.75
F(11,33)	10.7051^{NS}	16.0606^{NS}	2.9100^{NS}	24.9462**	13.5537^{NS}	4.5044^{NS}
S_{ED}	14.5410	15.1882	29.7965	9.12	13.1804	26.7868
CD(0.05)	-	-	-	18.313	-	-

* significant at 5% level ** significant at 1% level NS non significant

Table 4.4 Effect of treatments on panicle length (cm)

Treatments	*Kharif*	*Rabi*
T1	15.75	15.00
T2	18.73	17.80
T3	17.78	17.45
T4	19.48	18.45
T5	18.93	18.20
T6	20.80	19.33
T7	20.56	19.25
T8	21.00	20.38
T9	21.23	20.25
T10	21.35	20.03
T11	20.58	20.15
T12	20.55	19.53
$F(11,33)$	2.2237^{NS}	2.7349*
S_{ED}	1.5947	1.3311
CD(0.05)	-	2.6755

* significant at 5% level NS non significant

4.1.4 Panicle length (cm)

During kharif season the panicle lengths among the different treatments were non significant. It is clear from Table 4.4 that during *rabi* season the maximum panicle length (20.38cm) was noticed in T8 plots which received 50% of recommended dose of NPK through crop residues in *Kharif* and 100% RDF of NPK through fertilizers in *rabi* season. T1 showed the lowest panicle length (15.00cm) and among the treated plots the minimum value was shown by T3 (17.45 cm) which received 50% RDF of NPK through fertilizers in both *kharif* and *rabi.*

4.2 YIELD AND YIELD ATTRIBUTES

4.2.1 Number of productive tillers hill^{-1}

Observation of number of productive tillers hill^{-1} presented on Table 4.5 reveals that no treatment could significantly influence the same in *kharif* season.

However, in *rabi* season the treatments varied significantly and the maximum number of productive tillers were T9 (8.55) in rabi. The second best treatment in *rabi* was control (8.5). The lowest number of productive tillers in *rabi* season was recorded in T7. The number of productive tillers hill^{-1} in *rabi* season was less than the number in *kharif* season for all treatments.

4.2.2 Sterility percentage.

Sterility percentage in both *kharif* and *rabi* season are presented in Table 4.6 .The sterility percentage ranged from 12.03 and 24.4 per cent in *kharif* and from 13.25 to 25 per cent in *rabi* season respectively .

T6 plots recorded the least sterility percentage in both while the control plots recorded the highest percentage. The higher percentage was observed in plots treated with chemical fertilizers alone in both seasons while those treatments that received FYM, crop residues, and green manures in *kharif* seasons recorded significantly lower percentages. T6 was on par with treatments T7, T8 and T9. The trend was similar in *rabi* season also.

Table 4.5 Effects of treatments on Sterility percent, Test weight and number of productive tillers hill^{-1}

Treatments	*Kharif*			*Rabi*		
	Number of productive tillers hill^{-1}	Test weight (g)	Sterility percent	Number of productive tillers hill^{-1}	Test weight (g)	Sterility percent
T1	8.55	26.76	24.40	8.50	26.96	25.00
T2	9.70	26.98	20.25	8.40	26.25	21.05
T3	8.80	27.30	22.98	7.65	26.69	24.30
T4	8.90	28.64	22.00	7.65	28.95	22.13
T5	10.00	27.57	22.20	7.45	28.42	22.55
T6	9.50	30.88	12.03	8.20	30.49	13.25
T7	9.85	30.84	14.10	7.20	30.18	15.65
T8	9.25	30.59	13.62	7.85	30.29	15.20
T9	9.15	29.98	13.75	8.55	29.37	15.05
T10	10.50	29.76	18.30	7.70	29.96	19.25
T11	10.30	28.06	17.37	8.45	27.27	18.07
T12	9.35	27.86	21.23	7.70	28.56	22.58
$F_{(11,33)}$	1.0270^{NS}	3.1128*	11.9197**	1.8188**	4.5870**	10.7397**
S_{ED}	0.8426	1.2492	1.7474	0.4913	0.9975	1.8003
CD(0.05)	-	2.5110	3.5123	0.9876	2.0050	3.6187

*significant at 5% level ** significant at 1% level NS non significant

4.2.3 Test weight

Thousand grain weight (Test weight) recorded from different treatments are presented in Table 4.5. The results indicated that all the treated plots recorded a significant increase in thousand grain weight in *rabi* season. However in *kharif* season it was not profoundly influenced by the treatments. In rabi season the highest thousand grain weight was recorded in T6 (30.49) and T6, T7 ,T8 , T9and T10 were on par with each other.

4.2.4 Grain yield

The influence of treatments on grain yield are abridged in Table 4.6. In *kharif* the maximum yield was received in T6 (5320.87 kg ha^{-1}) followed by T8 (5020.78 kg ha^{-1}). T8 , T7,T10 and T9 were found on par in *kharif* season among the treatments where organic manures are used along with NPK fertilizers . The lowest grain yield was recorded in control. (2582.52kg ha^{-1}). T5 was on par with T12 and T4.

In *rabi* season the maximum yield was recorded in T9 plots (4185.02 kg ha^{-1}). T9, T8 T6, T10 ad T7 were on par with one another in which FYM, crop residues and green manures were applied in 25% and 50% substitution for nitrogen along with chemical fertilizers in *kharif.* The lowest grain yield was recorded in control. (2210.98 kg ha^{-1}).

4.2.5 Straw yield

The data presented in Table 4.6. Indicated that straw yields were influenced by the treatments appreciably. In *kharif* season, T8 (6817.00 $kgha^{-1}$) showed maximum straw yield followed by T7 (6372.64 $kgha^{-1}$). Among the treatments in which organic manures are included in *kharif* season , T7 ,T6 , T9, T11 andT10 were on par .

In *rabi* season T9 gave the maximum straw yield (5714.77 $kgha^{-1}$) followed by T8 (5547.5 $kgha^{-1}$) .Among the treatments receive only chemical fertilizers in both *kharif* and *rabi* T4 ,T5 and T3 were on par . All the treatments

Table 4.6 Effect of treatments on productivity of rice crop in rice – rice sequential cropping system (kg ha^{-1})

Treatments	Grain yield (kgha^{-1})			StrawYield (kgha^{-1})		
	Kharif	*Rabi*	System productivity (kgha^{-1})	*Kharif*	*Rabi*	System productivity (kgha^{-1})
T1	2582.52	2210.98	4793.51	3177.96	3765.56	6943.54
T2	3459.72	3111.76	6571.48	3930.64	4873.62	8804.33
T3	3666.75	3425.38	7092.13	4599.69	5165.05	9764.74
T4	3945.92	3366.14	7312.06	4293.04	5507.71	9802.40
T5	4075.77	3610.06	7685.83	4585.75	5193.91	9779.66
T6	5320.87	4028.21	9349.03	5449.93	6296.17	11746.10
T7	4869.29	3909.74	8779.03	5449.93	6372.64	11808.80
T8	5052.78	4150.18	9170.95	5547.50	6817.00	12364.51
T9	4789.94	4185.02	8974.96	5714.77	6290.40	12005.17
T10	4818.79	3955.03	8773.83	5436.00	6153.34	11589.33
T11	4638.45	3819.14	8457.96	5505.69	6263.76	11774.44
T12	4299.40	3346.97	7646.37	5380.25	5763.79	11141.04
F(11,33)	54.0574**	44.1399**	92.33**	26.0041**	24.0835**	94.5889**
S_{ED}	150.5746	118.6005	194.64	221.4606	252.093	236.54
CD(0.05)	302.6549	238.3871	391.3219	445.1359	492.058	475.4524

* significant at 5% level ** significant at 1% level NS non significant

which received organics in *kharif* showed no remarkable difference among themselves .Higher straw yields in both *kharif* and *rabi* revealed the superiority of organic manures in combination with chemical fertilizers over the supply of inorganics alone in enhancing the yield.

4.2.6 System productivity in kharif and Rabi

The significance of substitution of either 50% or 25% substitution of RDF with organics along with inorganics in kharif and rabi in enhancing the system productivity is revealed in Table 4.6.

In the case of grain yield maximum system productivity (9349.08 kgha^{-1}) was noticed in T6 and was on par with T8, T9, T7 and T10 all of which had its 50% or 25% of the RDF substituted with FYM, crop residues or green manures in *kharif* and 75 % or 100% of RDF of NPK through inorganic fertilizers. The minimum system productivity was observed T1 (4793.35kgha^{-1}).

The maximum system productivity in straw yield was recorded in T8 (12364.51 kgha^{-1}) and was on par with T9, T7, T11 and T6. The minimum was recorded in T1 again (6943.52kgha^{-1}) .In all the treatments in which system productivity exceeds 11t ha^{-1} per annum a part of the RDF were replaced by organics.

4.3 PLANT NUTRIENT CONTENT

4.3.1 Total Nitrogen content

The data on total N content given in Table 4.7 and 4.8 showed significant variation among the treatments at crop stages in both *kharif* and *rabi* seasons.

During the *kharif* season, at maximum tillering stage the highest N content was obtained in T5 (1.70%) followed by T11(1.58%). However the minimum N content (1.31%) was reported in T2. At panicle initiation the maximum value was observed in T5 (1.14%) and here the minimum value (0.93%) was recorded in T7.

During the *rabi* season the maximum value for N content (1.94%) at active tillering stage was in T4 while the minimum (1.27%) in T9 .At panicle initiation stage T5 and T9 showed the maximum N content (1.40%) while the minimum (1.12%) in T2.

Table 4.7 Effect of treatments on Nitrogen content at active tillering and panicle initiation in *kharif* and *rabi* (%)

Treatments	*Kharif* (%)		*Rabi* (%)	
	Active tillering	Panicle initiation	Active tillering	Panicle initiation
T1	0.84	1.08	0.96	1.05
T2	1.31	1.24	1.53	1.12
T3	1.48	1.17	1.62	1.32
T4	1.60	1.01	1.94	1.20
T5	1.70	1.14	1.62	1.40
T6	1.38	1.01	1.48	1.26
T7	1.31	0.93	1.42	1.17
T8	1.44	0.94	1.39	1.16
T9	1.38	1.01	1.27	1.40
T10	1.26	1.07	1.37	1.19
T11	1.58	1.07	1.57	1.24
T12	1.48	1.09	1.44	1.18
$F_{(11,22)}$	12.9816**	4.9447**	23.3365**	11.1859**
S_{ED}	0.0860	0.0578	0.0685	0.0444
CD(0.05)	0.1729	0.1162	0.1377	0.0892

** significant at 1% level

Table 4.8 Effect of treatments on nitrogen content at harvest in *kharif* and *rabi* (%)

Treatments	*Kharif* (%)		*Rabi* (%)	
	Grain	Straw	Grain	Straw
T1	1.18	0.46	0.99	0.43
T2	1.24	0.46	1.07	0.44
T3	1.27	0.43	1.21	0.44
T4	1.26	0.49	1.18	0.49
T5	1.22	0.56	1.16	0.52
T6	1.28	0.56	1.32	0.50
T7	1.21	0.52	1.35	0.50
T8	1.27	0.50	1.26	0.48
T9	1.29	0.50	1.22	0.50
T10	1.24	0.51	1.28	0.46
T11	1.24	0.50	1.13	0.56
T12	1.24	0.53	1.13	0.39
F(11,22)	1.2584**	0.6987**	53530**	1.4395**
S_{ED}	0.0406	0.0663	0.0637	0.0545
CD(0.05)	0.0817	0.1332	0.1280	0.1094

** significant at 1% level

Table 4.9 Effect of treatments on Phosphorus content at active tillering and panicle initiation in *kharif* and *rabi* (%)

Treatments	*Kharif* (%)		*Rabi* (%)	
	Active tillering	Panicle initiation	Active tillering	Panicle initiation
T1	0.16	0.14	0.11	0.08
T2	0.21	0.16	0.17	0.10
T3	0.20	0.19	0.19	0.14
T4	0.15	0.19	0.16	0.14
T5	0. 18	0.18	0.18	0.13
T6	0.19	0.16	0.15	0.11
T7	0.18	0.14	0.14	0.11
T8	0.18	0.16	0.14	0.09
T9	0.20	0.18	0.16	0.09
T10	0.20	0.17	0.17	0.10
T11	0.19	0.16	0.17	0.13
T12	0.21	0.15	0.16	0.12
F(11,22)	1.4626**	1.3737**	4.8978**	4.04**
S_{ED}	0.0221	0.0232	0.0133	0.0128
CD(0.05)	0.0445	0.0467	0.0268	0.0258

** significant at 1% level

4.10 Effect of treatments on phosphorus content at harvest in *kharif* and *rabi* (%)

Treatments	*Kharif* (%)		*Rabi* (%)	
	Grain	Straw	Grain	Straw
T1	0.18	0.09	0.13	0.09
T2	0.16	0.10	0.15	0.11
T3	0.16	0.08	0.15	0.09
T4	0.18	0.10	0.14	0.09
T5	0.19	0.10	0.13	0.09
T6	0.14	0.09	0.15	0.09
T7	0.18	0.09	0.15	0.08
T8	0.15	0.09	0.15	0.09
T9	0.19	0.09	0.15	0.07
T10	0.18	0.09	0.18	0.09
T11	0.17	0.09	0.14	0.09
T12	0.18	0.09	0.14	0.07
F(11,22)	1.2435**	0.7497**	2.7511**	1.5478**
S_{ED}	0.0204	0.0110	0.0160	0.0878
CD(0.05)	0.0410	0.0221	0.0212	0.0237

** significant at 1% level

At harvest stage (Table 4.8) the treatments varied profoundly. The grain N content in *kharif* was maximum (1.29%) in T9 followed by T6 (1.28%). However in straw N content, the highest value (0.56%) was in T5 along with T6. The N content in grains during *rabi* harvest stage was highest in T7 (1.35%) and the minimum in T2 (1.07 %) among the treated plots. In straw N content was the highest in T11 (0.56%).

4.3.2 Phosphorus content

The data on total P_2O_5 content given in Table 4.9 and 4.10 at different crop stages in kharif and *rabi* seasons, showed remarkable variation among the treated plots.

During the kharif season, the maximum value (0.21%) was obtained in T2 and T12 (Farmers practice) at active tillering stage and the minimum in T4 (0.15%) and control. At panicle initiation stage maximum P_2O_5 content was noticed in T3 and T4 (0.19%) and the minimum in T6 and control (0.14 %).

During the rabi season, highest P2O5 content (0.18%) during the active tillering stage was obtained in T5 and the lowest in T1 (0.11%). At the panicle initiation stage the maximum value (0.14%) in T3 and T4 and 0.09% is the minimum in T8 and T9.

At the harvest stage in *kharif* the maximum grain P_2O_5 content was noticed in T5 and T9 (0.19%) and the lowest value was noticed in T6 (0.14%) .In the case of straw highest grain P_2O_5 content was obtained in T2, T4and T5 (0.10%) and the lowest in T3 (0.08%) in . During the harvest in *rabi* the highest P_2O_5 content in grains was observed in T10 (0.18%) and the minimum in T1 and T5 (0.13%).The *rabi* straw P_2O_5 content was the highest in T2 (0.11%).and minimum in T9 and T12 (0.07%).

4.3.3 Potassium content

The data on total K_2O content given in Table 4.11 and 4.12 at different crop stages in both *kharif* and *rabi* seasons, showed appreciable variation among the treated plots.

Table 4.11 Effect of treatments on Potassium content at active tillering and panicle initiation in *kharif* and *rabi*(%)

Treatments	*Kharif* (%)		*Rabi* (%)	
	Active tillering	Panicle initiation	Active tillering	Panicle initiation
T1	1.56	0.76	1.68	0.81
T2	2.08	1.20	2.03	1.25
T3	2.01	1.31	2.07	1.36
T4	2.03	1.50	1.92	1.54
T5	2.14	1.40	2.16	1.57
T6	2.18	1.24	2.27	1.45
T7	2.18	1.23	1.97	1.38
T8	2.13	1.31	2.17	1.47
T9	2.17	1.36	2.34	1.59
T10	2.15	1.53	2.26	1.64
T11	2.11	1.70	2.26	1.75
T12	2.06	1.62	2.16	1.71
F(11,22)	61.4807**	10.6673**	12.9626**	10.6526**
S_{ED}	0.0590	0.1059	0.115	0.1093
CD(0.05)	0.1185	0.2128	0.2021	0.2197

** significant at 1% level

4.12 Effect of treatments on Potassium content at harvest in *kharif* and *rabi* (%)

Treatments	*Kharif* (%)		*Rabi* (%)	
	Grain	Straw	Grain	Straw
T1	0.25	1.88	0.26	1.79
T2	0.20	2.31	0.20	2.25
T3	0.21	2.41	0.20	2.10
T4	0.22	1.86	0.20	2.06
T5	0.25	2.41	0.25	2.28
T6	0.24	2.02	0.29	2.07
T7	0.22	2.41	0.25	2.11
T8	0.25	2.25	0.24	2.12
T9	0.20	2.26	0.20	2.23
T10	0.32	2.33	0.34	2.29
T11	0.25	2.20	0.25	2.53
T12	0.23	2.30	0.27	2.21
F(11,22)	5.4127**	4.0746**	4.6921**	1.4522**
S_{ED}	0.0198	0.1363	0.0271	0.2084
CD(0.05)	0.0397	0.2740	0.0544	0.4189

** significant at 1% level

During *kharif* at the active tillering stage the highest value (2.18%) was noticed in T5 and T6 and the minimum (1.56%) in T1. At the panicle initiation stage the maximum K_2O content (1.70%) obtained in T11 and minimum value noticed in T1 (0.76%)..

During the *rabi* season , at the active tillering stage T9 showed the maximum K_2O content (2.34%) and the minimum value 1.68% in the control plots . While during the panicle initiation stage the highest K_2O content (1.75%) was noted in T11 and the minimum 0.85 % in T1.

During *kharif* at the harvest stage the highest grain K_2O content was noticed in T10(0.32%) and the minimum in T9 and the minimum (0.20%) in T2 and T9. The highest straw K_2O content was in 2.41% in T7, T5 and T3 and the lowest value 1.86% in T4. During *rabi* the maximum grain K_2O content was noticed in T10 (0.34%) and the minimum (0.20%) by T2,T3 and T4. While the highest straw straw K_2O content was observed in T11(2.53%)and the minimum in control (1.79%).

4.4 UPTAKE OF NUTRIENTS

4.4.1. Uptake of nitrogen

The uptake of nitrogen during *kharif* and *rabi* during active tillering, panicle initiation and harvest, was profoundly influenced by the different treatments as given in Table 4.13 and 4.14.

During the *kharif*, among the treated plots, the minimum uptake (29.59 $kgha^{-1}$) was recorded in T2 and was 47% less than the highest uptake in T6 (43.50 $kgha^{-1}$.) and T6, T7 and T8 were on par with each other. At the panicle initiation stage the maximum N uptake was in T7 (50.04 $kgha^{-1}$.) and it was on par with T6 and T8. The minimum value was recorded in T1 (30.72 $kgha^{-1}$.) and it was 62.89% less than T7. In grains the maximum uptake was obtained in T6 (68.78 $kgha^{-1}$.) and the minimum in T1 (31.77 $kgha^{-1}$). While in straw the maximum uptake was in T8 (39.15 $kgha^{-1}$) and the minimum in 16.33 $kgha^{-1}$in control.

4.13 Effect of treatments on Nitrogen uptake in *kharif* and *rabi* kgha^{-1} at active tillering and panicle initiation

Treatments	*Kharif* kgha^{-1}		*Rabi* kgha^{-1}	
	Active tillering	Panicle initiation	Active tillering	Panicle initiation
T1	17.52	30.72	20.94	32.53
T2	29.59	37.72	35.61	37.78
T3	32.32	36.57	38.63	41.86
T4	35.62	37.64	41.46	48.52
T5	39.36	40.78	45.67	52.01
T6	43.50	49.75	53.11	67.34
T7	42.60	50.04	50.52	63.41
T8	42.54	48.59	49.47	63.21
T9	37.77	43.57	40.85	66.54
T10	34.49	44.22	38.63	53.26
T11	34.51	42.34	37.01	55.01
T12	33.03	38.33	32.93	52.48
$F_{(11,22)}$	22.8299**	16.7442**	46.0901**	84.6335**
S_{ED}	2.1111	2.0405	1.8312	1.7352
CD(0.05)	4.2433	4.1014	3.6807	3.4877

** significant at 1% level

Table 4.14 Effects of treatments on the uptake of nitrogen at harvest in *kharif* and *rabi* ($kgha^{-1}$)

Treatments	*Kharif* $kgha^{-1}$			*Rabi* $kgha^{-1}$		
	Grain	Straw	Total	Grain	Straw	Total
T1	31.77	16.33	49.77	22.03	13.07	35.10
T2	44.32	24.06	67.66	33.52	17.30	50.82
T3	47.05	23.87	69.83	41.52	22.10	61.34
T4	49.45	28.32	76.83	40.40	21.90	62.30
T5	52.52	26.26	80.76	44.37	24.41	67.46
T6	68.78	30.74	103.62	52.48	26.51	78.99
T7	58.94	35.30	92.25	52.68	26.94	79.60
T8	64.15	39.15	97.97	52.70	26.49	79.20
T9	62.13	37.08	93.21	51.03	28.96	80.34
T10	59.89	28.01	91.17	49.69	24.33	74.01
T11	58.95	34.13	90.04	43.34	24.21	67.46
T12	53.43	27.82	84.10	38.43	21.33	59.99
$F_{(11,22)}$	42.49**	7.7254**	18.7863**	46.3953**	13.7222**	81.2792**
S_{ED}	2.1986	3.2813	4.9314	1.9247	1.6952	2.1451
CD(0.05)	4.4192	6.5944	9.9121	3.8686	3.4073	4.3116

** significant at 1% level

Table 4.15 Effect of treatments on Phosphorus uptake at active tillering and panicle initiation in *kharif* and *rabi* kg ha^{-1}

Treatments	*Kharif* kgha^{-1}		*Rabi* kgha^{-1}	
	Active tillering	Panicle initiation	Active tillering	Panicle initiation
T1	2.86	6.32	1.83	3.56
T2	3.72	6.27	2.30	5.69
T3	4.19	5.91	3.28	6.37
T4	4.12	5.63	2.97	6.34
T5	4.10	6.58	3.75	6.54
T6	5.00	9.36	4.15	7.84
T7	4.67	9.43	3.86	7.79
T8	4.66	9.45	3.33	7.68
T9	4.98	8.72	3.03	7.48
T10	4.28	8.31	2.94	7.61
T11	4.22	8.38	2.91	7.77
T12	3.32	7.26	2.66	5.73
$F_{(11,22)}$	2.5446**	5.5256**	8.1149**	12.9644**
S_{ED}	0.5671	0.8796	0.3255	0.5038
CD(0.05)	1.1399	1.7679	0.6543	1.0126

** significant at 1% level

Table 4.16 Effect of treatments on Phosphorus uptake at harvest in *kharif* and *rabi* kgha^{-1}

Treatments	*Kharif* kg ha^{-1}			*Rabi* kg ha^{-1}		
	Grain	Straw	Total	Grain	Straw	Total
T1	4.96	3.34	8.29	2.99	2.79	5.77
T2	5.96	4.93	10.64	4.60	4.44	9.03
T3	5.99	4.41	10.40	4.72	3.83	8.76
T4	7.42	5.79	13.21	4.87	3.82	8.69
T5	7.77	5.11	12.88	4.85	4.44	9.29
T6	7.56	5.35	12.91	5.97	4.87	10.84
T7	8.75	5.60	14.35	5.84	4.24	10.41
T8	8.34	6.13	13.47	6.03	4.91	10.95
T9	9.20	5.86	15.06	6.33	4.19	10.52
T10	8.55	5.44	13.99	7.05	4.66	11.71
T11	7.95	5.81	13.78	5.18	4.38	9.63
T12	7.57	4.95	12.49	4.66	3.36	8.53
F(11,22)	2.7960**	4.1371**	4.4393**	11.0747**	3.3207**	9.0640**
S_{ED}	1.0993	0.5335	1.2948	0.4498	0.4510	0.7361
CD(0.05)	0.0096	1.0723	2.6026	0.9040	0.9064	1.4795

** significant at 1% level

During the active tillering stage in *rabi*, highest uptake among the treated plots was recorded in T6 (53.11 kgha^{-1}.) and it was on par with T7 and T8. The minimum value (20.94%) was in T1. At the panicle initiation stage the maximum uptake was noticed inT6 (67.34 kgha^{-1}.) and the minimum value in T1 (32.53 kgha^{-1}). T6 and T9 are on par so as T7 and T8. At harvest the maximum uptake in grain in *rabi* was in T8 (52.70 kgha^{-1}) closely followed by 52.68 kgha^{-1}in T7 and the minimum in T1.(22.03 kgha^{-1}.). N uptake in straw was highest in T9 (28.96 kgha^{-1}), while minimum uptake among treated plots was in T1 (13.07 kgha^{-1}).

4.4.2 Uptake of Phosphorus

The data on the uptake of phosphorus in *kharif* and *rabi* seasons are shown in Tables 4.15 and 4.16 and it influenced by treatments remarkably.

During *kharif*, at the active tillering stage the maximum uptake was noticed in T7 (5.00 kgha^{-1}.) and minimum in T1 (2.86). At the panicle initiation stage, T8 showed the maximum uptake (9.45 kgha^{-1}.), which was closely followed by T7 (9.43 kgha^{-1}.) minimum value 5.63 kgha^{-1}.in T2. After the harvest of the *kharif* crop, in grains T9 shows the maximum uptake (9.20kgha^{-1}.) and it was 85.48 % higher than the minimum value 4.96 kg ha^{-1}.in T1. While the uptake in straw revealed that the maximum P uptake was in T8 (6.13 kgha^{-1}) and minimum in T1 (3.34 kgha^{-1}).

During the *rabi* season, among the treated plots, at the time of active tillering the maximum uptake was in T6 (4.15 kgha^{-1}) and the lowest (1.83 kgha^{-1}) in T1. While at panicle initiation, T6 showed the maximum uptake (7.84 kgha^{-1}) and T1 (3.56 kgha^{-1}) the minimum. In *rabi* grain phosphorus uptake was maximum inT10 (7.05 kgha^{-1}) and the minimum uptake value was 2.99 kgha^{-1} in T1. Regarding the straw phosphorus uptake in *rabi* seasons, it was highest for T9 (4.91 kgha-1) and minimum for T1 (2.79 kgha^{-1}).

Table 4.17 Effect of treatments on potassium uptake during active tillering and panicle initiation in *kharif* and *rabi* kg ha^{-1}

Treatments	*Kharif* kg ha^{-1}		*Rabi* kg ha^{-1}	
	Active tillering	Panicle initiation	Active tillering	Panicle initiation
T1	16.82	47.36	16.52	83.50
T2	28.00	73.71	28.10	88.71
T3	29.77	80.63	31.01	86.25
T4	34.25	80.82	31.94	86.25
T5	36.35	80.39	39.35	86.19
T6	45.66	106.90	44.54	112.18
T7	44.66	105.48	44.00	117.87
T8	43.50	99.34	46.42	127.18
T9	43.88	100.37	43.83	128.14
T10	42.29	100.81	42.90	113.78
T11	38.65	97.20	40.28	120.23
T12	37.87	93.66	36.91	113.74
$F_{(11,22)}$	23.0310**	31.5219**	19.9446**	187.6905**
S_{ED}	2.5174	4.3197	2.7874	2.4513
CD(0.05)	5.0599	8.6826	5.6026	4.9272

** significant at 1% level

Table 4.18 Effect of treatments on Potassium uptake during harvest in *kharif* and *rabi* kg ha^{-1}

Treatments	*Kharif* kg ha^{-1}			*Rabi* kg ha^{-1}		
	Grain	Straw	Total	Grain	Straw	Total
T1	7.41	73.44	80.85	5.88	57.01	62.89
T2	7.05	116.72	123.77	6.09	87.60	93.69
T3	7.76	126.34	134.09	6.85	97.21	104.06
T4	8.83	103.31	112.14	6.95	88.68	95.62
T5	10.37	121.57	131.94	9.14	106.08	115.22
T6	12.72	121.16	137.88	11.41	112.65	124.06
T7	10.59	153.13	163.71	9.81	114.45	124.26
T8	12.35	152.99	165.34	10.25	118.81	129.06
T9	9.42	140.88	150.30	8.38	126.86	135.24
T10	15.34	143.47	158.81	13.08	122.43	135.51
T11	11.86	137.68	149.54	9.75	117.45	127.20
T12	9.97	133.91	143.88	8.96	114.84	123.81
F(11,22)	19.4164**	9.211 NS	10.1599 NS	12.8989**	253.8733**	373.1214**
S_{ED}	0.7887	10.4670	10.6592	0.8606	1.7557	1.5732
CD(0.05)	1.5853	-	-	1.7297	4.7054	3.1622

* significant at 5% level ** significant at 1% level NS non significant

4.4.3 Uptake of Potassium

The data on the uptake of potassium in *kharif* and *rabi* seasons shown in Table 4.17 and 4.18 was influenced by treatments significantly.

During the *kharif* season at the active tillering stage among the treated plots the minimum uptake (16.82 kgha^{-1}) was obtained in T1 and maximum in T6 (45.66 kgha^{-1}.) which was on par with the uptake values in all the organic manure treated plots. During the panicle initiation stage, T6 (106.90 kgha^{-1}) have the maximum uptake value and T1 (47.36 kgha^{-1}) showed the minimum. T6 was on par withT7, T10, T9 and T8. Analysis of the plant samples after harvest suggested that maximum uptake in grains was recorded in T10 (15.34 kgha^{-1}) and the minimum uptake in T2 (7.05 kgha^{-1}). Regarding the K uptake in straw maximum (153.13 kgha^{-1}.) was obtained in T7 and minimum in T4 (103.31 kgha^{-1}) though the treatments do not varied significantly.

In *rabi* season, at the active tillering stage, the maximum uptake was in T8 (46.42 kgha^{-1}) which was on par with T6, T7, T9 and T10. The minimum uptake (16.52 kgha^{-1}) was by T1. While during the panicle initiation stage the highest uptake was in T9 (128.14 kgha^{-1}), which was on par with T8 and among the treated plots the minimum, was in T2 (83.50 kgha^{-1}). Analysis of plant samples after the harvest revealed that maximum K uptake in grains was in T10 (13.10 kgha^{-1}) and minimum was in T1 (5.88 kgha^{-1}) .In the case of K uptake in straw , T9 (126.86 kgha^{-1}) recorded the maximum , while T1 recorded the minimum (57.01 kgha-1) .

4.5 Available Nutrients

4.5. 1 Available nitrogen

Available N status in *kharif* and *rabi* crops are presented in Table 4.19 . The results showed no remarkable variation among the treatments in the initial soil samples.

The analysis of soil test data after *kharif* showed maximum value for T9 receiving 25% of RDF through FYM during *kharif* and 75% of RDF of NPK in *rabi* season (265.38 kgha^{-1}). The control plots recorded lower values 168.20 kgha^{-1}and found inferior to treated plots.

4.19 Effects of treatments on soil available N, P_2O_5 and K_2O ($kgha^{-1}$)

Treatments	Before *Kharif*			After *Kharif*			After *Rabi*		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
T1	199.08	12.31	103.27	168.20	12.58	90.06	194.69	13.11	106.36
T2	203.75	13.63	100.39	183.07	13.08	107.86	207.68	14.55	101.05
T3	215.05	13.74	113.16	192.56	15.07	95.56	224.29	13.24	113.83
T4	222.23	14.09	101.29	215.25	14.86	101.88	223.50	14.00	109.69
T5	235.90	15.72	117.08	250.36	15.25	94.06	265.72	15.73	118.89
T6	268.83	15.08	133.09	255.9	16.11	117.88	264.54	15.95	135.43
T7	262.91	15.01	129.79	264.24	17.01	110.09	256.32	13.64	129.87
T8	260.84	13.86	127.16	253.35	13.67	127.61	261.27	15.71	126.57
T9	268.23	13.74	132.87	265.38	16.07	119.30	256.49	13.40	128.44
T10	262.89	14.69	132.77	261.94	15.82	120.96	272.36	15.69	132.20
T11	250.27	14.55	135.52	250.46	14.52	114.37	254.39	13.81	135.16
T12	243.84	8.30	112.37	247.86	13.96	105.16	242.49	12.87	114.18
$F_{(11,22)}$	7.5279^{NS}	1.6279^{NS}	5.8853^{NS}	48.4961**	0.9442^{NS}	4.0395^{NS}	19.1391**	0.8579^{NS}	3.7260^{NS}
S_{ED}	13.15	2.1313	7.8934	7.0437	1.9366	8.3070	8.1391	1.7783	8.6748
CD(0.05)	-	-	-	14.1578	-	-	16.3246	-	-

** significant at 1% level NS non significant

The analysis of soil samples after *rabi* season revealed that T10which received showed maximum value (272.36 $kgha^{-1}$). Second best treatment was for T5 (265.72 $kgha^{-1}$). The minimum value was in T2 plot which received 50% RDF of NPK through chemical fertilizers among the treated plots.

4.5.2 Available Phosphorus.

Soil analysis and interpretation of the data collected (Table 4.19) revealed that the available Phosphorus in kharif and *rabi* showed no significant variation among the treatments. Though statistically insignificant, the highest value for available phosphorus before *kharif* was recorded in T5 (15.08 $kgha^{-1}$) and the lowest value in T12 (8.30 kgha-1). After *kharif*, T7 recorded the maximum value (17.01$kgha^{-1}$) and the minimum in T2 (13.02 $kgha^{-1}$) among the treated plots. While after rabi , the maximum available Phosphorus was noted in T6 (15.95 $kgha^{-1}$) and minimum in T12 (12.87 $kgha^{-1}$) among the treated plots.

4.5.3 Available K_2O

The data pertaining to the available K_2O content of soil before the experiment and at harvest are presented in Table 4.19.Though the treatments showed no significant variation among themselves, available K_2O content of soil before the *kharif* crop recorded the maximum value (133.09 $kgha^{-1}$). Minimum being recorded in T2 (100.39 kg ha^{-1}) .The available K_2O status in all the plots before *rabi* season were not significant. The maximum value was exhibited by T8 (127.61 $kgha^{-1}$). Analysis of post harvest samples of *rabi* crops indicated that the treatments showed no significant variation among themselves.

4.5.4 Available Sulphur

Analysis of available S is given in Table 4.20 and the maximum value for available S was noticed in T9 (8.42 $kgha^{-1}$), which was on par with T5 (7.70 $kgha^{-1}$) and T8 (7.29 $kgha^{-1}$). Control plot showed minimum value i.e., 2.05 $kgha^{-1}$. Among the treated plots lower values were given by T7 (3.51 kgha-1) and T4 (3.79$kgha^{-1}$).

Table 4.20 Effect of treatments on soil available Zinc and Sulphur ($kgha^{-1}$)

Treatments	Before *kharif*		After *kharif*		After *rabi*	
	Zinc	Sulphur	Zinc	Sulphur	Zinc	Sulphur
T1	0.215	2.05	0.256	1.54	0.276	1.38
T2	0.318	4.13	0.306	4.78	0.283	3.64
T3	0.376	5.36	0.311	4.75	0.359	3.40
T4	0.254	3.79	0.295	6.87	0.272	4.04
T5	0.371	7.70	0.322	3.40	0.295	7.52
T6	0.352	6.64	0.466	4.25	0.384	5.42
T7	0.364	3.51	0.356	4.06	0.463	3.74
T8	0.293	7.29	0.314	4.98	0.298	5.33
T9	0.463	8.42	0.352	5.61	0.368	8.17
T10	0.277	4.73	0.329	4.53	0.299	5.07
T11	0.292	4.76	0.462	4.09	0.297	5.35
T12	0.289	4.73	0.332	6.15	0.275	4.44
$F(11,22)$	1.8456**	9.2557**	4.4009**	5.3574**	2.3314**	15.2806**
S_{ED}	0.0693	0.8815	0.0424	0.8294	0.0546	0.6601
CD(0.05)	0.1393	1.7719	0.0851	1.6670	0.1098	1.3268

** significant at 1% level

The available sulphur status after *kharif* season revealed that the minimum values for available S after *kharif* was exhibited by T5 (3.40 $kgha^{-1}$). The highest value for available S was shown by T4, which receive 75% of RDF of fertilizers through inorganics in both *kharif* and *rabi*. This was on par with T12 i.e. farmers practice which was supplied with 3t FYM ha^{-1} i.e. 30 kg $plot^{-1}$ in *kharif* along with inorganics in both *kharif* and *rabi*.

Available S status after *rabi* season, emphasized the advantage of organics treated plots against plots treated by inorganics only. The maximum value (8.17 $kgha^{-1}$) for available S was noted in T9 plots. The second best treatment was for T5 (7.52 $kgha^{-1}$). The minimum value was observed in T1 (1.38 $kgha^{-1}$).

4.5.5 Available zinc

The data pertaining to the available zinc in soil, given in Table 4.20 before *kharif* crop showed highly significant variation among the treatments. The maximum value for available zinc was noted in T9 (0.463 kg ha^{-1}). The second best treatment values were for T3 (0.376 $kgha^{-1}$) and T5 (0.375 $kgha^{-1}$.They were closely followed by T7 (0.365 $kgha^{-1}$) and T6 (0.352 $kgha^{-1}$).

After the harvest of *kharif* crop, before *rabi,* the maximum value for available zinc was exhibited by T6 (0.466$kgha^{-1}$). . The second best treatment (0.462 $kgha^{-1}$) was for T11 plots which received 25% of recommended NPK through green manure in kharif and 75% of RDF of NPK through fertilizers. The inorganics treated plots showed lower values for available zinc compared with those plots, which received both organics and inorganics. The minimum value for available zinc among was exhibited by T1.

Analysis of post harvest soil samples of *rabi* the maximum values for available zinc was shown by plots with T7 (0.463 $kgha^{-1}$) .T6 plots showed the second best available zinc value ie 0. 384 $kgha^{-1}$ .The minimum value for available zinc was in T4 (0.272 $kgha^{-1}$) closely followed by 0.275 kg ha^{-1}in plots with T12.

4.6 Physical properties

4.6.1 Bulk density

As seen from the Tables 4.21 it is evident that the bulk density of soil (BD)varied significantly among the different treatments during both *rabi* and *kharif* seasons.

Before the start of the experiment the treatments which showed lowest BD (1.17 and 1.18 $Mgcc^{-1}$) values for T6 and T7 and highest BD value for T1 (1.29 $Mgcc^{-1}$). After the harvest of *kharif* crop also the lowest BD was exhibited by T6 (1.13 $Mgcc^{-1}$) and the highest value by T1 (1.26 $Mgcc^{-1}$),T8 , T7 and T9 also showed lower BD values 1.17$Mgcc^{-1}$, 1.18 $Mgcc^{-1}$, and 1.18 $Mgcc^{-1}$ respectively. After *rabi* season T1 plots showed highest BD (1.29). During this time T6, T7, T8 andT9 showed lower BD values 1.15 1.16, 1.15 and 1.19 $Mgcc^{-1}$ which were on par with each other, showing the superiority of INM in improving soil physical properties over the complete use of inorganic chemicals.

4.6.2 Water holding capacity

When the values obtained for water holding capacity (WHC) in the present study were analyzed, from Table 4.21, it was clear that the mean value for various treatments were significantly different. Before the start of the experiment in *kharif* T6 showed maximum WHC 45.80 %. After the harvest of *kharif* crop, the minimum WHC was shown by T5. T7, T8, T10 and T12 showed higher WHC which were on par with each other. After *rabi* season, the lowest water holding capacities were exhibited by T1 (control) and all plots which received inorganic fertilizers only, in *kharif* and *rabi*. While the highest WHC after *rabi* was for T6 (45.49%) showing the superiority of INM in improving soil porosity.

4.7 Soil chemical properties

4.7.1 Soil organic carbon

As detailed in Table 4.22, organic carbon (OC) content for all treated plots, initially, was higher than the untreated plots. The minimum (0.65 %) was

Table 4. 21 Effect of treatments on Soil Physical properties – Bulk density and Water holding Capacity

Treatments	Bulk Density $Mgcc^{-1}$			Water Holding Capacity %		
	Before *Kharif*	After *Kharif*	After *Rabi*	Before *Kharif*	After *Kharif*	After *Rabi*
T1	1.29	1.26	1.29	39.53	41.71	39.97
T2	1.27	1.24	1.26	39.82	42.85	40.32
T3	1.26	1.24	1.23	40.95	41.63	40.43
T4	1.27	1.23	1.24	39.94	41.47	40.85
T5	1.24	1.23	1.23	42.04	40.79	41.12
T6	1.17	1.13	1.15	45.80	43.11	45.49
T7	1.18	1.18	1.16	43.43	44.67	45.37
T8	1.19	1.17	1.15	43.69	44.74	45.15
T9	1.20	1.18	1.18	45.11	46.26	44.91
T10	1.20	1.19	1.20	45.36	44.74	44.40
T11	1.20	1.19	1.21	44.61	44.28	44.56
T12	1.20	1.22	1.19	43.09	44.17	43.76
$F_{(11,22)}$	3.2337**	10.1859**	10.7541**	18.958**	6.7912**	6.3506**
S_{ED}	0.0379	0.0167	0.0195	0.8154	0.9194	1.2678
CD(0.05)	0.0641	0.0335	0.0395	1.6390	1.8481	2.5483

** significant at 1% level

Table 4.22 Effect of treatments on Soil chemical properties-Organic Carbon and Cat ion Exchange Capacity

Treatments	Organic Carbon %			Cation Exchange Capacity Cmols (+) kg^{-1}		
	Before *Kharif*	After *Kharif*	After *Rabi*	Before *Kharif*	After *Kharif*	After *Rabi*
T1	0.65	0.67	0.67	5.95	6.70	6.75
T2	0.69	0.71	0.69	6.50	6.27	5.37
T3	0.70	0.71	0.72	6.80	5.80	6.75
T4	0.68	0.70	0.69	4.83	7.97	6.23
T5	0.70	0.73	0.70	5.45	6.97	6.60
T6	0.72	0.75	0.73	7.95	7.18	7.47
T7	0.77	0.78	0.77	7.05	7.35	7.30
T8	0.77	0.80	0.77	6.28	8.23	7.48
T9	0.78	0.82	0.79	6.95	8.58	8.22
T10	0.78	0.82	0.80	7.78	7.20	6.98
T11	0.77	0.80	0.79	6.33	7.22	7.15
T12	0.71	0.74	0.73	7.73	6.43	7.07
F(11,22)	2.0843**	2.7187**	1.9252**	14.1913**	14.6519**	4.8734**
S_{ED}	0.0436	0.0436	0.0453	0.3562	0.3004	0.4566
CD(0.05)	0.0875	0.0877	0.0911	0.7160	0.6037	0.9178

** Significant at 1% level

recorded in T1. The maximum 0.77% being recorded in T9 and T10 plots. The values did not vary appreciably among the organic manure applied plots. The organic carbon content after *kharif* crop was maximum in T9 and T10 (0.82%) closely followed by T8 and T11 (0.80%). In all the plots treated with organic manures, higher values were observed. The minimum OC value (0.70%) was noticed inT4 among the treated plots. The OC content after *rabi* crop showed increased values in almost all the plots treated with organic substances in *kharif* season .The maximum value shown by T10 (0.80%) and the minimum value(0.67%) for T1.

4.7.2 Cat ion exchange capacity

The data regarding CEC of soil before the experiment and after the harvest are presented in Table 4.22. The values showed significant difference among treatments. Before *kharif* crop the values ranged from 4.83 to 7.95 Cmols(+) kg^{-1}. After *kharif* crop , the values ranged from 5.80 to 8.58 Cmols(+) kg^{-1} and after *rabi* , the range was from 5.37 to 8.22 Cmols(+) kg^{-1}.

The analysis of soils collected before *kharif* clearly revealed the superiority of the treatments, which received 50% of RD of N through FYM. T10, which received 50% of the RD of nitrogen through green manure, also showed higher values for CEC before *kharif* season. T12 (Farmers practice), which obtained FYM in kharif, also showed high CEC values. The lowest value was exhibited by T4 (4.83).

After *kharif* crop, the results revealed the superiority of treatments, which received 50% and 25% of RDF through organic manures. T9, T8 and T4 were on par .The lowest CEC was in T3 (5.80) which received 50% of RDF of NPK through fertilizers in *kharif* and 100% RDF of NPK through fertilizers.

After *rabi,* the minimum value was noted in T2 (5.37), which received 50% RDF of NPK through fertilizers in both *kharif* and *rabi.* Higher CEC values were shown by treatments receiving organic manures during *kharif.* The maximum CEC value showed by T9 (8.22) .This was followed by T8 (7.48) which received 50% of RD of NPK through crop residues during *kharif* and

100% RDF of NPK through chemical fertilizers during *rabi*. They were closely followed by T6 (7.47) and T7 (7.30) which received 50% and 25% RDF of N through FYM during *kharif* and 100% and 50% RDF of chemicals in *rabi*.

4.8 Biological studies

Data on soil biological properties given in Table 4.23 revealed that the soil microbial properties varied remarkably with different treatments, in both *kharif* and *rabi*.

4.8.1 Bacterial count

The biological count was the highest in T9 closely followed by ($29.75*10^6g^{-1}$)T6 and T7 .Among the treated plots the minimum bacterial count ($7.51*10^6g^{-1}$)in control during the start of the experiment.

After *kharif* season the bacterial count showed increased trends, the rise being very evident in organic manure treated plots. The highest bacterial count was noted in T7 ($37.32*10^6g^{-1}$) closely followed by T6 and T8. The minimum count was noticed in T1 ($12.27*10^6g^{-1}$). After *rabi* , the general population count decreased and here also the highest count was noted in T7 ($29.22*10^6g^{-1}$) which was followed by T10 ($28.90*10^6g^{-1}$) . The minimum count was here again noted in T4.

4.8.2 Fungal count

Data on fungal count in *kharif* and *rabi* reveal that the treatments are significantly different. Before *kharif* the maximum fungal count was shown by T6 ($14.29*10^4g^{-1}$) followed by T9 ($4.09*10^4g^{-1}$). The minimum fungal count was noted in T4 ($5.88*10^4g^{-1}$). The plots treated by organic manures like FYM, crop residues, green manure showed enhanced soil fungal and enzymatic activity. After *kharif* season fungal count enhanced highest count ($29.51*10^4g^{-1}$) recorded in T10. The minimum count was noticed in T4 ($11.70*10^4g^{-1}$) among the treated plots. After *rabi* season, the fungal count showed the same trend, the minimum

Table 4.23 Effect of treatments on soil microbial population in *kharif* and *rabi*

Treatments	Before *Kharif*			After *Kharif*			After *Rabi*		
	Bacteria $*10^6 g^{-1}$	Fungi $*10^4 g^{-1}$	actinomycete $*10^8 g^{-1}$	Bacteria $*10^6 g^{-1}$	Fungi $*10^4 g^{-1}$	actinomycete $*10^8 g^{-1}$	Bacteria $*10^6 g^{-1}$	Fungi $*10^4 g^{-1}$	actinomycete $*10^8 g^{-1}$
T1	7.51	7.58	1.80	12.27	12.53	2.30	9.42	7.37	1.60
T2	10.41	6.83	2.87	15.14	13.39	2.73	8.94	10.76	1.20
T3	11.97	11.65	2.67	13.25	14.46	3.70	10.76	10.54	2.47
T4	13.58	5.88	3.03	15.12	11.70	3.26	8.92	10.79	2.47
T5	16.30	12.91	2.93	15.91	15.41	3.70	13.20	13.44	2.76
T6	27.40	14.29	3.87	35.77	25.27	4.30	27.54	21.48	3.20
T7	27.27	12.80	3.13	37.32	23.25	3.53	29.22	23.02	3.43
T8	23.40	11.58	3.56	35.21	23.97	4.33	27.38	21.36	3.07
T9	29.75	14.02	3.06	33.26	25.98	4.17	27.94	24.34	3.10
T10	24.16	13.09	3.30	32.09	29.51	3.87	28.90	25.26	4.00
T11	19.35	13.53	3.37	29.34	26.32	4.33	27.22	23.37	3.5
T12	15.54	13.51	2.97	25.05	23.55	3.30	19.93	18.26	2.80
$F_{(11,22)}$	16.6852**	11.8733**	0.9778^{NS}	22.1189**	13.0851**	1.3288^{NS}	90.1692**	15.6254**	4.2055**
S_{ED}	2.5663	1.2204	0.7536	2.9880	2.5029	0.7947	1.3317	2.3165	0.4456
CD(0.05)	5.1583	2.4530	-	6.0059	5.0308	-	2.6767	4.6561	0.8956

** Significant at 1% level

count was in T1 ($7.37*10^4 g^{-1}$) and the highest fungal activity noticed in T10 ($25.26*10^4 g^{-1}$) and T9 ($24.34*10^4 g^{-1}$).

4.8.3 Actinomycete count

Between the seasons the actinomycete population showed significant variation only after *rabi* among the treatments. During the season before *kharif*, the maximum population count ($3.87*10^8 g^{-1}$) was noted in T6 while minimum in T1 ($1.80*10^8 g^{-1}$) .While after *kharif*, the population count followed the same trend with out much increase in the count of population , the highest count noted in T8 and T11 ($4.33*10^8 g^{-1}$) ,while T1 recorded the minimum value($2.30*10^8 g^{-1}$) . The population count showed enhancement in organic matter treated plots while during post *rabi* season the maximum count was noted in T10 ($4.00*10^8 g^{-1}$) followed by T10 ($3.5*10^8 g^{-1}$).The minimum count was noted inT2 ($1.20*10^8 g^{-1}$)

4.9 Effect of treatments on insect and weed incidence pattern.

4.9.1 Effect on insect

The insect build up of rice stem borer (*Scirpophaga incertulas*) and rice case worm (*Nymphula depunctalis*) noticed during the cropping period.

In the case of case worm attack the treatments showed significant variation among them as revealed by Table 4.24. The lowest case worm incidence recorded in T6 (3.00) and followed by T7 (5.00). Organic manure applied plots in the long term manurial trial clearly show low incidence of case worm attack.

The attack by stem borer was studied by counting the number of white ear heads $plot^{-1}$ by visual observation. The analysis did not provide any significant variation among treatments though it showed that the lowest number of white ear heads $plot^{-1}$ in T5 (100% RDF of NPK through chemical fertilizers in *kharif* and *rabi*.). The maximum incidence noted in T6 and T9 plots (36.25 and 31.25) which receive FYM and crop residues to substitute 50% and 25% of RD of nitrogen in *kharif.*

Table 4.24 Effects of treatments on insects and weeds

Treatments	Insect attack		Weed
	Stem borer incidence Number of white earheads plot^{-1}	Case worm attack Intensity Score (1,3,5,9)	Intensity Score (1,3,5,9)
1	23.70	9.00	9.00
2	20.00	7.50	7.50
3	27.50	9.00	9.00
4	22.50	8.00	8.50
5	13.00	3.00	7.50
6	36.25	5.00	3.50
7	27.50	8.00	6.00
8	23.75	8.50	8.50
9	31.25	7.50	8.50
10	20.00	7.50	7.50
11	25.00	7.50	7.50
12	12.50	8.00	8.00
F(11,33)	3.6914^{NS}	6.5195**	4.5073**
S_{ED}	5.0300	0.9699	1.0225
CD(0.05)	10.1102	1.9494	2.0552

(Ratings : 0% - score 1, 0 to 25% - score 2, 25 to 50% - score 3, 50 to 75% - score 4 ,and 75 to 100% - score 5)

* Significant at 5% level ** significant at 1% level NS non significant

4.9.2 Weed incidence

The treatments show significant variation among themselves in the case of weed incidence studies. As per the Table 4.24 the weed incidence at the time of field visual observation was, the lowest in T6 (3.50) , it was maximum in T1 plots (control). T7 also showed lower incidence of weeds (6.00) compared with other plots. In plots applied with FYM in *kharif* broad leaved weeds like *Ludwigia parviflora, Cloeme* spp, *Commelina benghalensis* etc predominated, while grasses and sedges dominated in crop residues and chemical applied plots. In the post harvest period T6 and T7 show quick establishment of weeds.

4.9.3 Disease incidence

No major diseases noted except a mild attack of bacterial blight. Organics applied plots were affected less severely and the crops showed inherent health and plants show better recovery compared to those plants in plots treated with inorganic chemicals only on a long term basis.

4.10 ECONOMIC ANALYSIS

The data summarized in Table 4.25 revealed that the net income was highest for T9 (Rs 42850.75) followed by T8 (Rs 41259.19). The lowest net income was observed in the control (Rs 19783.10).The highest benefit cost ratio was recorded in T9 (1.34) and the lowest in control T1 (0.95).

Table 4.25 Economics of Cultivation

Treatments	Total Cost Rs ha^{-1}	Total Income Rs ha^{-1}	Net income Rs ha^{-1}	BCR
T1	20715.00	40498.10	19783.10	0.96
T2	25698.00	54804.62	29106.62	1.13
T3	27172.00	59409.64	32237.64	1.19
T4	27359.26	60985.15	33625.89	1.23
T5	28646.00	63580.44	34934.44	1.22
T6	37079.50	77189.68	40110.18	1.08
T7	32775.63	73261.81	40486.18	1.24
T8	35302.00	76561.19	41259.19	1.17
T9	31979.13	74829.87	42850.74	1.34
T10	35262.00	73006.13	37744.13	1.07
T11	34894.63	70977.52	36082.89	1.03
T12	29416.00	64668.61	35252.61	1.20

For Cost and income details, see Appendix 3.

DISCUSSION

5. DISCUSSION

An investigation was carried out at Cropping Systems Research Centre (CSRC), Karamana to find out the effect of long term integrated nutrient management in rice-rice sequential cropping system on growth and yield of rice, soil physico chemical biological properties, insect, and disease and weed incidence. The results obtained are discussed below

5.1 Growth characters

Analysis of the data in Tables 4.1 to 4.4 revealed that the plant height, number of tillers hill^{-1}, number of roots hill^{-1} and the length of panicle in *kharif* and *rabi* are influenced by the recommended levels of recommended dose of fertilizers or its combinations with or without organics and their combined effects varied significantly.

Nitrogen encourages vegetative growth and is an important component of chlorophyll, enzymes, amino acids and proteins (Mehra , 2004) . It was clear from the results that the height of plants increased with increased doses of NPK. It was noticed by Meena *et al.*, (2002) that the height of hybrid rice increased with the successive increments of N levels. Kumari *et al* (2000), Thomas (2000) and Anu (2001) also reported the favourable influence of nitrogen and potassium on plant height . Phosphorus is involved in plant processes like photosynthesis, cell division, tissue development and growth.(Bhattacharya and Jain, 2000). Table 4.1 reveals that T5 showed a drop in plant height during the active tillering and panicle initiation stages in both *kharif* and *rabi* . It can be supported by the findings of Shiv Mangal Prasad *et al* (2001) that increasing fertilizer level from 50-75% of recommended dose caused greater increase in all growth attributes than from 75-100%.

The tiller production was profoundly influenced by the N,P,K treatments at the active tillering and panicle initiation stages during *kharif* and *rabi* as indicated in Table 4.2. Meena *et al* (2002) reported that the number of effective tillershill^{-1} increased significantly with the application of increased K levels up to 75 kg K_2O ha^{-1}. Singh and Singh (2000) also reported a similar enhancement in the tillering in rice due to the increased application of potassium..

It is clear from Table 4.3 that number of roots $hill^{-1}$ is favoured by increased levels of RDF. Root count increased from control to T5 due to enhanced additon of NPK. It was in agreement with Bhan *et al* (1995) that root development increased gradually with the application of N up to $80kgha^{-1}$.

Data given in Table 4.4 revealed that panicle length was significantly influenced by N,P and K fertilizers in *rabi* season. Among the chemical input treatments T2 to T5 were on par and significantly superior to the control. Similar trend was noticed by Meena *et al* (2002).

The growth characters as presented in Tables 4.1 to 4.4 clearly revealed that substitution of a part of RDF through organics exerted profound influence in all growth characters. . Maximum plant height and roots $hill^{-1}$ are reported in T7 and T6 respectively in the crop growth stages studied during *kharif* and rabi which received 50% and 25% RDF from FYM during the beginning of the season. Among the organics FYM and crop residues gave higher tiller count during both *kharif* and *rabi* seasons. While panicle length differed significantly only during the *rabi* seasons. The maximum panicle length was noticed in T8 in which 50% of RDF of nitrogen is supplied by organics in *kharif* and 100% RDF of NPK through chemical fertilizers in *rabi* . It has been clearly elucidated that from long term experiments, the use of organics not only improve the crop response to added fertilizers but also enhance the physico chemical biological properties properties the use organic manure, apart from improving physical and biological of soil and micro nutrient deficiency were also not observed in such plots (Motsara,2000) which in turn positively influence crop growth. Enhancing the rate of FYM application influence the root characters of rice crop (Bridjit and Potty, 2002).Green manure application at 6.25 t ha^{-1} and increase the plant height and tiller number reported Balasubramaniyan, 2004.

The conjunctive use of organic and inorganic nutrients during *kharif* and *rabi* significantly increased the growth attributes as given in Tables 4.1 to 4.4. Kavimani *et al* (2000) observed significant influence of plant height of cereals due to the combined application of FYM and inorganic nitrogen. Ravi sankar *et al* (2002) reported that in rice- rice cropping system the growth parameters such as plant height , and dry matter production of the second crop increased significantly by the addition of crop residues. This might be due to the increased availability of nutrients and higher uptake. Singh *et al* (2000) reported that combined application of green manure and NPK fertilizers in rice wheat system produced about 75% higher root biomass than the application of NPK fertilizers alone .Similar trends were given by Bhoite(2005) , Yadav *et al* (2005) and Verma *et al* (2006)

5.2 Yield and Yield attributes

5.2.1 Yield attributing characters:

Yield attributing characters viz. the number of productive tillers hill^{-1} and thousand grain weight were not differed during Kharif season as per Tables 4.5 and 4.6. However during *rabi* seasons the number of productive tillers hill^{-1} increased with increased levels of NPK. T4 and T5 were on par with each other while number of productive tillers hill^{-1}in T6 were slightly higher than in T7. The difference was evident in grain yields. Posthamisri *et al* 2006 reported that grain weight, panicle number and test weight were positively influenced by the addition of higher rate of nitrogen fertilizers. Similar reports were given by Fragaria and Balingar (2001).

Sterility percentage decreased with the increased supply N and K, since K stimulate the buildup and the translocation of carbohydrates and grain development which increased the number of filled grains and test weight in rice. These findings were corroborated by Renjini, 2002.

According to Table 4.5 plots treated with FYM and crop residues recorded decreased sterility percentage and increased test weight. Enhanced grain weight due to higher organic matter addition was reported by Babu (1996). Continuous supply of organic matter provides favourable condition for the availability of major and minor nutrients which increase filling percentage in panicle. Greater number of productive tiller hill^{-1} were reported in T10 and T11 in *rabi* since like other organics, green manure application helping maintaining prolonged availability of nutrients, improve root penetration and improve soil physical conditions and nutrient uptake. These results were on the same line with Yadav *et al* (2005). The problem of accumulation of autotoxins excreted by the roots of rice into the soil alleviated by the addition of FYM through its nutrient supplying power and positive effect on physico-chemical and biological properties of soil, imparting a positive influence on yield attributing characters as supported by Renjini, 2002. The enhancement in the efficiency of applied chemical fertilizer and a steady supply of essential plant nutrients through out the growth period are the advantages of INM. Farm yard manure when applied along with 100% RDF , FYM solublize native P and K in soil by the production of organic acids and enhances their availability ,along with the chelating of soil N, thereby improving the uptake of nutrients and minimize the loss of fertilizers which influences the yield attributing characters and yield.

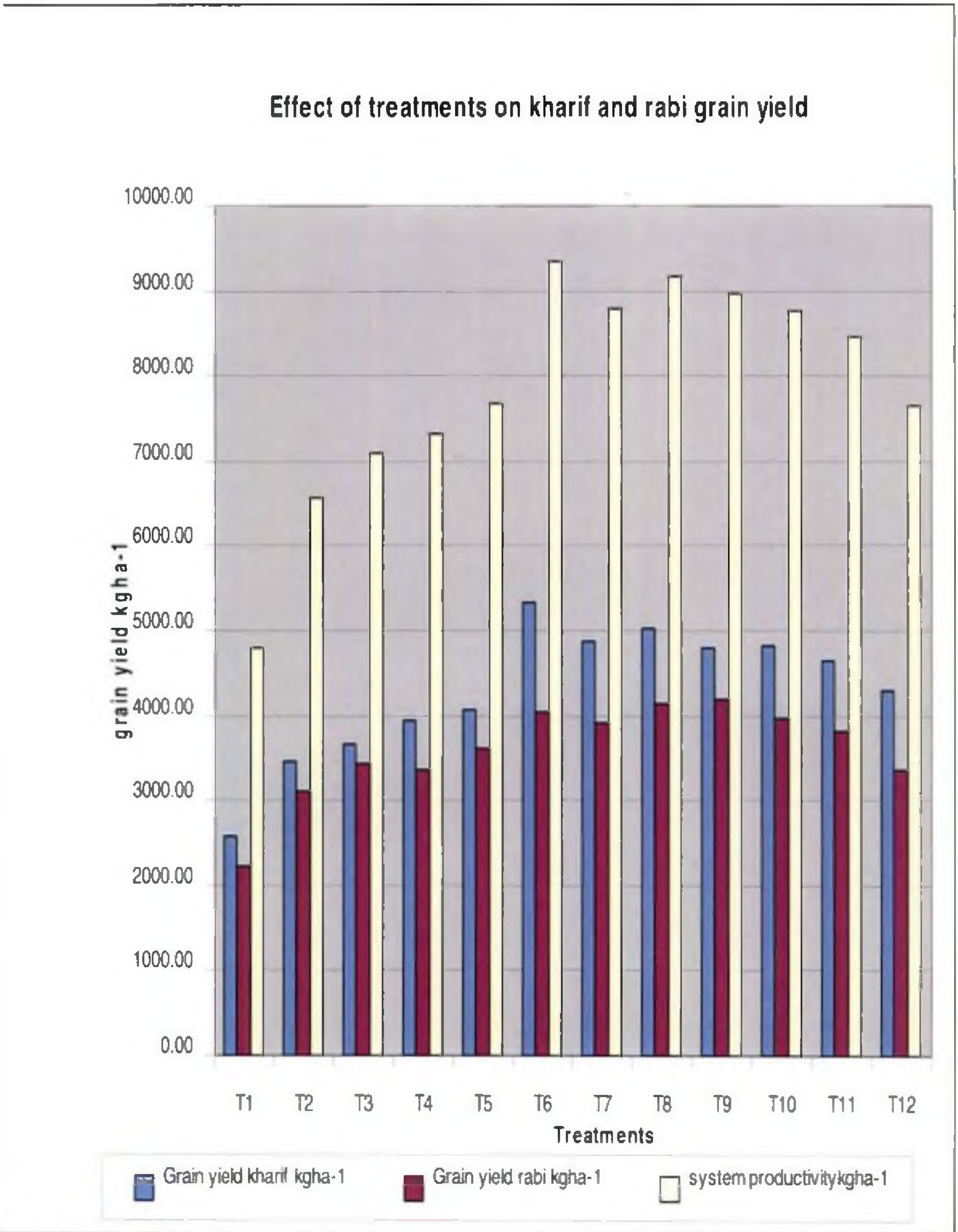
5.2.2Yield

The grain, straw and total yield during the year 2004-2005 as influenced by the RDF and its combinations with and with out organics during *kharif* and *rabi* seasons are abridged in Table 4.6.

5.2.2.1 Grain yield (Fig 5.1)

Kharif **season** : The maximum grain yield in *kharif* was exhibited by T6 (5320.87 $kgha^{-1}$) which was on par with T8 , in both 50% of RDF of NPK substituted by FYM and crop residues in *kharif* .T8 was on par with T7, T10, and T9. In all these treatments 50 or 25% of RDF was substituted either by FYM, crop residues or green manure. The farmers practice in which full dose of N, half dose of P and K with an addition of 3 t ha^{-1} of FYM in *kharif* gave lower yield than all the treatments where organics and inorganics were collectively applied. This clearly indicates that balanced NPK nutrition is a key factor influencing grain yield. Among the chemical fertilizer treatments T5 recorded the highest yield and was on par with T4 (75% RDF in both *kharif* and *rabi.).* Treatments viz.T3 and T2 in which 50% of RDF was applied as fertilizers during *kharif* season recorded lower yield than T5. However, T3 and T2 recorded yields significantly higher than the absolute control and was par with each other. The results also indicates that during the *kharif* season , application of 100% RDF alone was not beneficial to the crop probably due to the higher leaching losses as

Fig. 5.1


Effect of treatments on kharif and rabi grain yield
10000.00
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
grain yield kgha-1
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
Treatments
Grain yield kharif kgha-1
Grain yield rabi kgha-1
system productivity kgha-1

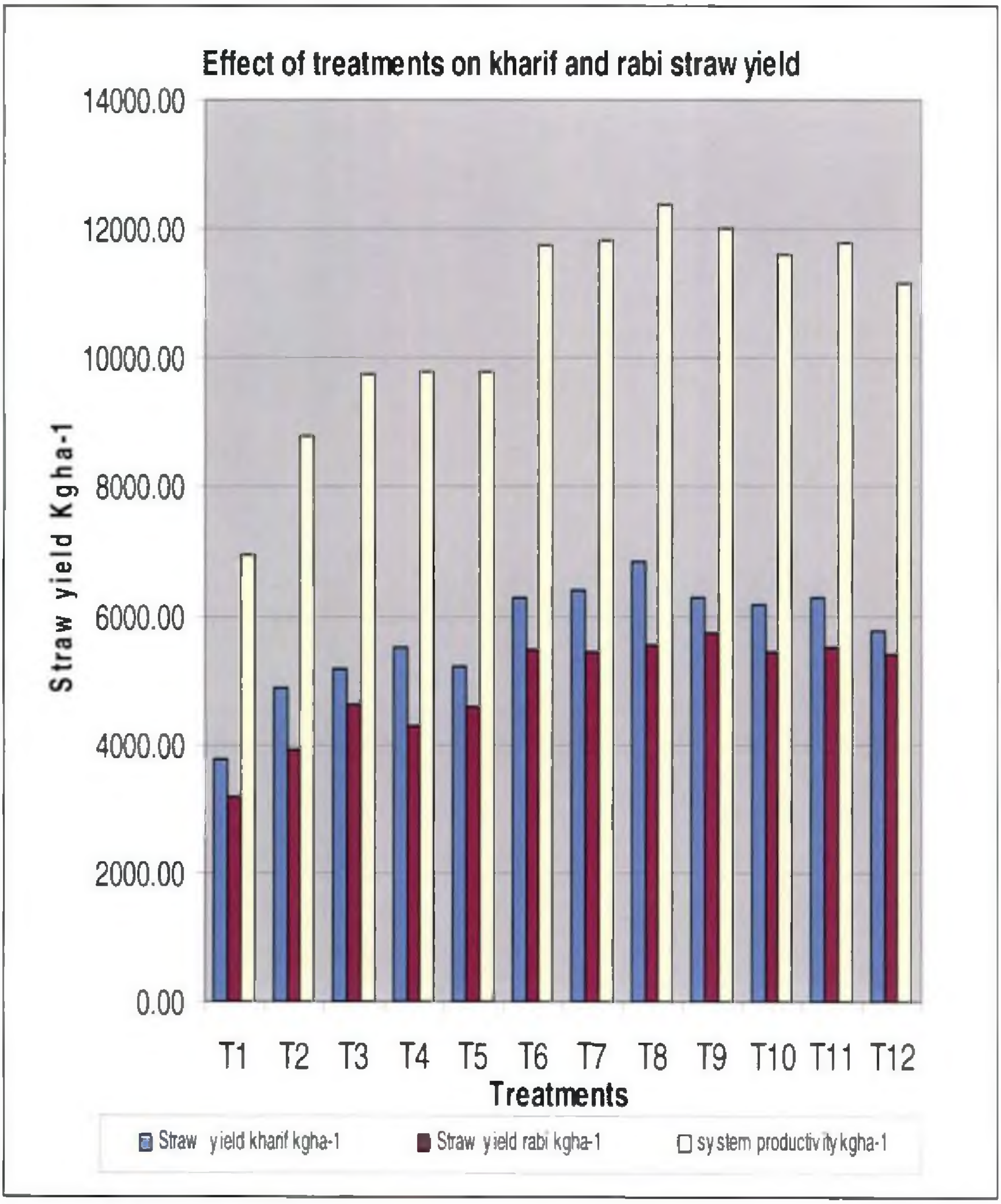
continuous rainfall was usual in the season With the increased doses of NPK, grain and straw yield enhanced . Increase in nutrient supply, enhance soil organic carbon, promote an increase in dry matter production, provide increased nutrient availability, and increase yield attributes and yield. Thus the improved physico chemical biological properties promote soil health, increase the root development and improve nutrient uptake there by improving yield and growth characters. These findings were supported by Raju and Reddy (2000a), Bhoite(2001) and Balasubramaniyan (2004).

***Rabi* Season** : Grain yield was remarkably influenced by the treatments during the *rabi* season .Maximum grain yield was in T9 (4185.05 kgha^{-1}) which was on par with T8,T6 T10 and T7. All these treatments had received either 25 or 50% of substitution of RDF with organics during *kharif*. It is also noted that during the *rabi* season application of RDF as in organics alone either at 100 or 75%, with the above mentioned organics gave grain yields not significantly different. It clearly shows that a savings of 25% RDF as fertilizers is possible in this type of INM. The full dose of RDF through chemicals as in T5 gave better response than other combination of 50 and 75% RDF as fertilizers and 50 and 100% RDF as fertilizers during both *kharif* and *rabi*. The better response of fertilizers in *rabi* season as compared to *kharif* season might be due to less rainfall during *rabi*. Higher grain yield in *rabi* can also be attributed to the favourable effect of FYM, crop residues and green manure in N mineralization which may increase the nitrogen supply to the plants increasing growth and yield. The results corroborated with Banerjee *et al*, 2006.

5.2.2.2 Straw yield: (Fig 5.2)

Kharif season : The maximum straw yield in *kharif* was recorded in T8 (6817.00 kgha^{-1})which was on par with T7. Unlike the grain yield, the T6 treatment gave a lower straw yield than T8 probably due to higher partitioning of dry matter produced as grains in this treatment. Results reveal that a straw yield of more than 6 t ha^{-1} was obtained in all the treatments in which a part of RDF was substituted with organic manure. The straw yield was not influenced by the treatments which received fertilizers alone during *kharif* . It again indicates that for partitioning of dry matter towards higher grain yield a balanced application of fertilizers are required.

Fig 5.2


Effect of treatments on kharif and rabi straw yield
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
Straw yield Kgha-1
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12
Treatments
Straw yield kharif kgha-1
Straw yield rabi kgha-1
system productivity kgha-1

Rabi season : Highest straw yields were recorded T9 (5714.77 $kgha^{-1}$) and T8 which received 25 and 50 % of the RDF through organic manure in *kharif* and 75 and 100% of RDF through fertilizers in *rabi* . No marked variations were noticed in treatments from T6 to T12 which reviewed FYM, crop residues and green manure as a part of RDF during kharif .However among the chemical fertilizer treatments T3 and T4 were on par with T5 and present significantly higher yield than control.

In *rabi* season the highest grain and straw yields were obtained in T9, which might be attributed to the residual fertility effects due to crop residue application. Since the straw incorporated is a good source of potassium which is made available to the plants in a long run. This increases grain and straw yield which positively influences height and tiller production.

5.2.3 System Productivity (Fig 5.1, Fig 5.2)

The system productivity of the long term experiment during 2004-2005 as per Table 4.6 the highest grain yield was noticed in T6 (9349.08 $kgha^{-1}$) and was on par with T8, T9,T7 and T10. In the treatments T6, T8, T10 where 50% of RDF was substituted with organic manure viz FYM, crop residues and green manure and 100% RDF as fertilizers during *rabi* invariably gave higher yield. However T9 andT7 also gave comparable yields in which 25% of the RDF was substituted with crop residues,FYM and green manure during *kharif* in which 75% RDF applied through in organics during *rabi* season can be recommended as the best treatments since there is a saving of 25% fertilizers .It is also evident from Table 4.6 that 8.5 t ha^{-1} per annum and more yield was obtained in all the treatments where 50 % or 25% of RDF was substituted with organic manure in *kharif.* When we compare this result with Farmers practice it seems that there was a remarkable yield reduction which might be due to the reduction in P and K fertilizers levels to half as compared to the RDF. The beneficial effect of P and K in rice cultivation and balanced nutrient application was reported by several workers like Raju and Reddy (2000a and b).

The RDF as fertilizers alone gave highest yield in T5 and was on par with T4 indicates that present recommendation is fruitful only in situations where there is application of organic manure at least once a year. If fertilizers alone applied 75% of RDF is sufficient for rice cultivation .The application RDF only as 50% recorded a reduction in grain yield of rice in high rainfall tropics. .The grain yield during *kharif* and *rabi* were lowest in absolute control System productivity straw yield during the year was highest in T8 and was on par with T9. All the treatments in which INM was practiced recorded more than 11t ha^{-1} straw yield per annum in this type of sequential cropping of rice .The treatments T5, T4 and T3 treatments were on par in straw yield production indicating that 100% or 75% of RDF is better than its lower level.

5.3 Nutrient contents:

5.3.1 Nitrogen content

The nitrogen content at active tillering, panicle initiation and harvest present in Tables 4.7 and 4.8 reveals that during the *kharif* and *rabi* seasons T4 and T5 show the maximum N content at active tillering. It can be attributed to the increased and speedy release of nutrients from NPK fertilizers which enhance the nutrient uptake. Organic matter needs more time to decompose. The effect of rice straw or any crop residue show significant response when it is applied for long terms. At panicle initiation stage there was a substantial reduction in N content in leaves since nitrogen is being Tran located to the developing panicle. This mobilization of nutrients seems to be increased in plots where FYM and crop residues are applied on a long term basis. During the harvest stage analysis reveal that the grain N content was higher in T9, T6 and T8 among the organic matter applied plots, which reveal their N furnishing properties. In T6 plots FYM application enhanced N mineralization, prevented N losses and increase NUE enhancing the over all uptake.

5.3.2 Phosphorus content:

An idea regarding the P content at active tillering, panicle initiation and at harvest was given by Tables 4.9 and 4.10. In both *kharif* and *rabi* the control plots showed lower values compared to the treated plots showing that the nutrient uptake is affected by the soil fertility status. During the harvest stage of the *kharif* crop the maximum phosphorus content in grain was in T9, which may be due to the application of crop residues. P content of green manure and FYM are higher, so total P content in treated samples from T9, T10 and T11 was also higher. In *rabi* the highest grain P content was noticed in T10 since green manures enhance P availability in soils and increase P uptake by crops .The organic manures added produce organic acids and enhance the dissolution of bound P in soil. These results were on the same line with Bellaki *et al*, 1998.

5.3.3 Potassium content

Information in Tables 4.11 and 4.12 reveals the K content of the crop at different crop growth stages. The organic matter applied plots showed higher K content in both *kharif* and *rabi* , organic manures especially crop residues reduce K fixation and provide a rich pool of K enhancing the crop uptake., thus enhancing the K content in treated samples

5.4 Uptake of nutrients (Fig 5.3,5.4,5.5,5.6)

5.4.1 Nitrogen uptake

Data in Tables 4.13 and 4.14 reveal that N uptake at *kharif* and *rabi* during the different crop growth stages were profoundly different. The N uptake was faster and increased considerably between panicle initiation and harvest in *kharif* and *rabi* and this was in conformity with the findings of Satheesh and Balasubramaniam (2003). In all the crop growth stages higher N recovery patterns are seen when organic manures with inorganic fertilizers are given. At the harvest stage, the total N was maximum in T6 in kharif and T9 in *rabi* which is reflected in their yields. This may be due to increased availability of major and minor nutrients, improved soil physico chemical biological properties.

5.4 .2 Phosphorus uptake

P uptake pattern in *kharif* and *rabi* are given in Tables 4.15 and 4.16 and the results varied significantly with different fertility managements. P uptake seems to increase with increased additions of NPK. In both *kharif* and *rabi* , FYM applied plots show maximum values of P uptake in active tillering and panicle initiation. FYM increases the availability of P and enhance uptake. Organic matter produces organic acids which may dissolute bound forms of P and enhances its release for plant uptake by reducing Soil pH. Same results were obtained by Amita Gharu and Tarafdar , 2004. Moreover higher root proliferation in those plots in which a part of N is substituted by organic manures, due to higher P,K and micronutrient availability could have resulted in higher uptake. The results were on the same lines with that of Satheesh and Balasubramaniyam ,2003.

Fig. 5.3

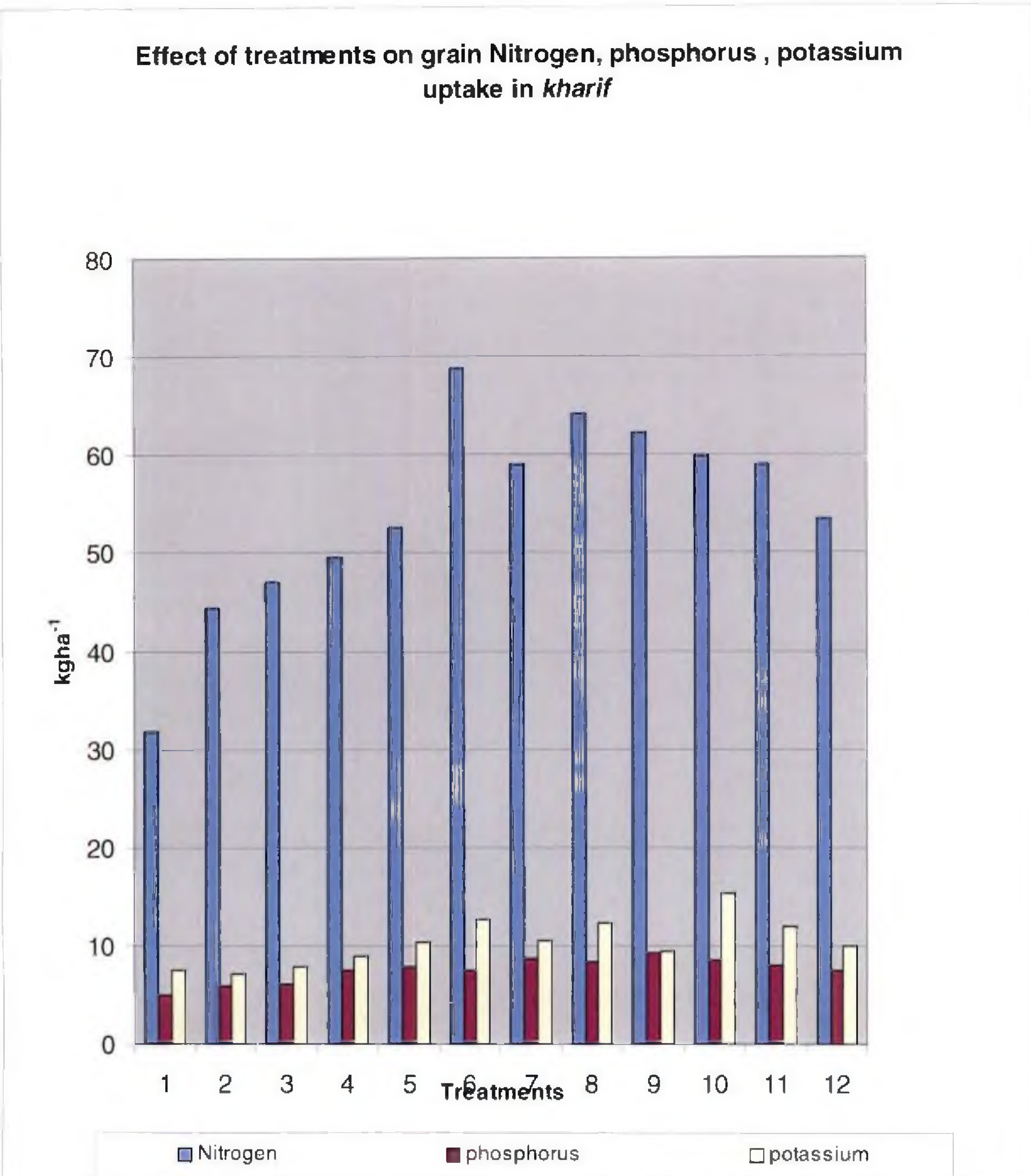

Effect of treatments on grain Nitrogen, phosphorus , potassium uptake in *kharif*
80
70
60
50
40
30
20
10
0
kgha-1
1
2
3
4
5
6
7
8
9
10
11
12
Treatments
Nitrogen
phosphorus
potassium

Fig. 5.4

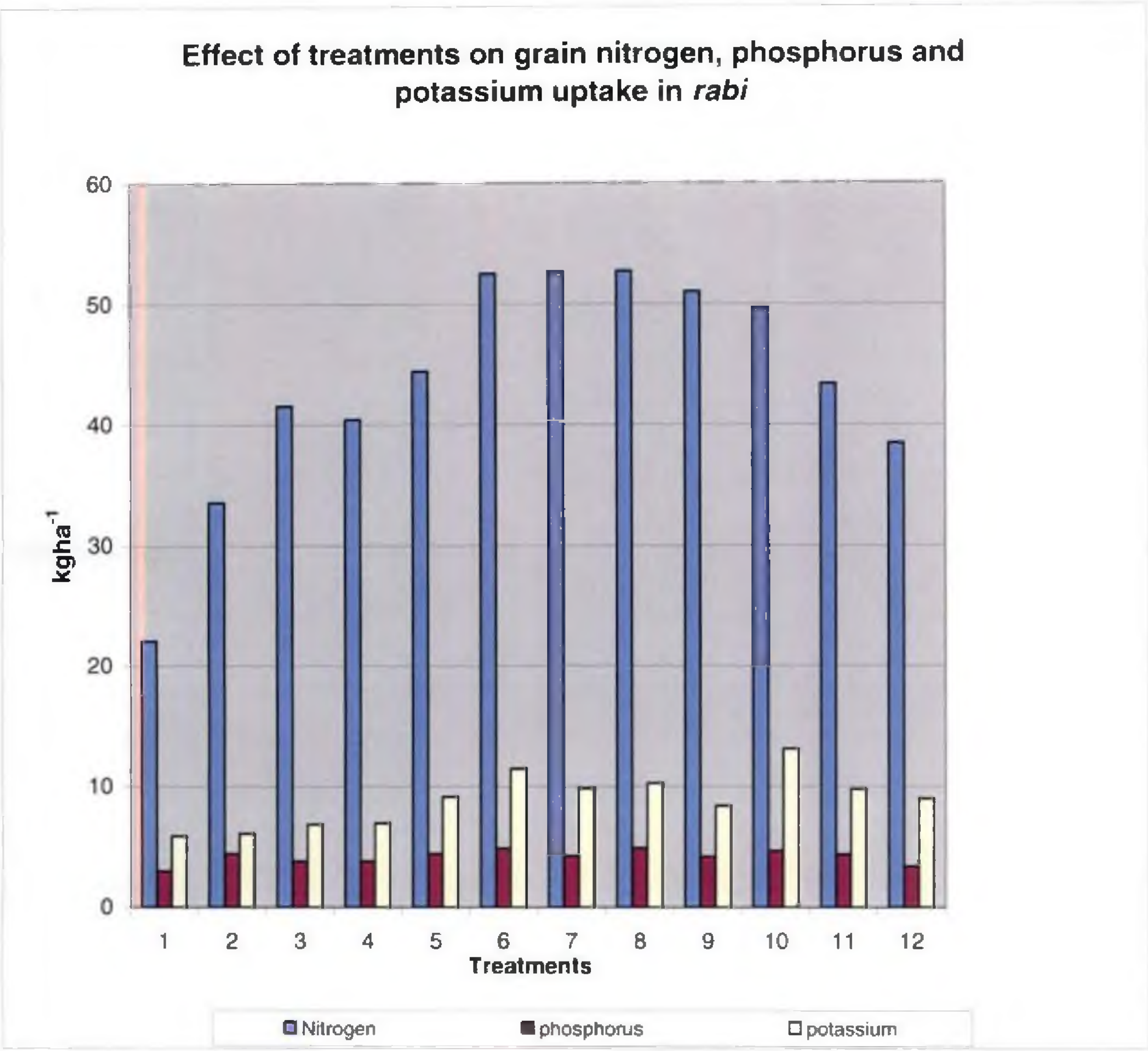

Effect of treatments on grain nitrogen, phosphorus and potassium uptake in *rabi*
60
50
40
30
20
10
0
kgha-1
1
2
3
4
5
6
7
8
9
10
11
12
Treatments
Nitrogen
phosphorus
potassium

Fig. 5.5

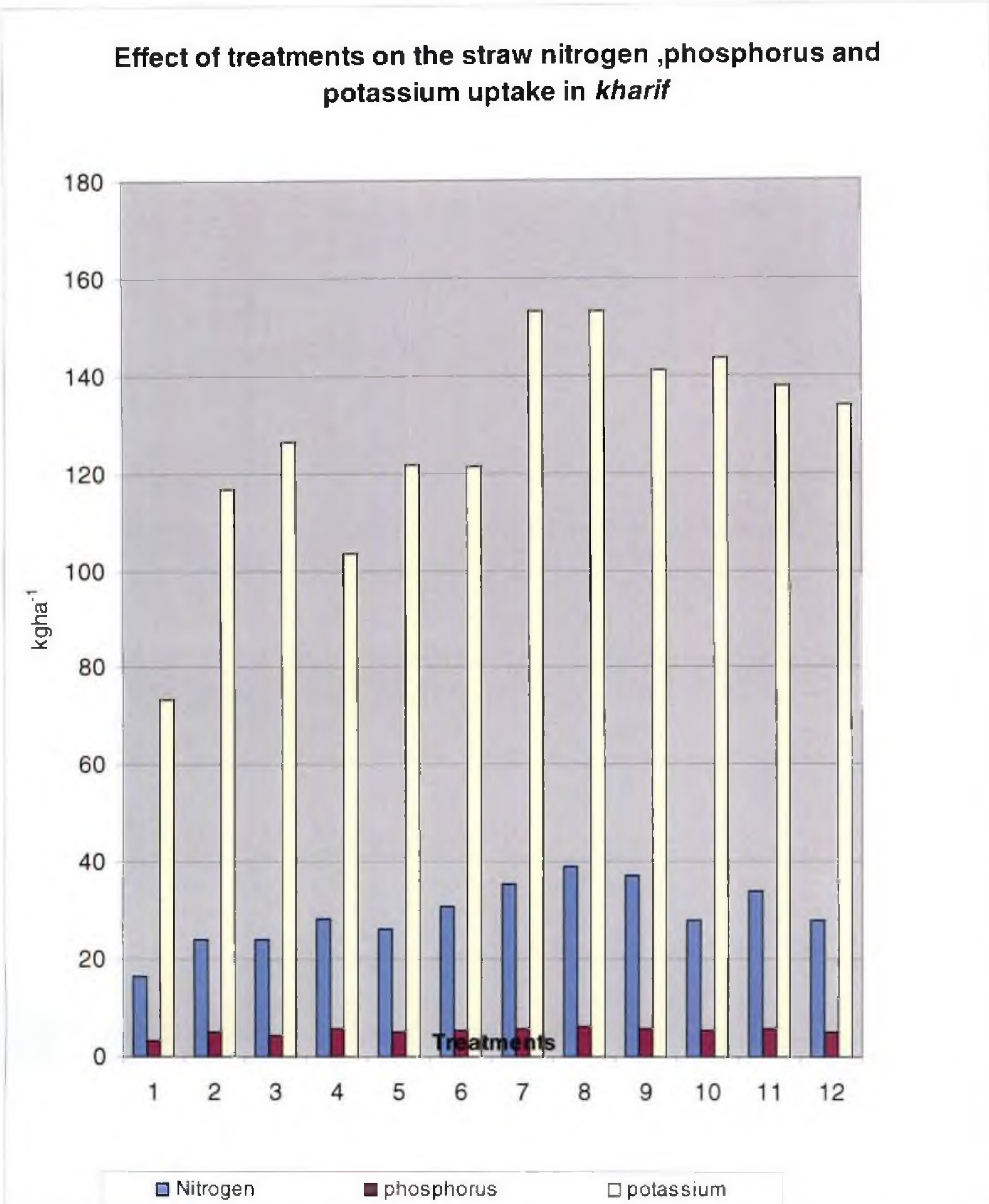
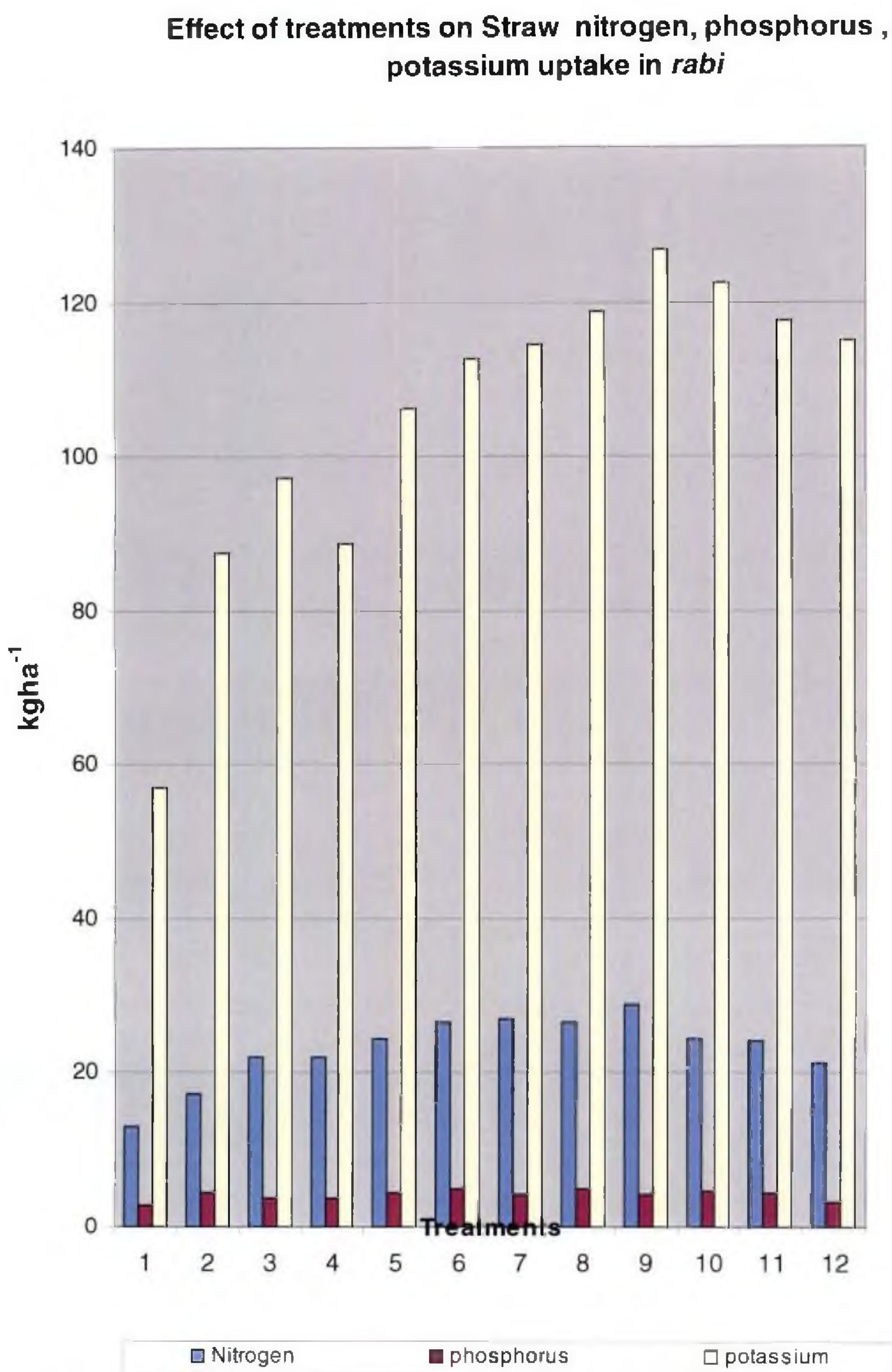

Effect of treatments on the straw nitrogen ,phosphorus and potassium uptake in *kharif*
180
160
140
120
100
80
60
40
20
0
kgha-1
Treatments
1
2
3
4
5
6
7
8
9
10
11
12
Nitrogen
phosphorus
potassium

Fig. 5.6


Effect of treatments on Straw nitrogen, phosphorus , and potassium uptake in rabi
140
120
100
80
60
40
20
0
kgha-1
Treatments
1
2
3
4
5
6
7
8
9
10
11
12
Nitrogen
phosphorus
potassium

5.4 .3 Potassium uptake

K uptake in *kharif* and *rabi* at different growth stages of the crop are indicated in Tables 4.17 and 4.18 . As per Maene 2001 , the removal of K by plants is higher than the removal of N. There was an increase in K uptake in both seasons at all growth stages with the incremental doses of NPK. The same results were obtained by Sheeba and Chellamuthu (1999). Higher dry matter production and significant differences in grain yield due to the higher application of N might have contributed to higher uptake of K.

5.5 Available Nutrients

5.5 .1 Available Nitrogen

There was no significant variation among the treatments in *kharif* while the treatments vary remarkably in *rabi* as per Table 4.19 .Soil available N show increase in availability in organic manure applied plots in both *kharif* and *rabi*. With the increase in availability of N, P and K release from soil bound forms are aggravated and this improves crop yield and greater biomass addition in soil. Organic acids produced in soil due to organic manure, enhance P dissolution and accelerate the release of fixed K, thereby indirectly enhancing N-availability. Same results were obtained by Amita Gharu and Tarafdar (2004). Organic manure increase the supply of organic carbon in soil which is a measure of available supply of organic carbon this cause increase in microbial N in soil. Residue addition provide a stable supply of organic carbon and cause increase in microbial population which release a large amount of N stored in labile microbial biomass. The same result was reported by Dobermann and Fairhurst (2002). In soils with good WHC and moisture content, available N is high, which can be due to the fact that adequate moisture content in soil increase N mineralization and this findings was in conformity with Chakraborthy *et al.* (2005). Since N mineralization in correlated with microbial biomass carbon and available N furnished from microbial biomass carbon and organic matter increases N availability in soil. These findings were on similar lines with Soon and Arshad (2004). Carter *et al.* (2004) was of the view that soil water filled pore space, if decreased below a 66 per cent value, N mineralization decreases and this will decrease N availability in soils.

5.5 .2 Available P

Available P values in both *kharif* and *rabi* show so no profound variation among the treatments as per Table 4.19. When compared with control plots, the available P in all treated plots were higher, indicating that available P in higher in fertilized plots. Compared to initial soil available P status, increases after *Kharif* season, especially in organic manure applied plots. Available P was enhanced in green manured plots, Raju and Reddy (2000b), and FYM applied plots (Santhy *et al* 2000).

5.5 .3 Available K

Results in Table 4.19 reveal that available K did not vary remarkably with the different treatments. Prolonged use of NPK fertilizers enhances leaching and cause heavy depletion and this explains the decrease K availability in T3 and T5 after *kharif.* Soil available K show substantial decrease, after *kharif* because of the release of K from non-exchangeable K-pool, enhances the K uptake by crop. Some results were obtained by Singh *et al.* (2000). Mishra *et al.* (2001) reported that in rice, removal of K was higher than N removal. The K contained in green manure and FYM is prone to less leaching loss than other organic sources. It was reported by several workers that FYM when used along with fertilizer N increases available K status. Rice straw showed maximum contribution in available K in soil among the different organic materials, because the K use efficiency of straw was as high as 50-60 per cent and comparable with that of inorganic K fertilizer as reported by Navneet kaur and Benepal (2006) and due to higher carbon nitrogen ratio of FYM and straw, they take more time for decomposition *i.e.,* increase in incubation time occurs and thus K mineralization is enhanced increasing the available K pool in soil.

5.5 .4 Available Zinc

From table 4.20 it is clear that in both *rabi* and *kharif* , increase in NPK levels increase Zn availability. Before *kharif* the high available Zn values were attributed to T3 and T5 which has got high available P and K and similar findings were by Mehra (2004), Hegde and Sudhakara Rao (2001) opined that organic matter addition helps to correct Zn deficiency and organic matter supply provide traces of zinc which were not supplied only by chemical fertilizers. Zinc increases the mean stubble yield (Mani *et al*

., 2001) and increase the number of filled grains per panicle , number of productive tillers hill-1 and greatly reduced spike let sterility and all these will indirectly increase the yield.

5.5 .5 Available Sulphur

Sulphur availability (Table 4.20) was less in control compared to fertilized plots . In support of this Ch Srinivasa Rao *et al* (2001) reported that S is deficient in soils with low organic matter, coarse textured low organic carbon soils. S is a constituent of organic matter, and Mehra 2004 reports that surface soils rich in FYM contain higher S content.

5.6 Soil Physical Properties

5.6.1 Bulk density:

As per Table 4.21 soil physical properties were profoundly influenced by various treatments.

The highest BD is in T5 in *kharif* season, which was on similar lines with the results obtained by Selvi *et al*, 2003. From T_1 to T_5, though BD values did not vary significantly, it was evident that BD decreased from control to T_5. Increase in fertilizer levels might have attributed greater biomass addition due to better plant growth, root proliferation which lead to improved productivity. Chaudhary *et al*, 2006 and Bharadwaj and Omanwar, 1994, supported these findigs. BD was maximum at control in both seasons, due to the absence of organic and inorganic sources of nutrients. With the increase in addition of NPK form of nutrients, there was incremental beneficial effect on aggregate stability, percent of water stable aggregates, which may decrease BD. Supported by Selvi *et al* (2005).

In both seasons, the additions of favourably decrease the BD enhancing other soil physical properties. BD values were the lowest among those plots where FYM was applied which might be due to its high carbon nitrogen ratio and decreased rate of decomposition under wet continuous in a rice-rice sequential cropping system. FYM increases soil organic carbon percent, improve root biomass, provide better soil aeration and improve the mechanical composition of soil and increase soil porosity. These views were on similar lines with Parihar, 2004 , Bhatnagar *et al* (1992) and Achrya 1988.

Crop residues also effectively decreases BD values due to better aggregation, enhances porosity, WHC increased infiltration rates. Supported by Ranjan Bhattacharya *et al*, (2004). Sarawad *et al*, 2005 reported that lowest BD was in plots treated with plots which were applied with N through green manures like Sunhemp. Channabasvanna (2002) and Balakki and Badanur (1997) stressed this point.

The significant decrease in BD in plots where both organics and inorganics were applied may be due to better addition of crop residues, enhanced soil porosity and soil aggregation. Singh *et al*, 2000 and Mishra and Sharma 1997 supported these findings. Increase in mean weight diameter, which is a measure of soil aggregate stability, was also enhanced due to FYM+ NPK application as per Selvi *et al*, 2004. In plots treated with FYM and NPK, there is a build up of soil biomass carbon and N by the enhanced activity of micro organisms and it is clear from Table 4.24 that microbial status in these plots was higher. The same is true for crop residues, since due to the slow decomposition of paddy straw, there was positive influence in organic carbon of soil, improved microbial activity, decreased BD and enhanced supply of soil available nutrients and micro nutrients, which was supported by Surekha *et al*, 2004.

5.6.2 Water Holding Capacity of Soil:

Results in Table 4.21 indicate that WHC of NPK treated soils to increase with NPK application, may be due to better plant growth, increase biomass production, root proliferation and improvement in organic carbon percentage and these will decrease BC increase soil porosity and increase WHC of soil. These results also obtained by Bhardwaj and Omanwar 1994 and Choudhary *et al*, 2006. The WHC of the treated plots were higher than the control plots due to greater biomass addition in treated plants, there by increase OM content in soils and this will again improve soil physico-chemical-biological properties and reduce the water lost through evaporation, percolation, seepage compared to control. Similar views were forwarded by Bhagat *et al* (1999).

Soil compaction increases significantly with increased levels of K (Yadav *et al* 2004) which may lead to developing denser root system which add more OM to soil, enhance CEC and organic carbon percentage, there by improving soil physical properties enhancing WHC.

Organic matter when added to soil can increase its WHC, even by the inherent WHC of organic matter added. Continuous addition of organic matter changes the total porosity of soil, which affects the WHC positively as explained by Mahemaraja *et al* (1986). Bhagat *et al* (1999) supported this by reporting that incorporation of organic matter to soil modifies the soil structure and improve water retention and thus reduce evaporation, deep percolation and seepage losses. Rice straw, FYM and green manure contain high concentration of water soluble K which improves its availability which improves plant productivity, and increases organic matter production which decreased BD, improve microbial activity and soil aggregation enhancing WHC as evident from the studies of Yadavinder Singh *et al*; 2005.

The WHC of NPK+FYM treatment was higher than the application of NPK fertilizer alone, because fertilizer along with FYM increases the carbon sequestration in soil. This result in higher organic carbon percentage in soil, and improved soil physicochemical-biological properties, enhanced soil porosity, produce favourable pore geometry for soil and improve WHC of soil. These findings were on similar lines with Ranjan Bhattacharya, 2003.

The crop residue addition in soil along with fertilizer provide a stable supply of carbon and energy for microbial biomass, increase soil available N and K, and micronutrients, there by improve microbial activity. Cementing action of microbial exudates increases soil aggregation and improve porosity and WHC of soil.

5.7 Soil Chemical Properties:

The chemical properties, as per Table 4.22 viz. organic carbon content and cation exchange capacity were remarkably influenced by the different treatments. In both *Kharif* and *rabi*, the organic carbon values for all treatments were high compared to the control. The combined application of organics and inorganic sources of nutrients resulted in significant increase in CEC over control.

5.7 .1 Organic carbon

The organic carbon value in both T5 seasons are higher than T_2,T_3 and T_4. Yadav *et al* (2005) got similar results that 100% NPK maintained higher values for Organic Carbon. This may be due to, good proliferation of roots due to the combined application P and K, and so greater addition of crop biomass to soil, and hence building up of organic matter and humus. Significant build up of soil organic matter due to the continuous addition of inorganic fertilizers have been reported by Bhardjwaj and Omanwar (1994). Bhardwaj *et al* (1992) also supported the finding.

In plots treated with organic matter, the highest buildup of soil organic carbon was evident in plots treated with crop residues and green manure. In support of this Bajpai *et al* (2006) reported that organic carbon content increased over the control and the initial levels by the continuous application of FYM/Rice straw/green manure over the years in long term manurial trials. From Table 4.22 , we can find that organic carbon percent increased after *kharif* season in almost all treatments and this can be attributed to the addition of straw and green manure containing high organic carbon and the slow decomposition of applied and native soil organic carbon due to the anoxic condition (flooded) in rice-rice cropping system. Hence flooding can improve organic carbon. This was supported by Surekha *et al* (2004). Improvement in physical condition of soil by increased organic carbon and substantial improvement in microbial activities were noted in organic carbon rich plot soils, which may in turn increase productivity. This was supported by Bird *et al* (2001) and Dobermann and Fairhurst (2002). T8 show greater yield (both straw and grain) in *rabi* is due to the residual effect of straw and its supply of organic carbon in long run along with the improvement in soil physico-biological properties. This was favoured by the studies of Santhy *et al* (2002).

FYM significantly improved the magnitude of organic carbon in combination with inorganic fertilizers (than initial status) due to the mineralization of FYM which improved organic carbon availability (Singh *et al*, 2001). The organic carbon content in T7 plots were higher in both seasons compared to T6 plots may be due to greater NPK application along with FYM .FYM sustained soil P^H, increased available N and P and furnished organic carbon and greater dose of NPK which improved growth and root production and enhanced addition to soil organic matter. This was backed by Sengar *et al* (2001) and Ghuman *et al* (2006). Addition of fertilizers and FYM together increase soil sequestration and this increase the yield of roots and plant residues and hence add to soil organic matter increasing soil organic carbon compared to the application of NPK fertilizers alone. The same results were obtained by (Ranjan Bhattacharya *et al*, 2004).

5.7 .2 Cation exchange capacity

Results in table 4.22 clearly revel that CEC was profoundly influenced by the treatments in both *Kharif* and *rabi.*

CEC of soils increased from T1 (control) to T5 except a decrease at T4. This is because, the increase in fertilizer levels from 50-100% RDF gradually increased CEC due to the indirect addition of organic matter, through better addition of plant biomass and roots as supported by (Subramanian and Kumarswamy, 1989). However in plots supplied with high doses of NPK (T_3,T_4 and T_5) the low CEC values can be attributed to the dominance of Kaolinite content in clay minerals as explained by Deepa (1998). Again Selvi *et al* (2003) reported that continuous long term addition of NPK fertilizers can increase the leaching of K, $Ca2^+$ and Mg^{2+} and can decrease CEC.

Application of organic matter enhanced CEC remarkably in the treated plots. OM addition enriched soil with organic carbon, humic fraction and improved soil microbial biomass on which CEC is largely depended as found out by Saini *et al* (2005). Table 4.3 indicates that root proliferation was high in plots treated with FYM and crop residues in *kharif* and they show enhanced organic carbon and as per table 4.24, they show greater microbial activity, effects of all of which are reflected in CEC. The addition of rice straw and comport increases the addition of P and K and this can increase organic carbon indirectly and can enhance CEC. Moreover, in rice straw incorporated plots, the mineralization is slow due to wider carbon nitrogen ratio of straw and more organic carbon is continuously present and this can positively influence CEC in soil. There findings were in line with Raju and Reddy (2000).

The CEC of T_6 and T_7 were lower after *rabi* seasons compared with T_8 and T_9. This can be explained by the fact that FYM along with NPK can absorb soil Ca^{2+} and

Mg^{2+} and can make them available for plant absorption, making a decline of exchangeable Ca^{2+} and Mg^{2+} in soils thus decreasing the soil CEC. These were in similar lines with the study of Selvi *et al* (2003). The CEC of green manure treated plots were less when compared with those treated with FYM and crop residues. This can be explained by the fact that since green manure are of lower C:N ratio rapid mineralization of nutrients can occur leading to their rapid leaching loss or plant uptake and this in turn can negatively affect soil organic carbon and comparatively reduce soil microbial biomass carbon and their activity These views were supported by Lupwayi *et al* (2004).

5.8 Soil biological properties

Soil harbours a dynamic population of micro organisms and they play a vital role in decomposition of organic matter, phosphate solubilisation , N transformations , humification of organic residues etc

Counts of microbial population are presented in Table 4.23. The results reveal that among the microbes the bacterial population was highest compared to fungi and actinomycetes in both the seasons. The results were in conformity with Selvi *et al* 2004. The control showed generally lower values for microbial population. Soil bacteria usually show increase in population with incremental doses of N. The application of 100% N alone and control recorded lower values for bacterial population than 100% NPK (Martynik and Wagner , 1978) since P and K contents influences the various growth characters of crop which is positively correlated with microbial population. Sharma *et al* 1983 reported that nitrogen fertilization stimulated the growth of fungi and thus the enhancement of microbial activity, favoured the availability of major and minor nutrients and promoted yield and growth in T4 and T5.

Patil and Varade (1998) observed that NPK fertilizers helped the build up of microbial population, due to proliferation of roots, addition of crop residues and increased root biomass than the control.

The readily available organic carbon fraction in FYM supported the development of microbial biomass hence enhanced population growth bacteria, fungi and actinomycetes in T6 and T7 in *kharif* and *rabi* seasons. Fungal activity was generally increased in green manure applied plots since narrow carbon nitrogen ratio of green manure easily furnishes N stimulating fungal growth.

Bacteria , fungi and actinomycetes population were comparatively high in INM adopted plots . The higher levels of N as well as use of FYM produce favourable effect on soil bacteria. Hence these plots show higher organic carbon, good physical properties, lower BD and higher WHC and this promotes good yield attributing characters and yield. Soil microbial biomass N, P, and carbon were better influenced by the integration of inorganics and organic sources of fertilizers to the RD rather than the single use of any plant nutrient source which reflects their synergistic effects.

5.9 Effect of treatments on weeds, insects and diseases

The effects of various treatments as revealed in Table 4.24 give an idea on the population and types of weeds in the experimental field due to the long term application inorganic as well as organic nutrients. The quantity of nitrogen applied significantly influenced the weed count. Ramana *et al*, 2005 and Roy and Mishra(1999) in support of this opined that N levels exerted significant influence on grasses dicots and sedges as well as total population .

Regarding the insect attack, Table 4.24 reveals that stem borer attack was higher in T6, T9 and T7 plots though the treatments showed no profound variation among themselves. This can be due to the larger and continuous supply of nitrogen by the organic matter by its residual effects. Increased nitrogen causes greater succulence and it triggers the attack of leaf eating and sucking pests viz . Stem borers and brown plant hoppers. Several workers reported that enhanced supply of nitrogen to the crop plants initiate insect attack. The case worm incidence pattern reveals that its action was limited in organic manure applied plots on along term basis and it significantly varied with treatments. Organic substances like composts, crop residues and green manure contain certain chemicals which seem to deter the activity of insects above the economic threshold levels.

Though no severe disease incidence was noticed, diseases like sheath blight, blast brown spot etc were invariably correlated with higher doses of nitrogen , and careful P management is also and important factor that control disease incidence.

5.10 Economic Analysis:

The economics of cultivation worked out in Table 4.25 reveals that the maximum net income and benefit cost ratio is for T9 which can be due to lower cost of labour and inputs applied. This explains the highest benefit cost ratio (BCR) in T9. Lowest net returns and BCR in T1 indicates lowest returns and lowest net income.

SUMMARY

SUMMARY

The experiment entitled ' Impact of long term integrated nutrient supply system on soil health and rice productivity, was carried out at Cropping System Research Centre ,Karamana, to study the effects of long term application of commercial fertilizers alone and the combined effects of organics and inorganics on the growth and yield attributes , productivity , and nutrient uptake of rice with the changes in soil nutrient availability , physico chemical and biological properties of soil before and after the experiment covering *kharif* and *rabi* seasons.

Observations on growth and yield attributes, system productivity, plant nutrient content and nutrient uptake at different growth stages, variations in soil nutrient status and impact of treatments on physico chemical and biological properties of soil due to the long term application of fertilizers and organic manures in *kharif* and *rabi* seasons were studied. Some details regarding the impact of long-term fertilizer management on disease, insect and weed incidence are also collected. The data obtained were statistically analyzed , results presented and discussed in the foregoing chapter .The findings of the study are summarized below

The plant height was significantly influenced by all treatments in kharif at active tillering and panicle initiation stages, the maximum height recorded at both stages was in T7 which received 25% of RDF supplied as FYM in *kharif* and 75% of RDF through chemical fertilizers in *rabi*. During *rabi* season the plant height varied significantly among themselves only at the active tillering stage, and maximum height was observed in T7.

The tiller production hill^{-1} was profoundly influenced by the treatments at active tillering and panicle initiation in *kharif*, and the maximum tiller count was noticed in T7 and T6 during the active tillering, and panicle initiation . During *rabi* season T6 and T11 recorded maximum plant height in active tillering, panicle initiation and harvest.

The number of roots hill^{-1} were significantly influenced by the treatments during the maximum tillering stage of the *rabi* crop only and the treatment which received 50%

of RDF through FYM in *kharif* and 100% RDF through chemical fertilizers in *rabi* recorded maximum number of roots hill^{-1}.

The panicle length was profoundly influenced during the *rabi* season only in which the highest value was recorded in T8 in which 50% of RDF was supplied by crop residues and 100% of RDF through inorganics in *rabi.*

The number of productive tillers exhibited remarkable variations among themselves only in *rabi* and the maximum number as observed in T9 which receive 25% of RDF was supplied by crop residues in *kharif* and 75% RDF was supplied by inorganics in *kharif.*

The sterility percentage varied remarkably in both *kharif* and *rabi* and the minimum sterility percentage was recorded in T6 in both seasons where 50% of RDF was applied as FYM in *kharif* and 100% RDF through chemical fertilizers.

The test weight profoundly differed significantly among themselves only during the *rabi* , and the maximum test weight was observed in T6.

In the case of grain yields, in both *kharif* and *rabi* , the treatments varied remarkably .In *kharif* the maximum yield was noticed in T6 and the minimum yield in T1 while in *rabi* T9 produced the maximum grain yield and minimum yield was observed in T1.

Straw yields differed appreciably among themselves and the maximum straw yield was reported inT8 in *kharif* and T9 in *rabi.* Control exhibited lowest reported the lowest straw yield in both *kharif* and *rabi.*

The maximum grain nitrogen content in *kharif* was recorded in T9 and the maximum straw nitrogen was noticed in T5 and T6 while highest grain N content during *rabi* was recorded in T7 and maximum straw nitrogen content in T8.

The maximum grain P content in *kharif* was recorded in T9 and T5. The maximum straw P was noticed in T2, T4 and T5 while highest grain P content during *rabi* was recorded in T10 and maximum straw P content in T2.

The maximum grain K content in *kharif* was recorded in T10 and the maximum straw K was noticed in T3 and T7 while highest grain K content during *rabi* was recorded in T11 and maximum straw K content in T10 .

The maximum grain nitrogen uptake in *kharif* was recorded in T6 and the maximum straw nitrogen uptake was noticed in T8, while highest grain and straw N uptake during *rabi* was recorded in T8 .

The maximum grain P uptake in *kharif* was recorded in T9 and the maximum straw nitrogen uptake was noticed in T8, while highest grain and straw N uptake during *rabi* was recorded in T10 and T6 respectively.

The maximum grain K uptake in *kharif* was recorded in T10 and the maximum straw K uptake was noticed in T7. The maximum grain K uptake in *rabi* was in T10 and the highest straw K uptake was recorded in T9.

The soil available K and P showed no profound variation among themselves before and after the experiment but available N varied significantly in *rabi* season and T10 recorded maximum value at the end of the experiment.

Soil available Zn and S varied remarkably in both *kharif* and *rabi* and the higher values were noticed generally in organic matter applied treatments

Soil physical properties like bulk density and WHC were profoundly influenced by organic manure applied treatments, which produced soil environment friendly effects in them.

Soil chemical properties like organic carbon and CEC were influenced positively by the integrated application of organics and inorganics.

Soil biological properties as a result of organic manure application produced significant variations among the treatments in bacterial and fungal population while actinomycete count varied appreciably at the end of the experiment.

It was noticed that some influence were on weed and insect incidence by the various inorganic and organic nutrient management long term trials.

Regarding the economics of cultivation, the maximum net returns and benefit cost ratio was noticed in T9 and the minimum in control .

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IMPACT OF LONG TERM INTEGRATED NUTRIENT SUPPLY SYSTEM ON SOIL HEALTH AND RICE PRODUCTIVITY

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Abstract of the
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ABSTRACT

A field experiment was carried out in both *kharif* and *rabi* seasons during 2004-2005 at Cropping System Research station, Karamana to find out the effect of long term integrated nutrient supply system on soil health and productivity of rice (*Oryza sativa* L) –rice sequential cropping system.

The experiment was laid out in RBD with 12 treatments in 4 replications and treatments in *kharif* and *rabi* together form one set of treatment. The treatments included control , 50% ,75% and 100% levels of RDF in *kharif* and *rabi* and 50% or 25% substitution of recommended dose of nitrogen in *kharif* substituted by organic manure viz. FYM , crop residues and green manure.

The treatments exerted profound influence in majority of growth characters and yield attributes. Application of 25% or 50% substitution of RDF through organic manure along with 75% or 100% RDF in *rabi* through chemicals produced remarkable influence in growth and yield attributes.

In grain and straw yield of *rabi* and *kharif* , the highest values were given by those treatments which supplied either 50% or 25% of RDF through FYM or crop residues in *kharif* and 100% or 75% of RDF through inorganic fertilizers in *rabi* .Since these treatments were on par with each other, the best treatment is that which supply 25% RDF through organic manure in *kharif* and 75% of RDF through inorganic fertilizers in *rabi* since25% of the chemical fertilizers are saved there.

The highest NPK contents in grain and straw in both *kharif* and *rabi* were recorded and mostly in those treatments with 50% or 25% of RDF through organic manures in *kharif* along with 100% or 75% of RDF through in organics in *rabi*

The highest NPK uptake in all the crop stages in both *kharif* and *rabi* were also higher observed in plots those receive 50% or 25% of RDF through organic manures in *kharif* along with 100% or 75% of RDF through in organics in *rabi*

The soil available P and K values did not vary remarkably in both *Kharif* and *rabi* .However soil available nitrogen in soil varied profoundly before and after *rabi* seasons and the maximum available nitrogen was observed before *rabi* in those plots which supply 25% RDF through crop residues in *kharif* and 100% RDF through chemical fertilizers in *rabi* and 50% RDF through green manure in *kharif* and 100% RDF through chemical fertilizers in *rabi*.

The physical properties like bulk density and water holding capacity were also significantly influenced by the treatments before and after the experiment in which lower bulk density values were exhibited by organics applied plots in *kharif* and they also showed significantly higher water holding capacity compared to those treatments which were supplied with organic matter in *kharif*.

Soil chemical properties like organic carbon and CEC remarkably improved in organic manure applied plots along with inorganics in *rabi*.

The population count studies of bacteria, fungi, and actinomycetes revealed the positive influence of the collective application of organic matter and inorganic fertilizers on soil biological properties and its subsequent influence on soil health when compared with control.

As per the economic analysis of the cultivation the maximum benefit cost ratio was exhibited by the treatment which received 25% of RDF in *kharif* through crop residues and 75% of RDF through in organics in *rabi*.

APPENDIX 1

Weather data during the cropping period (June 2004-March 2005)

Standard week	Maximum temperature °C	Minimum temperature °C	Relative Humidity %	Rain fall mm
13	34	24	81	46
14	34	24	75	18
15	33	24	76	27
16	35	25	76	20
17	34	23	85	55
18	32	22	89	227
19	32	23	80	46
20	32	23	88	23
21	31	22	88	79
22	31	23	76	16
23	31	22	85	102
24	30	24	93	76
25	31	24	85	32
26	26	24	88	37
29	30	23	90	119
30	30	23	93	25
31	31	24	88	42
32	31	23	88	30
33	30	23	88	50
34	31	24	83	0
35	31	24	81	0
36	31	23	99	152
37	30	24	90	55
38	31	24	86	99
39	30	24	88	35
40	30	24	90	114
41	32	24	81	2
42	32	24	86	49
43	32	27	93	27
44	35	24	90	36
45	32	23	88	51
46	31	24	90	24
47	32	24	86	5
48	33	23	77	4
49	32	23	79	20
50	33	23	78	0
51	33	21	62	0
52	34	23	72	0

Standard week	Maximum temperature °C	Minimum temperature °C	Relative Humidity %	Rain fall mm
1	33	23	76	0
2	32	21	80	0
3	33	23	78	0
4	34	24	82	0
5	33	24	80	1
6	34	23	75	0
7	34	22	75	0
8	35	25	89	0
9	34	23	78	0
10	34	25	80	10
11	34	24	78	6
12	34	25	76	0
13	35	26	77	1

APPENDIX 2

Composition of media used for the isolation of micro organisms

1. Fungi – Martins Rose Bengal Agar

Glucose	10g
Peptone	5g
K_2HPO_4	1g
$MgSO_4.7H_2O$	0.5g
Steptomycin	30mg
Agar	15g
Rose Bengal	0.035g
Distilled water	1000ml

2. Bacteria – Soil Extract Agar

Glucose	10g
K_2HPO_4	0.5g
Agar	15g
Soil Extract	100ml
Tap water	900ml

3. Actinomycetes - KenKnight,s medium

Dextrose	1g
K_2HPO_4	0.1g
$NaNO_3$	0.1g
KCl	0.1g
$MgSO_4.7H_2O$	0.1g
Agar	15g
Distilled water	1000ml

APPENDIX 3

Cost of Inputs

Labour @ Rs 185 per man day
Seeds @ Rs 14 per kg
Crop Residues @ 50 paisa per kg
Green manure @ 50 paisa per kg
Farmyard manure @ Rs 325 per tonne
Plant protection @ Rs 1500 per hectare (for both *kharif* and *rabi*)
Urea @ Rs 5.5 /kg
Missourie phos @ Rs 4.5/kg
Muriate of Potash @ Rs6.5/kg

Returns

Price of Grains Rs 7 per kg
Price of Straw Rs 1 per kg