INTEGRATED NUTRIENT MANAGEMENT IN A RICE-RICE CROPPING SYSTEM

By

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DECLARATION

I hereby declare that this thesis entitled **"Integrated nutrient management in a rice-rice cropping system"** 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, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "**Integrated nutrient management in a rice-rice cropping system**," is a record of research work done independently by **Mrs. DEEPA S.** 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

CEC	Cation Exchange Capacity
B.D	Bulk density
WHC	Water holding capacity
Kg	Kilogram
Ha	Hectare
g	Gram
c.c	Cubic Centimeter
%	Per cent
Kg ha^{-1}	Kilogram per hectare
N	Nitrogen
P	Phosphorus
K	Potassium
CSRC	Cropping system research centre
AICRP	All India co-ordinated Research Project
IRRI	International Rice Research Institute
PDCSR	Project Directorate of Cropping Systems Research

Introduction

INTRODUCTION

Rice, the major food crop grown extensively in the world, and the mainstay in Agriculture, contributes to 40 per cent of the total food grain production in India. As per statistics India has to produce an additional 75 million tonnes of food grains to provide food for one billion population. To sustain the present level of self sufficiency, about 3.3 million tonnes of rice has to be added annually, which would be equivalent to about 3 to 3.5 per cent annual growth. (Pillai, 1996). There is no scope for expansion of area under rice and the only possible way to achieve targeted production is the vertical yield increments from the present national average of 1.5 t ha^{-1} to 2.5 t ha^{-1}.

Intensive cropping has become the need of the day and it is possible with the introduction of thermo and photo insensitive high yielding varieties. Rice-rice cropping sequence is the most dominant system in southern parts of India, especially under irrigated conditions. According to Rajkhowa and Baroova (1991) rice-rice sequence is an extensive one which leads to nutrient depletion and affects soil health. Hence the system needs large amount of nutrients to sustain soil productivity. Long term fertilizer experiments conducted at many locations had revealed that even

with the application of recommended dose of fertilizers, it would not be possible to sustain the productivity of rice-rice system (Nambiar *et al.*, 1992). According to Gunjal *et al.* (1991) about 60 per cent of the agricultural land presently under cultivation suffers from serious problem of soil ill health, mainly due to indiscriminate use of chemical fertilizers. More over, the present energy crisis and the sudden hike in fertilizer prices often deter the farmers from using these nutrients in the recommended and balanced proportion. So there is a need to change from non-renewable sources to renewable sources of inputs. All these emphasize the importance of integrated nutrient management in sustainable productivity.

Integrated nutrient management involvesthe use of chemical fertilizers in conjunction with organic sources such as farm yard manure, crop residue, green manure etc. It is a proven fact that organic manure is not a complete substitute for inorganic fertilizers and vice versa. Using both organic and inorganic fertilizers is a workable way to save the costs and to maintain soil health resulting in sustained crop production. In addition to this, the conjunctive use of both sources as complementary and supplementary to each other will meet the nutritional deficiencies which are likely to occur due to continuous and intensive cultivation. Soils receiving organic manures need no application of secondary and micro nutrients (Kumara Samy, 1990).

Till recently, fertilizer recommendations were based on nutrient requirement of individual crops ignoring the residual effect of fertilizers and manures applied to previous crop on the succeeding crop. In order to make fertilizer use more efficient and profitable, the effect of fertilizer on the cropping system as a whole is to be studied rather than on individual crop basis.

A permanent plot experiment on integrated nutrient supply system in the rice-rice crop sequence was started at Cropping Systems Research Centre, Karamana under the AICRP on cropping system in 1985-86. There are 12 sets of treatments. One set of treatment will be completed only after testing in both Kharif and Rabi seasons. The 12 sets of treatments include 4 treatments of different levels of recommended fertilizers; six treatments of integration of chemical fertilizers with organic sources like farm yard manure, crop residues (rice straw) and green manures (glyricidia) along with one each of unfertilized control and farmer's practice of manuring. The major objectives of the trial at the time of formulation were,

(i) to find out the scope for nutrient substitution by organic sources,

(ii) to study whether high yields could be maintained by the itnegrated nutrient sources both on short term and long term basis, and

(iii) to work out the most judicious and economic combination of organic and inorganic fertilizers for formulating feasible recommendation to the cultivators.

On the basis of pooled analysis of data over 7 years from 1987-88 to 1993-94, it was revealed that application of 50 per cent N through FYM and 50 per cent N and full P and K through chemical fertilizers during Kharif followed by 100 per cent of the nutrients through fertilizers during rabi season gave significantly higher grain yields.

Permanent plot experiments become more useful, only when periodical soil analysis and critical examination of the soil test data are made. This will help to identify the residual effects of nutrients and imbalances created due to continuous application of manures and fertilizers either alone or in combination. The effects of organic manure in improving the physical and chemical properties of soils are well known. The comparative efficiency due to prolonged application of farm yard manure, green manure and crop residue along with chemical fertilisers upon the physico-chemical properties of the soil which in turn affect the growth and yield of rice has not been studied in detail under the soil and climatic conditions of southern Kerala. Hence the present study was undertaken to analyse the various parameters which were responsible for the above result.

The present study aims at finding out

(i) the effect of organic manure used in conjunction with inorganic fertilizers on the growth and yield of rice,

(ii) the effect of integrated use of manures and fertilizers on the availability and uptake of major nutrients.

(iii) the changes in the physico-chemical properties of soil under rice-rice cropping system, and

(iv) the residual effects of the combined application of organic and inorganic sources.

Review of Literature

REVIEW OF LITERATURE

An investigation was carried out at Cropping Systems Research Centre, Karamana to find out the effect of organic manures in combinations with inorganic fertilizers on the availability and uptake of major nutrients in a rice-rice cropping system and changes in the physico-chemical properties of the soil for sustaining productivity.

The relevant literature available on the subject are reviewed here under. Wherever sufficient literature was not available on rice-rice system, results of experiment conducted on related crops are also cited.

2.1 Effect of organic manures on growth, yield attributes and yield of rice

Organic manures are considered as efficient nutrient supplementing sources. They improve the physico-chemical properties of the soil and influence the availability and uptake of nutrients.

2.1.1 Organic manures as sources of plant nutrients

Organic manures obtained from plants and animals are considered as valuable source of nutrients for plants, farm yard manure, rural and urban composts, green manures and crop residues supply less quantities

of plant nutrients. These organic manures work like slow release nitrogen fertilisers. Nitrogen is slow acting and only less than 30 per cent of phosphorous and 75 per cent of potassium become available to the immediate crop. The rest of the plant nutrients become available to subsequent crops as their residual effect (Guar, 1984). According to Inoko (1984) only about 25-30 per cent of N contained in compost and farm yard manure could be absorbed by rice plants during one crop season and the accumulated nutrients from the continuous application of organic matter were gradually mineralised and utilised by successive crops which sustained the productivity. The beneficial effects of farm yard manure incorporation on wheat and paddy yields might be due to its richness in almost all nutrients available in slow forms (Nakada, 1980).

Green manures are good source of nitrogen for rice. These are comparatively high in nitrogen, low in C:N ratio and contain considerable amount of plant nutrients such as K, Ca and other mineral elements. Bouldin (1988) showed that green manures contained two fractions, one which decomposes during the 1st rice crop and the other which decomposes slowly over the years. He further observed that with most green manure crops, the 1st fraction was 50-80 per cent of total N. So the residual effect is relatively small when green manure is applied only once. But the cumulative effects of several applications are possible.

Paddy straw considered to be a good source of nutrients contains about 0.6 per cent N, 0.1 per cent P and S, 1.5 per cent K, 5 per cent Si and 40 per cent C. (Ponnamperuma, 1982).

2.1.2. *Effect of organic manure on growth of rice*

Kawata and Soejima (1976) opined that there existed some close relationship between compost or farm yard manure application and development of rice root system. Long term application of farm compost to paddy fields promoted the development of lateral roots. According to Okamura *et al.* (1989) application of organic materials alleviated the decline of roots occurring in rice plants with chemical fertilizer application at the late stage of growth. Song and Zhao (1993) reported that continuous application of manure to paddy fields enhanced root development, by reducing tissue lignification increasing root diameter, providing nutrients, lacking in the rhizosphere and forming chelated Fe. and Mn. Abe *et al.* (1995) found that the use of organic materials as fertilizers increased the number of roots through out the plant growth and also increased the percentage of nodal roots elongated to deeper layers.

Subbiah *et al.* (1983) reported that incorporation of organic residues (10t ha-1) had influence on dry matter production at maturity stage but had no influence in increasing tillers per sq.m and panicles per sq.m. In an experiment to find out the effect of farm wastes and green manures in

lowland rice, it was found that plant height was significantly influenced by the basal incorporation of farm wastes and green leaf manure (Budhar *et al.*, 1991). Sharma (1994) reported that plants with FYM application were taller and produced more tillers and dry matter than those grown without FYM. Incorporation of soybean residue increased plant height and total number of tillers in rice variety CR-1009 (Arul Murugan *et al.*, 1995). Krishna Moorthy *et al.* (1995) found that organic manures increased the dry matter yield of rice at tillering and flowering stages and farm yard manure treatment was superior to green leaf manure in increasing dry matter yield.

2.1.3. Effect of organic manures on yield attributes

Many research works showed that addition of organic manures increased the yield of rice by enhancing the number of productive tillers, number of panicles per sq.m filled grains per panicles and 1000 grain weight. The impact of organic manure on yield attributes of rice are reviewed below.

Subbiah *et al.* (1983) reported that application of organic residues had a significant influence in increasing the dry matter yield, filled grain per panicle, grain yield and straw yield of rice var. Rasi. Among the organic manures sesbania green manure and FYM exerted almost similar effects in increasing the number of productive tillers (Zia *et. al.*, 1992). Akthar *et*

al. (1993) reported that in a rice-rice system, all yield parameters were higher with green manuring except 1000 grain weight. Incorporation of *Ipomoea carnea, Cassia toria and Pystia hysterophorus* @5 t ha^{-1} significantly improved yield and yield components namely panicle length, grains/ panicle and test weight of transplanted rice (Rathore *et al.*, 1993).

Sharma and Sharma (1994) reported that the incorporation of farm yard manure significantly increased the number of panicle per sq.m, spikelets per panicle, spikelet fertility per cent and grain and straw yield over Lantana and Eupatorium green leaf manure. Rathore *et al.* (1995) observed that grain yield and its components Viz number of panicles per sq.m, grains/panicle and 1000 grain weight were significantly higher in blue green algae and farm yard manure treated plots compared with the unfertilized control.

2.1.4 Effect of organic manures on yield of rice

Application of FYM provided considerable direct and residual effect on crop yields and improved soil fertility. Chettri and Rai (1988) observed that the mean yield of rice from plots given FYM alone @ 7t ha^{-1} was 20 per cent higher than check plots. While analysing the effect of continuous application of organic manures and fertilizers on yield of rice, it was found that yield in the FYM applied plots was significantly more than that in the green leaf manure and compost applied plots

(Udayasoorian *et al.*, 1988). Varghese (1990) reported that application of 10t farm yard manure ha^{-1} to rice without inorganic fertilisers produced 3.59t grains/ha and gave the highest input cost ratio.

Sharma *et al.* (1980) found that application of FYM to rice or wheat and especially to both the crops in Rice-Wheat system increased the paddy grain yield. Varma and Dixit (1989) could obtain yield increase in rice-wheat system due to FYM incorporation in both the crop.

Application of *Glyricidia sepium* or farm yard manure alone @ 5t ha^{-1} gave grain yield of 2.73 and 2.36 t ha^{-1} respectively compared with the control yield of 1.49t ha^{-1} Bal *et al.*, 1993). In a pot culture experiment with CV. Jaya, Balagopalan *et al.* (1994) found that application of dried leaves of *Glyricidia sepium* alone increased the grain and straw yield. Matewade and Sheelavantar (1994) found that the grain yield produced with green manure of *Sesbania rostrata* alone was equal to or more than that observed with the application of the recommended dose of N to crops. Bindra and Thakur (1995) also observed increase in yield due to green manuring.

Experiments in Senegal and Philippines have shown that green manuring with *Sesbania rostrata* can substantially increase the grain yield of succeeding rice crop (Meelu and Morris, 1988). In rice-wheat system Kolar *et al.* (1993) found residual response due to green manuring in rice

and they got mean response of wheat to residual effects of green manure as 0.4t ha^{-1}. But Narang *et al.* (1990) could not find any residual effect in wheat yield due to green manuring in rice in a rice-wheat system. Bindra and Thakur (1995) also reported the absence of residual response in wheat due to green manuring.

De *et al.* (1983) reported that incorporation of different crop residues increased the rice yield. Organic amendments with wheat or rice straw or farm yard manure increased the seed and straw yield of rice and seed yield of wheat in rice-wheat system (Kavimandan*et al.*, 1987). Maskina *et al.* (1985) found that incorporation of about 7t ha^{-1} wheat straw and applying 12t FYM ha^{-1} had similar effects on yield and yield attributes and on soil fertility parameters. Incorporation of crop residues after harvest improved soil properties but had no effect on yield (Sharma *et al.*, 1985). In rice-wheat system Sharma *et al.* (1987) could not obtain any beneficial effect on yield of both the crops due to straw incorporation. More (1994) reported that application of rice straw at 5 or 10t ha-1 did not significantly increase rice yield.

2.2 Effect of organic manures on soil properties

Application of organic manure to soil, improves the physical, chemical and biological properties of soil.

2.2.1. Effect of organic manures on physical properties of soil

It is well known that there exists a positive relationship between soil physical properties and amount of organic matter a soil contains. Organic manure application increases soil organic matter level, there by improving the physical condition of soil. The effect of organic manures on soil physical properties are reviewed below.

Organic manures are reported to improve the physical properties of soil (Djokoto and Stephen, 1961). Bulk density of soils decreased by continuous application of farm yard manure and green manure under dry farming situations (Havangi and Mann, 1970). According to Biswas *et al.* (1971) when the dose of organic manure applied was high the bulk density was lowered resulting in the improvement of soil conditions. Rama Swami and Raj (1973) opined that cattle manure enhanced the water holding capacity of the soil.

Application of FYM to rice or wheat and especially to both crops in rice-wheat system improved the physical properties of soil (Sharma *et al.*, 1985). Application of farm yard manure and crop residues significantly lowered the bulk density of the soil and penetrometer resistance and increased the cumulative infiltration and water holding capacity of soil (Sharma *et al.*, 1987; Ganal and Singh, 1988; Bhriguvanshi, 1988 and Sharma

and Sharma, 1994).

Dharwish *et al.* (1995) found that water retention was consistently but slightly improved by organic manure application. They opined that rapid microbial decomposition of the manure could be responsible for the lack of marked changes in the physical properties.

2.2.2 *Effect of organic manures on chemical properties of soil*

Studies revealed that organic manure application to soil improve the organic matter status and enhanced the availability of N, P and K. The effect of organic manures on chemical properties of soil are reviewed below.

A study by Shinde and Ghosh (1971) revealed that organic carbon content in the surface layer of medium black soil was significantly increased by application of farm yard manure at the rate of 5t ha^{-1}. Rama Swamy and Raj (1973) found that cattle manure treatment enhanced the organic matter content and N content of soil. According to Muthuvel *et al.* (1981) available N content of soil was positively influenced by organic matter addition in the permanent manurial experiment at coimbatore under rainfed condition. On the other hand continuous application of organic manures and chemical fertilisers had no effect on the available N content of soil under irrigated conditions. In the permanent manurial trial conducted at Pattambi with tall indica rice variety, continuous application of organic matter as cattle manure alone and as equal amounts of cattle

manure and green manure resulted in significant improvement in organic carbon content of the soil compared to inorganic fertilizer. But in dwarf indica, continuous application of organic matter for 31 seasons in different forms failed to give any significant increase in organic carbon level in the permanent manurial trial in the sandy soils at Kayamkulam (Kurumthottical, 1982). According to Udaya soorian *et al.* (1988) continuous application of organic manure increased the organic carbon contents from 0.911 to 1.584 per cent and among the organic manures farm yard manure had significant influence.

Chellamuthu *et al.* (1989) observed an increase in the organic carbon, available N and P contents of soil by farm yard manure application. It also resulted in the increase in total N content from 0.045 to 0.074 per cent. Ganal and Singh (1990) observed an increased level of available K after farm yard manure application. Varghese (1990) reported that application of 80 kg N as farm yard manure increased the pH of the soil. According to Rai *et al.* (1990) it is possible to increase the organic C, available K and Ca contents in soils by farm yard manure application Dhargave *et al.* (1991) reported an increased availability of phosphorus by the addition of 10 to 20t farm yard manure per hectare. The application of organic manures increases the soil organic carbon content and the available N, P and K (Sharma and Sharma, 1994 and Krishnamoorthy *et al.*, 1995). Dharwish *et al.* (1995) reported that continuous application of organic matter increased the organic carbon content of all the soils tested.

Green manures when incorporated just before transplanting of rice improved the soil environment due to aeration of reducing condition which helped to increase the availability of Fe, Zn and Mn (Thind and Chahal, 1987 and Sadna and Bajwa, 1987). Bala subrahmanian *et al.* (1993) got increased availability of NPK due to green manuring. Kolar *et al.* (1993) could find an increase in the organic carbon content due to green manuring in Rice-Wheat system.

Hwang and Kim (1977) reported that the use of rice straw markedly increased the organic N, K and silica contents in soil. According to Ponnamperuma (1980) rice straw has a positive effect on soil fertility and its continuous application increases the soil N content. Under intensive cropping, if the stubbles are ploughed back into the soil, significant quantities of nutrient would be returned to the soil, which gradually become available to the subsequent crops on decomposition (Ponnamperuma, 1984). Higher quantities of available nitrogen after decomposition of crop residues had been reported by many workers (Tiwari *et al.*, 1980a and Meelu and Rekhi, 1981). Dhillon and Dev (1983) opined that straw incorporation significantly increased the organic C, total N and hexosamine-N and amino acid N. They also observed that available N level was low and it decreased with continuous cropping where straw was continuously incorporated but total N increased by about 20 per cent after 4 crops. Dhillon and Dev (1983) observed an increase in organic carbon

level due to straw incorporation. According to Hesse 1984 liberation of certain forms of fixed P, forms of complex compounds with toxic Fe, buffering effect on pH and increase in CEC are the benefits accrued from organic manure application. Maskina *et al.* (1986) reported that incorporation of 7t ha^{-1} wheat straw and applying 12t farm yard manure ha^{-1} had similar effects on soil fertility parameters and increased soil organic carbon and available N, P and K. Sharma *et al.* (1988) opined that incorporation of organic wastes improved the N content and increased the available P content by 20 per cent.

Results from permanent manurial experiment at Pusa showed that CEC of soil increased with green manuring but the effects of farm yard manure and fertilisers were rather small (Maurya and Ghosh, 1972). Kurumthottical (1982) reported that organic matter application raised the CEC of soils in the permanent manurial trial on rice conducted at RARS, Pattambi. Udayasoorian *et al.* (1988) observed enhancement in CEC with soil application of compost.

2.2.3 Effect of organic manures on biological properties of soil

Effect of continuous manuring on microbial population in rice soils was studied by Nanda *et al.* (1988).The study revealed that bacteria were the important group of microbes followed by actinomycetes and fungi under rice rotation in lateritic sandy soils. Varghese (1990) observed that

farm yard manure application enhanced the natural occurence of *Azolla pinnata* in rice fields.

Toyota and Kimura (1992) observed that the number of antagonistic microorganisms among total micro-organisms were higher in farm yard manure amended soil than in chemical fertilizer amended soil.

2.3 Effect of organic manures on the uptake of nutrients

Rinaudo *et al.* (1983) found that green manure applied to rice significantly increased the N uptake in grain and straw. Application of farm yard manure in maize regulates the uptake of nutrients (Lal and Mathur, 1989a).

In a rice-wheat system incorporation of farm yard manure or straw mulch and farm yard manure + straw mulch increased the NPK uptake both with and without N fertilization in paddy (Varma and Dixit, 1989). Sharma and Mittra (1991) revealed that application of organic materials like wheat straw, farm yard manure, water hyacinth compost @5 t ha^{-1} and dual cropping of Azolla in acid laterite soils increased yield and NPK uptake in rice. Narang *et al.* (1990) reported that green manuring in rice-wheat sequence showed an increased uptake of P and K after two years. Bindra and Thakur (1995) could obtain increased NPK uptake due to green manuring in paddy.

2.4 Effect of INM on growth, yield attributes and yield of rice

A judicious combination of organic, biologic and inorganic sources was found to improve the general growth and yield of rice. The effect of integrated nutrient management on growth and yield of rice are reviewed here under.

2.4.1 Organic manure as a source of nutrient supplement

Meelu and Rekhi (1981) observed that combined use of 12t FYM and 80kg N ha^{-1} gave as much rice yield as with the application of 120 kg N ha^{-1}. It also gave residual effects equivalent to 30 kg each of N and P in berseem-rice cropping system. According to Maskina *et al.* (1986) yields with farm yard manure, piggery manure and 80kg N ha^{-1} were almost equal to those with 120 kg N ha^{-1} alone. Application of any one manure to rice gave a residual effect equivalent to 30 kg N and 13 kg P ha^{-1} in the subsequent wheat crop. Kavimandan *et al.* (1987) observed that yield of rice with farm yard manure and lower rates of NPK were comparable with recommended dose of NPK@ 120-60-40 kg ha^{-1}. Yadvinder singh *et al.* (1988) reported that the application of farm yard manure at 12t ha^{-1} could contribute for about 40 kg N ha^{-1}. Chandrarkar *et al.* (1990) observed that the application of FYM at 8t ha^{-1} and 40 kg N ha^{-1} as urea was on par with 80 kg N ha^{-1} as urea in producing rice yields. Jose Mathew *et al.* (1993) could obtain a saving in the mineral fertilizer requirement of rice to the

extend of 1/3 dose of N and K20 and 2/3 dose of P205 from a recommended fertilizer dose of 70-35-35 kg NPK ha^{-1}, when FYM was regularly applied in all seasons at the rate of 5 t ha^{-1}.Half to one third dose of chemical N could be substituted by organic nitrogen without any yield loss (Malik and Jaiswal, 1993) . The results of experiments conducted in a rice-wheat crop sequence revealed the possibility of saving N and P by 20 and 40 kg respectively by applying FYM to paddy crop (Kaushik *et al.*, 1984).

Khind *et al.* (1982) reported that the combined use of 60 kg N ha^{-1} applied as urea and green manure gave yields as high as that obtained from the level 120 Kg N ha^{-1} without green manuring. According to Narang *et al.* (1990) green manuring contributed 60 kg N ha^{-1} to rice but showed no residual effect in rice-wheat system. Kolar *et al.* (1993) reported that mean rice yields after green manuring+ 60 kg fertilizer N ha^{-1} was similar to rice given 120 Kg N ha^{-1} without green manuring. Bindra and Thakur (1995) reported that the fertilizer dose to paddy could be saved upto 50 per cent due to green manuring in rice. Balasubrahmaniam *et al.* (1993) opined that green manure in combination with chemical fertilizer resulted in better yield and residual effect for the succeeding crop. Saving to the tune of 25 per cent N was observed when fertilisers were combined with green manuring.

Permanent plot experiments on integrated nutrient supply system in rice sequence in different locations revealed that 50 to 25 per cent of fertilizer N could be substituted by locally available organic sources of N like farm yard manure, glyricidia and paddy straw (Vageesh *et al.*, 1990; Jayakrishna Kumar *et al.*, 1994; Hegde, 1996 and Jana and Ghosh, 1996).

2.4.2. *Effect of integrated nutrient management on growth and yield attributes*

According to Sharma and Mittra (1988) the growth and yield of low land rice CV.IR-20 and Ratna increased significantly with the combined use of organic materials and N fertilisers in acid lateritic soils.

Application of organic materials alleviated the decline of roots occurring in rice plants with chemical fertilizer application at later stages of growth (Okamura *et al.*, 1989).In maize-wheat system Lal and Mathur (1989b) observed that in the case of maize, number of roots per plant was maximum in the plots treated with farm yard manure alone but in the case of wheat maximum number of roots was recorded in plots receiving full dose of farm yard manure and fertilizer.

Mandal *et al.* (1990) observed increase in the number of panicles per sq.m, spikelets per panicle, percentage of filled grains and thousand grain weight with increase in NPK rates and farm yard manure application. According to Sharma (1994) the application of FYM at 10t

ha^{-1} one week prior to sowing of rice increased the dry weight of plants and tiller counts. Application of 75 per cent of the recommended dose of NPK (60-30-30 kg ha^{-1}) in conjunction with 10t farm yard manure or crop residue per hectar produced highest and significant number of panicles per sq.m, number of grains per panicle, percentage of filled grains and test weight (Paste *et al.*, 1995).

2.4.3 Effect of Integrated nutrient management on yield

Combined application of inorganic fertilisers along with organic manures produced highest yield of grain and straw (Subbiah *et al.*, 1983; Mahimiraja *et al.*, 1986 and Sharma *et al.*, 1987). In rice or rice-wheat system incorporation of 10-15t farm yard manure along with optimum rates of NPK produced an yield increase of 0.8-1.2t ha^{-1} (Singh and Nambiar, 1986). Yield of rice applied with farm yard manure + lower rates of NPK was comparable with recommended doses of NPK 120-60-40 Kg ha^{-1} (Kavimandan *et al.*, 1987). Mandal *et al.* (1992) reported that by applying 40 kg N ha^{-1} or NPK at 40-20-20 or 60-40-40 or 80-60-60 Kg ha^{-1} to rice they got yields of 3.17, 3.4, 3.59 and 4.05 t ha^{-1} .But with farm yard manure the yields were 3.81, 4.1, 4.59 and 4.86 t ha^{-1} respectively. In a rice-wheat system yield of both crops increased with increasing NPK rates and were higher with FYM than without it (Soni and Sikarwar, 1991).

At Maruteru (A.P) and CSRC, Karamana under rice-rice cropping system it was found that 50 per cent N substitution through farm yard manure in kharif followed by application of 100 per cent chemical fertilizer in rabi produced significantly higher grain yield than applying 100 per cent chemical fertilizer during both the seasons (PDCSR, 1992).In rice-wheat crop sequence where 50 per cent N as chemical fertilizer and the rest 50 per cent N as farm yard manure to rice and 100 per cent NPK as chemical fertilizer to the succeeding wheat crop crop given maximum yield of grain and straw of both rice and wheat could be obtained (AICARP, 1994a).

Rajamannar *et al.* (1995) concluded that combined application of organic manure with recommended levels of N increased the grain and straw yields of rice over sole application of organic manure or N.

Soundarapandian *et al.* (1986) opined that application of green leaf manure during the 1st season (June-Sept) and urea in the IInd season (Oct-Jan) was beneficial to rice. Combined application of green manure and urea to supply equal quantities of recommended N dose gave significantly higher yield than when urea alone was applied in 3 splits (Rabindra *et al.*, 1984). Raju *et al.* 1987 found that the combination of green manure with different rates of NPK recorded higher grain and straw yields over crop residues and NPK separately or in combination. Haroon *et al.* (1992) observed 37 per cent higher grain yield of rice when 50 per cent N was

applied through *Crotalaria juncea* and 50 per cent through urea than a full dose applied as urea. Rekhi and Bajwa (1992) in a rice-wheat cropping system obtained highest rice yields when green manure was combined with 120 kg N ha^{-1}. It also increased the residual yield of wheat by 0.15t ha^{-1}. Kolar *et al.* (1993) reported that the total productivity of rice-wheat cropping with green manure and urea at 60 kg N ha^{-1} to rice and 90 kg N ha^{-1} to wheat was 13.1t ha^{-1} which was significantly more than that of 10.1t ha^{-1} without green manuring.

According to Narasimha Rao *et al.* (1986) application of 120 Kg N ha^{-1} in the form of urea alone and 100 Kg N ha^{-1} as urea+2t of paddy straw/ ha gave high rice grain yield and net profit. Total productivity of rice-wheat crop sequence was highest (5395 Kg/ha) with application of 75 per cent N through chemical fertilisers and 25 per cent through cut straw (AICARP, 1994b).

2.5 Effect of Integrated nutrient management on soil properties

Studies revealed that continuous application of inorganic fertilisers alone deteriorated soil health and affected soil productivity. The effect of integrated nutrient management on soil properties are reviewed here under.

2.5.1. Effect of integrated nutrient management on physical properties

While studying the effect of application of green manure, groundnut cake and FYM alone and in combination with ammonium sulphate it was observed that the over all effects of organic manures were manifested in the improvement of water stable aggregates, hydraulic conductivity and the water retention characteristics and that green manure was better than ground nut cake or FYM in this respect (Biswas *et al.*, 1970).

Results of a study by Manickam and Venkataraman (1972) to find out the effects of prolonged application of various inorganic fertilisers alone and in combination with FYM on physical properties of soil revealed that combined use of organic and inorganic materials had registered low values for bulk density and also proved to be beneficial in increasing the water holding capacity of the soil. The beneficial results by the long term application of FYM in conjunction with chemical fertilisers in improving the bulk density of the soil were also reported by Prasad and Singh (1980). The combined application of inorganic fertilisers with organic manures Viz. FYM or compost improved the physical condition of soil by increasing the hydraulic conductivity, porosity, aggregation, available water content, water holding capacity and reducing the bulk density of soil (Mahanfiraja *et al.*, 1986; Patnaik *et al.*, 1989 and Bhriguvanshi,1988). Application of

compost @ 15t ha^{-1}+ 60-30-30 Kg NPK ha^{-1} over a period of 4 years did not produce any significant change in the soil physical properties (Gurung and Sherchan, 1993).

In a rice-rice crop sequence the use of organics to meet 50 per cent N along with 50 per cent recommended dose of fertilisers recorded lower bulk density.Incorporation of paddy straw either to meet 50 per cent or 25 per cent N along with chemical fertilisers enhanced the hydraulic conductivity, water stable aggregates, porosity, moisture retention capacity and water holding capacity of the soil (Bellakki *et al.* 1995).

2.5.2 Effect of integrated nutrient management on chemical properties

In the permanent manurial experiment on dwarf indica rice at Pattambi, significant variation was observed in available N content of soil Highest value of 106.2 Kg ha^{-1} was observed in treatments where 90 kg N ha^{-1} was supplemented through organic and inorganic sources together with P_2O_5 and K_2O. Lowest quantity of available N was noticed in treatment which received only NPK fertilisers (Kurumthottical, 1982). In a trial to find out the response of wet land rice to nitrogenous fertilisers in soils amended with organic manures, it was found that organic manures exhibited residual effects in terms of available P (Maskina *et al.*, 1989). Liu *et al.* (1990) opined that the complementary use of organic manures with inorganic fertilizer increased the soil organic matter, total N, effectiveness

of soil P, population of soil organisms especially some bacteria and the activity of soil enzymes.

The results of permanent plot experiment on integrated nutrient supply system in rice-rice sequence at ARS, Siriguppa revealed the superiority of bulky organic manures in maintaining soil fertility over inorganic fertilisers. Highest available N (356.2 Kg ha^{-1}) in soil was recorded when 50 per cent NPK was supplied through inorganic fertilizer and 50 per cent through glyricidia. Highest available P (105.5 kg ha^{-1}) was recorded when 75 per cent NPK was supplied through fertilisers and 25 per cent through glyricidia (Vageesh *et al.*, 1990). Prasad and Rokima (1991) opined that the quantity of N, P and K added through chemical fertilizer, organic manure and biofertilisers were effective to build up N and P but not K in rice-rice system.

Sharma and Mittra (1990) opined that the complementary use of chemical fertilisers and organic manures, would augment the efficiency of fertilisers as organic manures affect phosphorus availability in soil through mineralization of organic P, liberation of Ca bound P through Co_2 formation and complexing of Al and Fe-P through increased microbial activity.Studies conducted by Zia *et al.* (1992) on the residual effects of organic manure and inorganic fertilizer indicated that both organic and inorganic sources increased the total N content of soil. The P content of the soil was not appreciably affected by the application of inorganic N

sources and Sesbania green manure. The maximum increase in P content of soil was due to farm yard manure application. All the fertilizer sources had a positive effect on the organic matter content of soil. The increase in organic matter content was maximum for FYM and rice straw and lowest for Sesbania green manure.

Vasanthi *et al.* (1995) reported that in rice-rice system, application of vermicompost at 5t ha^{-1} in both the seasons increased the organic carbon content and the available N status of soil by 87.7 and 42.9 per cent respectively when compared to NPK alone . Long term experiments conducted in rice-rice crop sequence at ARS, Siriguppa showed increase in CEC, available N and K due to long term application of manures and fertilizers (Bellakki *et al.*, 1995).

Studies on permanent plot experiments on different locations indicated that at Kharagpur application of 100 per cent NPK through fertilisers in both seasons and N substitution through green manures resulted in markedly higher available N than with others. In Bhubaneswar organic carbon status increased when organic manures were used for substituting a part of inorganic N. At Maruteru, build up of available P was noticed in treatments receiving 25 per cent N substitution through the farm yard manure (Hegde,1996).

2.6. Effect of integrated nutrient management on nutrient uptake

Tiwari *et al.*: (1980b) reported the beneficial effect of green manure alone and in combination with the fertilizer N on NPK uptake in permanent manurial experiment in upland rice. Chakraborti and Chalam (1992) reported that application of 50 per centrecommended N through green manure and the rest through urea in 2 equal splits recorded higher N uptake in rice. In a long term fertilizer cum manurial experiment on paddy-wheat cropping sequence, application of N and FYM increased the uptake of N,P and K (Sharma *et al.*, 1980). Lal and Mathur (1989b) reported that application of chemical fertilisers in combination with FYM could regulate the nutrient uptake from the soil. Combined application of organic and inorganic manures enhanced the N and P uptake (Singhania and Singh, 1991) and NPK uptake (Mandal *et al.*, 1993).

Studies conducted at ARS, Siriguppa indicated that there was no appreciable variation in the uptake of NPK by rice sequence when bulky organic sources were used in conjunction with inorganic fertilisers as compared to 100 per cent nutrient supply through inorganic fertilisers. Maximum uptake of NPK (489.1Kg ha^{-1}) was observed when 150 per cent of recommended dose of NPK was applied through inorganic fertilisers. Next to this, highest N (177 Kg ha^{-1}) and P (29.7 Kg ha^{-1}) uptake were recorded when 50 per cent NPK was supplied through glyricidia Highest K uptake was recorded when 75 per cent of NPK was supplied through

inorganic fetilisers and 25 per cent through glyricidia (Vageesh *et al.*, 1990). Jana and Ghosh (1996) reported that in a rice-rice crop sequence, for the rainy season rice, the uptake of NPK was more when 75 per cent of the fetilisers were applied as inorganic and 25 per cent as organic source where as in winter season maximum uptake of the nutrients by rice was recorded when 100 per cent of NPK was supplied as inorganic fertilizers.

2.7 Effect of integrated nutrient management on sustained productivity

Gill and Meelu (1982) opined that in addition to biological nitrogen fixation integrated use of organic manures and inorganic fertilisers could contribute to the increase in the N content of rice soils as well as to the increase in the long term productivity and enhancement in ecological sustainability. Continuous use of FYM alone or in combination with fertilisers had resulted in the highest degree of stability in crop yields (Ghosh, 1987). The combined use of organic and inorganic nutrient sources is an effective strategy for sustaining soil productivity (IRRI, 1988). According to Nambiar and Abrol (1989)integrated use of organic and inorganic fertilisers was effective in arresting the deterioration in productivity under intensive farming through correction of marginal deficiencies of secondary and micro nutrients in the course of decomposition of organic manures and its beneficial properties on soil. Panda and Sahoo (1989) advocated the application of 5-10t ha^{-1} of FYM in addition to fertilizer for sustained production in rice.

At Chiplima (Orissa) under rice-rice sequence total grain productivity was higher (10282 kg ha^{-1}) when 25 per cent N in Kharif season was substituted by FYM as compared to the treatment which received 100 per cent chemical fertilizer during both the seasons (PDCSR, 1990). Under rice based cropping system, use of 100 per cent chemical fertilisers alone gave 15-36 per cent higher yield in the initial 2 years but in the following years a combination of organic sources with chemical fertilizers resulted in higher yield compared to chemical fertilisers alone (Yadav *et al.*, 1987). Sustained rice yields could be obtained under integrated nutrient management at Rajendranagar where the grain yield and NPK uptake were highest in treatments when part of N was substituted by paddy straw (AICARP,1994c). According to Rao and Moorthy (1994) organic and inorganic fertilisers applied in equal proportion can be used to realise higher and sustained yields in irrigated rice.

Materials and Methods

MATERIALS AND METHODS

An investigation was carried out at Cropping Systems Research Centre, Karamana with the objective to find out the effect of organic sources in conjunction with inorganic fertilizers on the availability and uptake of major nutrients and changes in the physico-chemical properties of the soil due to continuous manuring and also for sustained productivity in a rice-rice cropping system.

The experiment was done during the second crop season from October to February in the year 1995-96. The details of the materials used and methods adopted for the study are presented below.

3.1 Experimental Site

The experiment was conducted at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, a sub-station under NARP (Southern region) of the Kerala Agricultural University. It is located at 8.5°N latitude and 76°.9 E longitude and at an altitude of 29m above mean sea level.

3.2 Soil

The soil of the experimental site was sandy loam with pH 5.3, low in cation exchange capacity, high in organic carbon, low in available N and medium in available P and K contents. Soil samples were collected from 30 cm depth and a composite sample was used for ascertaining the chemical properties. The important physico-chemical properties of soil of the experimental site are given in Table 1.

Table 1. Physico-chemical properties of soil of the experimental site

1.	Mechanical composition		
		Sand	72%
		Silt	7%
		clay	20%
2.	Texture		Sandy loam
3.	pH		5.3
4.	EC (dS m^{-1})		0.016
5.	CEC (C mol (P+)Kg^{-1})		6.84
6.	Organic Carbon (%)		1.19
7.	Available N (Kg ha^{-1})		156.0
8.	Available $P_2 0_5$ (Kg ha^{-1})		31.0
9.	Available K_2O (Kg ha^{-1})		178.0
10.	Bulk density (g cm^{-3})		1.30

3.3 Season

The experiment was conducted during the rabi season of 1995-96 from 13th October 1995 to 12th February 1996.

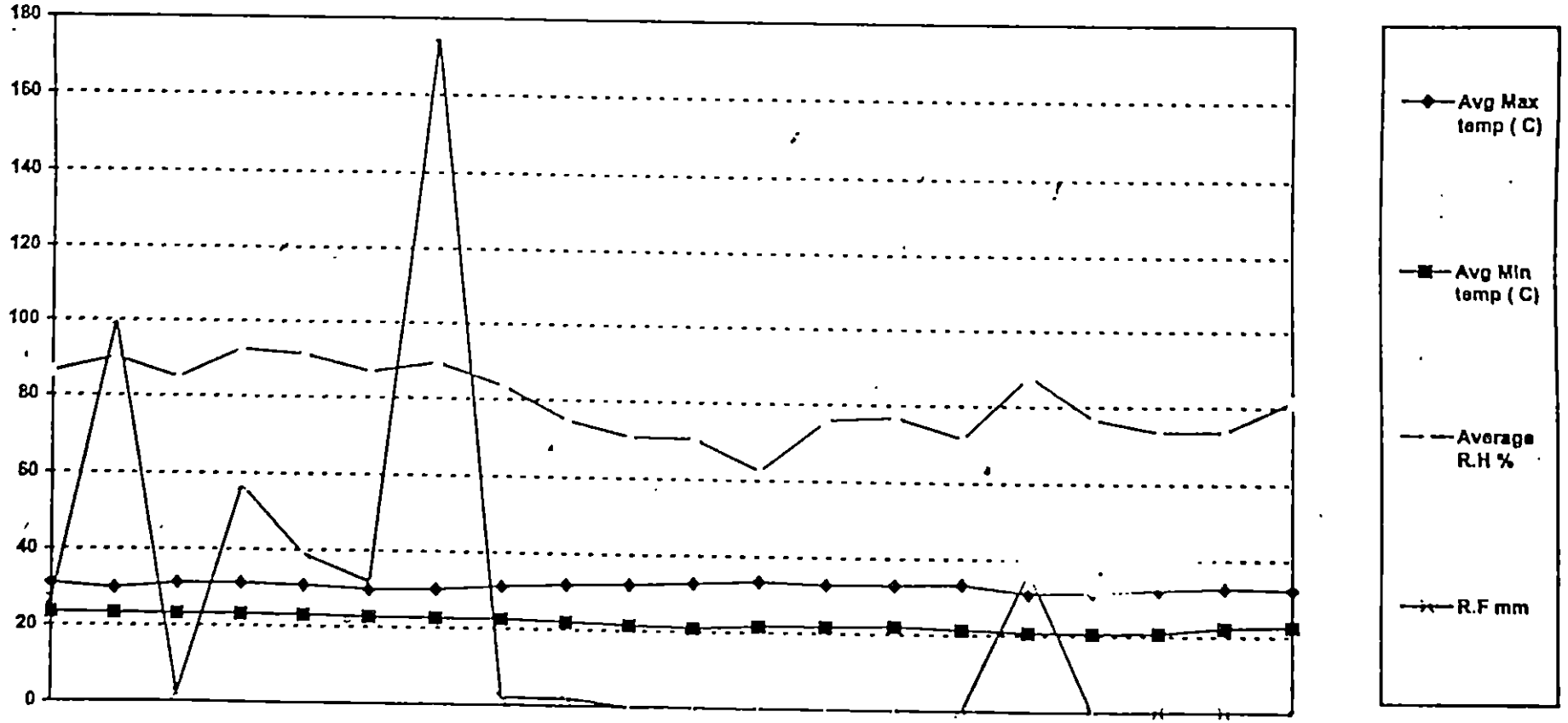
3.4 Weather conditions

Data on weather conditions like temperature, rainfall and relative humidity were obtained from Indian Meterological Department observatory, Thiruvananthapuram. Weather conditions were satisfactory for proper growth and establishment of the crop. The average values of climatic parameters for the cropping period are given in Appendix-1 and graphically represented in figure 1. Mean maximum and minimum temperature ranged from 30°C to 33.4°C and 20.7°C to 23.5°C respectively. The mean relative humidity ranged from 62.5 to 92.5%. The total rain fall received during the cropping period was 473mm, in 10 days.

3.5 Cropping history of the field

A permanent plot experiment was started in the year 1985-86 at Cropping Systems Research Centre, Karamana. The regular sets of treatments had been tested in both Kharif and rabi seasons in all the years. The experiment is being continued.

Fig:1 - Weather Data During the Cropping Period from 01.10-95 to 11.02-96



Standard Week Starting from 01.10.95 to 17.02.96

3.6 Materials

3.6.1 Seeds

The rice variety, selected for the experiment was 'Kanchana' (Ptb-50), the progeny of a cross between IR-36 and Pavizham. It was released from RARS, Pattambi, Kanchana is having a duration of 100-120 days with red kernels. The variety is resistant to blight and blast diseases and stem borer and gall midge. The seeds were obtained from CSRC, Karamana.

3.6.2 Manures and fertilizers

N, P and K were applied as urea (46 per cent N), Mussoriephos (20.5 per cent P205) and Muriate of potash (60 per cent K20). In rabi season, there was no application of organic manures

3.7 Methods

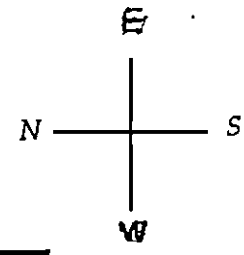
3.7.1 Design and layout

The experiment was laid out in randomized block design which comprised 12 sets of treatment combinations distributed over kharif and

rabi seasons. The treatments were replicated four times. The layout plan of the experiment is given in Fig.2. The details of the layout are given below.

Design	Randomized block design
Treatments	12
Number of blocks	4
Number of replications	4
Plot Size	
Gross plot	16 × 6.3m = 100.8m^2
Net plot	
Kharif	15.2 × 5.7m = 86.64m2
rabi	15.2 × 5.9m = 89.68m^2
Spacing	
Kharif	20 × 15cm
Rabi	20 × 10cm
Variety	Kanchana (Ptb 50)
Fertilizer recommendation	90-45-45 kg NPK ha^{-1}

Fig. 2 layout Plan - Randomised block design



	T_4	1	T_8	24	T_{10}	25	T_9	48
R_4	T_6	2	T_{12}	23	T_1	26	T_7	47
	T_3	3	T_2	22	T_5	27	T_{11}	46
	T_9	4	T_8	21	T_{11}	28	T_{12}	45
R_3	T_7	5	T_3	20	T_1	29	T_2	44
	T_4	6	T_6	19	T_{10}	30	T_5	43
	T_2	7	T_9	18	T_1	31	T_{10}	42
R_2	T_3	8	T_8	17	T_4	32	T_{11}	41
	T_{12}	9	T_5	16	T_6	33	T_7	40
	T_9	10	T_8	15	T_1	34	T_3	39
R_1	T_5	11	T_4	14	T_6	35	T_7	38
	T_{12}	12	T_{11}	13	T_2	36	T_{10}	37

Treatments	Kharif	Rabi
T1.	No fertilizer, no organic manure (control)	No fertilizer, no organic manure (control)
T2	50 per cent recommended NPK through fertilizers	50 per cent recommended NPK through fertilizers
T3	50 per cent recommended NPK through fertilizes	100 per cent recommended NPK through fertilizers
T4	75 per cent recommended NPK through fertilizers	75 per cent recommended NPK through fertilizers
T5	100 per cent recommended NPK through fertilizers	100 per cent recommended NPK through fertilizers
T6	50 per cent recommended N through FYM + 50 per cent N and full P and K through fertilizers.	100% recommended NPK through fertilizers
T7	25 per cent recommended N through FYM+75 per cent recommended N and Full P and K through fertilizers	75 per cent recommended NPK through fertilizers
T8	50 per cent recommended N through crop residue +50 per cent recommended N and full P and K through fertilizers.	100 per cent recommended NPK through fertilizers
T9	25 per cent recommended N through crop residue + 75 per cent recommended N and full P and K through fertilizers.	75 per cent recommended NPK through fertilizers

T10	50 per cent recommended N through green manure + 50 per cent recommended N and full P and K through fertilizers.	100 per cent recommended NPK through fertilizers
T11	25 per cent recommended N through green manures+75 per cent recommended N, and full P and K through fertilizers.	75 per cent recommended NPK through fertilizers
T12	Farmers' practice (100 per cent recommended N and 50 per cent of recommended P and K through chemical fertilizers)	Farmers' practice. (100 per cent recommended N and 50 per cent of recommended P and K through chemical fertilizers)

3.8 Field culture

3.8.1 Land preparation

The experimental plots were puddled twice and levelled. Weeds and stubbles were removed. After clearing and thickening of the bunds the plots were again dug and perfectly levelled.

3.8.2 Fertilizer application

Urea, Mussorie phos and Muriate of potash were applied to each plot as per the treatments. Full amount of P, one third N and half K were applied to the experimental plots before final Ploughing and thoroughly incorporated at the time of final ploughing. One third nitrogen was applied at the time of active tillering and one third N and half K were applied at the time of panicle initiation. The plots were drained one day prior to fertilizer application and after 48 hours water was allowed to stand.

3.8.3 Seeds and sowing

Pre-germinated seeds at the rate of 60 kg ha^{-1} were broadcast on the nursery area. After 20 days, the seedlings were pulled from the nursery and transplanted in the main plots at a spacing of 20x10cm with two seelings per hill.

3.8.4 Maintenance of crop

Transplanting was done when the field was having a thin film of water. Subsequently the water level was raised to about 5cm. Two hand weedings were done 20 days and 45 days after transplanting.

Two sprayings of Dimecron against leaf stem borer and one spraying of Hinosan against Helminthosporium leaf spot were given in the vegetative stage of the crop. After flowering, one spraying with Metacid was given against Rice bug. No other pests or diseases were found on the crop in magnitudes requiring chemical control.

The plots were drained completely one week prior to harvest.

3.8.5 Plant sampling

Samples were collected from the area left for sampling. Four hills were randomly selected within the net plot area to record biometric observations.

3.8.6 Harvest

The crop was harvested after taking necessary observations. The border and sampling rows were harvested separately. Net plot area of individual plot was harvested and weight of grain and straw recorded.

3.9 Observations

Observations on growth characters, yield attributes, yield and uptake studies were made from 8 selected treatments.

(T1, T5, T6, T7, T8, T10 and T11)

3.9.1 Growth characters

3.9.1.1 Number of tillers per hill

Total number of tillers per hill was recorded at active tillering, panicle initiation and at harvest stages from 4 hills selected randomly from the sampling area. Tiller number was then expressed as total number of tillers per hill.

3.9.1.2 Number of roots per hill

The number of fully developed roots were counted from the pulled out plants and expressed as total number of roots per hill.

3.9.2 Yield attributes and yield

3.9.2.1 Number of productive tillers per hill

The productive tillers of the four hills selected from sampling area were recorded before harvest and expressed as productive tillers per hill.

3.9.2.2 1000 grain weight

The weight of the 1000 grains of the samples drawn from the cleaned produce from each plot was recorded in grams.

3.9.2.3 Sterility per cent

The sterility per cent was worked out by using the formula.

$$\text{Sterility per cent} = \frac{\text{Number of unfilled grains}}{\text{Total number of grains}} \times 100$$

3.9.2.4 Grain Yield

The grain harvested from each net plot were dried, cleaned, weighed and expressed as t ha^{-1}.

3.9.2.5 Straw yield

The straw harvested from each net plot was dried to constant weight under sun and the weight expressed as t ha^{-1}.

3.9.3 Plant analysis

The whole plants of rice at active tillering, panicle initiation and harvest stages were analysed for nitrogen, phosphorus and potassium. In the case of rice, the grains were analysed separately. The samples were dried to constant weight in an electric hot air oven at 70°C, ground and passed through a 0.5mm mesh in a willey mill. The required quantity of samples were then weighed out accurately in an electronic balance, subjected to acid extraction and the nutrient contents were determined and expressed on dry weight basis.

3.9.3.1 Total nitrogen content

Total nitrogen content was estimated by modified micro kjeldahl method as suggested by Jackson (1973).

3.9.3.2 Total phosphorus content

Total phosphorus content was estimated by Vanado-molybdo-phosphoric yellow color method. (Jackson, 1973) and read in a Klett Summerson photo electric colorimeter.

3.9.3.3 Total potassium content

Total potassium content in plant was estimated by flame photometry and K20 content was read in a Flame photometer (Jackson, 1973).

3.9.4 Uptake studies

The total uptake of nitrogen, phosphorus and potassium by rice crop at active tillering, panicle initiation and at harvest were calculated as the product of the content of these nutrients in the plant sample and the respective dry weight and expressed as Kg ha^{-1}.

3.9.5 Soil analysis

Composite soil samples collected separately from 8 selected treatments before the start of the experiment and after the harvest of the crop were analysed to determine the available nitrogen, available

phosphorus and available potassium, organic carbon and physical properties such as bulk density, water holding capacity and cation exchange capacity.

3.9.6 Statistical analysis

The data generated were subjected to analysis of variance (Gomez and Gomez, 1976). Whenever the results were significant, the critical difference was worked out at five or one per cent probability.

Results and Discussion

RESULTS AND DISCUSSION

Integrated nutrient management involves the use of chemical fertilizers in conjunction with organic sources such as farm yard manure, crop residue, green manure etc.The conjunctive use of both sources as complementary and supplementary to each other will maintain soil health and also is a way to save the costs. An experiment was conducted at the Cropping Systems Research Centre, Karamana during the second crop season from October to February in the year 1995-96. The objective of this experiment was to study the effect of integrated nutrient management on the availability and uptake of major nutrients and the changes in the physico-chemical properties of soil. The results of the experiment entitled "Integrated nutrient management in a rice-rice cropping system" are presented and discussed below

4.1 Growth attributes

4.1.1. Number of tillers per hill

The mean number of tillers per hill taken at different growth stages are presented in Table 2.At active tillering and panicle initiation stages the treatment effect was significant. However at harvest stage there was no significant difference among treatments

Table 2. Effect of treatments on growth attributes

Treatments	Number of tillers at different growth stage				Number of roots at different growth Stages		
	Kharif	Rabi					
	Harvest	a.t	p.i	harvest	a.t	p.i	harvest
T1	5.93	4.44	6.31	8.81	74.81	102.63	67.94
T5	5.98	5.94	9.91	10.00	88.38	161.38	81.88
T6	6.73	6.25	11.25	11.56	109.88	180.25	113.25
T7	6.48	7.06	11.25	12.00	116.81	155.94	94.90
T8	6.98	5.19	11.52	10.94	81.81	171.58	103.56
T9	7.75	6.69	10.06	9.13	96.75	133.19	91.44
T10	6.68	5.00	10.81	9.88	96.63	144.50	89.06
T11	7	5.81	11.13	8.94	132.00	185.06	88.31
F	NS	4.319**	6.881**	NS	5.155**	3.87**	NS
SE (m)*	0.548	0.426	0.650	1.032	8.365	13.829	15.314
CD (0.05)	—	1.252	1.911	—	24.607	40.679	—

NS - Not significant; * - Significant at 5% level; ** = Significant at 1% .

From the results, it was clear that the number of tillers per hill at active tillering stage in treatment receiving 100 per cent of chemical fertilizer alone in both the seasons (T5) was on par with other treatments which received 50 or 25 per cent N substitution by organic manure in the Kharif season followed by 100 or 75 per cent recommended NPK through chemical fertilizers in rabi. It was also observed that the treatment which received 50 per cent N substitution by farm yard manure in Kharif and 100 per cent recommended NPK through chemical fertilizers in rabi (T6) showed no significant difference with treatments which received 25 per cent substitution by farm yard manure, (T7) crop residue (T9) or green manuring (T11) in Kharif followed by 75 per cent recommended NPK through chemical fertilizer in rabi. At panicle initiation stage all the treatments were found to be superior to control (no organic manure and no chemical fertilizer in kharif and rabi). Except control all the treatments were found to be on par. Though there was no significant difference in the number of tillers per hill at harvest, maximum number of tillers were recorded is treatments which received organic manure during kharif. During kharif, at harvest stage, the treatment which recieved 25 per cent recommended dose of N through crop residues (T9) recorded higher tiller counts. But in rabi, the treatment which received 25 per cent of recommended N through farm yard manure in kharif (T7) produced higher tiller counts. This may be due to the improvement in the physico-chemical properties of the soil,

which inturn influenced the growth of the crop. This is in confirmity with the results obtained by sharma (1994) and Arulmurugan *et al.* (1995). But Subbiah *et al.* (1983) found that incorporation of organic residues had no influence in increasing tillers per sq.m.

4.1.2 Number of roots per hill

Number of roots per hill obtained from different treatments are presented in Table 2. There was significant difference between treatment at active tillering and at panicle initiation stages but there was no significant difference at harvest.

The number of roots per hill at active tillering and at panicle initiation stages are found to be maximum in treatment which received 50 per cent of recommended N through green manure in kharif followed by 75 per cent of recommended NPK through chemical fertilizers. Number of roots per hill obtained from plots receiving chemical fertilizers alone in both seasons (T5), plots receiving 50 per cent recommended N through crop residue (T8) or green manure (T10) in Kharif and plots receiving 25 per cent of recommended N through crop residue (T9) in Kharif did not respond to treatments at active tillering stage. But at panicle initiation stage plots receiving 25 per cent of recommended N through crop residue in Kharif followed by 75 per cent of recommended NPK through chemical fertilizers in rabi(T9) was on

par with control. However at harvest stage no significant difference in the number of roots was observed both in treated and untreated plots. Through out the growth of the crop plots receiving organic manures in Kharif either to supplement 25 or 50 per cent of recommended dose in Kharif followed by 75 or 100 per cent of recommended NPK through chemical fertilizers in rabi produced better root counts. There are several reports which showed continuous addition of manure to paddy enhancing the number of roots (Song and Zhao. 1993 and Abe *et al.*,1995).

4.2. Yield attributes

4.2.1. Productive tiller per hill

The mean number of productive tillers per hill are presented in Table 3. Number of productive tillers per hill was not influenced by the treatments in Kharif and rabi. However number of productive tillers were higher in rabi than that in the Kharif seasons. Though statistically not significant maximum number of productive tillers in rabi were recorded in plots receiving 25 per cent of recommended N through farm yard manure in Kharif followed by 75 per cent of recommended NPK through chemical fertilizers in rabi (11.56).(T7) But in kharif maximum number of productive tillers were recorded in plots receiving 25 per cent of recommended N through crop residue and the rest through chemical fertilizers (T9).

Table 3. Effect of treatments on yield attributes

Treatments	Number of productive tillers per hill		1000 grain weight (g)	Sterility per cent
	Kharif	rabi		
T1	5.73	7.81	21.15	21.67
T5	5.75	8.25	24.80	20.69
T6	6.65	10.13	24.26	10.85
T7	6.43	11.56	27.07	14.59
T8	6.55	9.56	26.24	12.71
T9	7.38	8.19	25.95	12.67
T10	6.43	9.25	24.22	18.42
T11	6.58	8.00	24.17	17.94
F	NS	NS	3.170*	2.547*
SE(m)	0.512	1.034	1.016	0.317
CD (0.05)	—	—	2.988	0.933

NS - Not significant; * - Significant at 5% level

The performance of organic manure applied plots were better than untreated and complete inorganic fertilizers. The treatment which received organic manure in Kharif either as farm yard manure or crop residue produced higher productive tillers per hill both in Kharif and rabi seasons. The increase in productive tillers may be due to adequate nitrogen availability at all the critical growth stages of the crop. Application of farm yard manure in increasing the productive tillers per hill was reported by several workers (Mandal *et al.*, 1990; Sharma and Sharma, 1994 and Rathore *et al.*, 1995). But Subbaih *et al.* (1983) obtained no influence in increasing panicles per sq.m due to incorporation of organic residues. Paste *et al.* (1995) also reported highest and significant increase in panicles per sq.m. due to combined application of 75 per cent of recommended dose of NPK and 10t farm yard manure or crop residue per ha. According to Abe *et al.* (1995) it is possible to increase the number of productive tillers per hill through the application of chemical fertilizers.

4.2.2. 1000 Grain Weight

Thousand grain weight, recorded from different treatment are presented in Table 3. The results indicated that all the treated plots recorded a significant increase in thousand grain weight over control . However no significant difference among treatment was observed. Among the treatments, the treatment which received either 25 or 50 per cent of recommended N through farm yard manure or crop residue in

Kharif recorded higher values of 27.07g and 26.24g. The results indicated that organic manuring in soil could increase the thousand grain weight. Long term application of organic manures in soil is responsible for long and sustained availability of plant nutrients. Many workers reported increase in thousand grain weight due to long term application of organic manures and inorganic fertilizers (Mandal *et al.*, 1990; Arulmurugan *et al.*, 1995 and Rathore *et al.*, 1995). Akthar *et al.* (1993) could obtain enhancement in all yield parameters, except thousand grain weight due to green manuring.

4.2.3. Sterility percentage

Sterility percentage obtained from different treatments are presented in Table 3. The sterility percentage ranged from 10.85 to 21.67. Plots receiving 50 per cent of recommended N through farm yard manure in Kharif (T6) recorded the minimum sterility percentage (10.85) and it was significantly low in comparison with other treated plots. The above treatment was found to be on par with treatments which received 50 (T8) or 25 (T9) per cent of recommended N through crop residue in Kharif. Except control, maximum sterility percentage was obtained in treatments which received chemical fertilizers alone in both seasons(T5) . The results revealed that a considerable reduction in sterility percentage could be obtained due to organic manure application. Subbiah *et al.* (1983) and Sharma and Sharma (1994) also

observed similar trends. Increased availability of potassium by organic manure addition was reported by Ganal and Singh (1990). The low sterility percentage obtained in the organic manure applied plots may be attributed due to increased availability of potassium.

4.3 Yield

4.3.1 Grain Yield

Mean grain yield recorded from different treatments are presented in Table.4. In Kharif all the treated plots recorded a significant increase in yield except in treatment receiving 50 or 25 per cent of recommended N through green manuring. Maximum yield was recorded in treatment received 50 per cent of recommended N through farm yard manure in Kharif (T6) (3.68 t-ha^{-1}). In rabi all the treated plots recorded significant increase in yield. The lowest yield being recorded for treatments which received chemical fertilizers alone in both seasons (T5) and highest in T6 (plots receiving 50 per cent of recommended N through farm yard manure in Kharif followed by 100 per cent recommended NPK through chemical fertilizers in rabi). Plots receiving 50 or 25 per cent of recommended N through green manure (T10 or T11) was found to be on par with plots receiving chemical fertilizers alone in both seasons (T5). The maximum yield recorded treatment, T6 (plots

Table 4. Effect of treatments on grain yield and straw yield

Treatments	Yield			
	Grain ($t\ ha^{-1}$)		Straw ($t\ ha^{-1}$)	
	Kharif	Rabi	Kharif	Rabi
T1	2.95	1.93	5.98	3.67
T5	3.39	2.43	7.70	5.01
T6	3.68	3.20	7.86	6.51
T7	3.46	2.99	7.61	6.12
T8	3.32	2.76	6.92	6.06
T9	3.38	2.81	6.88	5.73
T10	3.25	2.75	6.38	5.48
T11	3.04	2.59	6.37	5.50
F	3.569*	12.073**	2.505*	2.680*
SE(m)	0.123	0.109	0.626	0.169
CD(0.05)	0.362	0.323	1.842	0.499

Table 4(a) Corelation of Soil N, P and K prior to the experiment with grain and straw yield

Available Nutrients	Kharif		Rabi	
	Grain yield	Straw yield	Grain yield	Straw yield
Available N	NS	– 0.2861	0.6837**	0.6551**
Available P_2O_5	NS	– 0.2399	0.3722*	0.3976*
Available K_2O	– 0.2592	– 0.3978	0.5785**	0.5685**

** - Siginificance at 1% level; * - Significance at 5% level; NS - Not significant

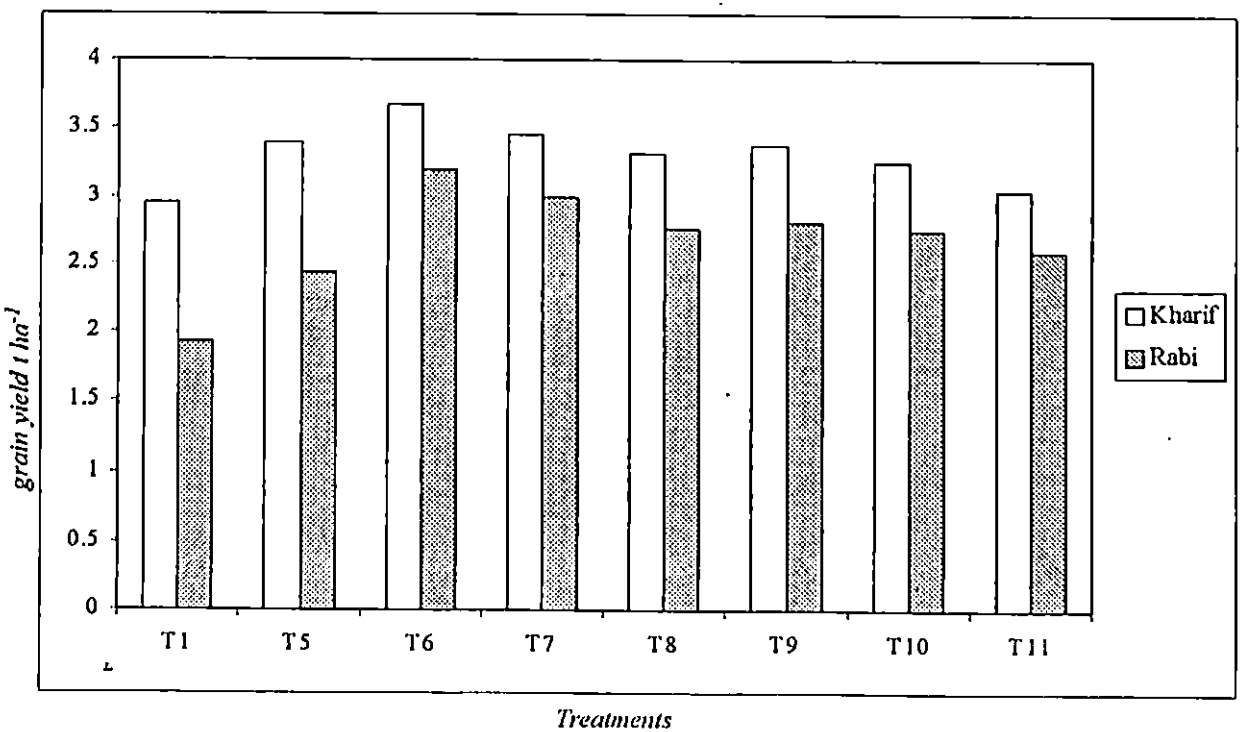
receiving 50 per cent of recommended N through farm yard manure in Kharif followed by 100 per cent of recommended NPK) was however on par with plots receiving 25 per cent of recommend N through farm yard manure in Kharif followed by 75 per cent of recommended NPK through chemical fertilizer in rabi (T7). When compared with the yield obtained in Kharif reduction in yield was observed in rabi.

The grain yield of both Kharif and rabi increased significantly due to application of different organic and inorganic sources of fertilizers compared with the control. Treatments which received 50 or 25 per cent of the recommended N through organic manure (farm yard manure or Green manure or crop residue) in Kharif produced better yield in rabi when compared to 100 per cent recommended NPK through chemical fertilizers in both seasons. A sharp increase in yield of rabi rice was observed when in Kharif the recommended 100 per cent does was split into half inorganic and half organic form of farm yard manure. Several workers reported that the application of organic manure to paddy improved the grain yield. (Subbiah *et al.*, 1983; Mahimiraja *et al.*, 1986; and Sharma *et al.*, 1987 John kutty and Anila Kumar, 1991). The results of the long term experiments conducted at RARS, Pattambi from 1973 to 1985 also showed the superiority of cattle manure application in increasing grain yield (KAU, 1991). Beneficial effect of farm yard manure application in increasing grain yield had been reported by Kurumthottical (1982)., Kavimandan *et al.* (1987)., Udaya

soorian (1988) and Padmam (1992) Application of crop residue improved the grain yield as reported by Narasimha Rao *et al.* (1986). Many workers could not obtain residual effects of green manuring in rice (Maskina *et al.*1986 and Narang *et al.*, 1990). According to Kolar *et al.* (1993) the residual effects of green manure application in rice could significantly increase the yield of wheat due to an increase in organic matter content of soil in a rice-wheat system. In the present study lower grain yield was noticed in the treatment which received inorganic fertilizer alone in both the seasons. Nambiar *et al.* (1992) reported that even with the application of recommended dose of fertilizers it would not be possible to sustain the productivity of rice-rice system without organic manure addition.

As seen from Table 4(a) available N,P and K prior to the rabi crop showed significant positive correlation with yield.The results from the present study clearly revealed that application of organic manure along with chemical fertilizer was essential to maintain high yields. The reason for higher grain yield by the residual effect of treatments receiving organic manure in conjunction with chemical fertilizer may be due to the addition of organic matter. This might have resulted in the slow release of nutrients and consequently better residual fertility. The results thus clearly indicated that the effect of application of organic manure was due to the improvement in the physico-chemical properties of soil such as bulk density, water holding capacity, cation exchange

Fig. 3. Effect of treatments on Kharif and Rabi grain yield



capacity and the availability of nutrients. The yield increase observed with the addition of organic manure in the presence of chemical fertilizer was brought about by the appropriate positive changes occurred in plant growth and yield attributes. The nutrient supplementation and enhancing the efficiency of applied inorganic nutrients by improving the physico-chemical properties of soil through organic manure addition were reported by several workers. (Saravanan *et al.*, 1987 and Soni and Sehgal, 1989).

In rabi the increase in yield was 6.48 to 31.46 per cent, with different organic sources, compared to that with 100 per cent through fertilizers in both the seasons. All the three organic sources used (farm yard manure, crop residue and green manure)could effectively substitute 25-50 per cent N needed without any adverse effect on productivity. In a rice-rice cropping system N substitution upto 25 per cent through any source during kharif enabled fertilizer economy to the extent of 25 per cent in the rabi season without any significant adverse effect.

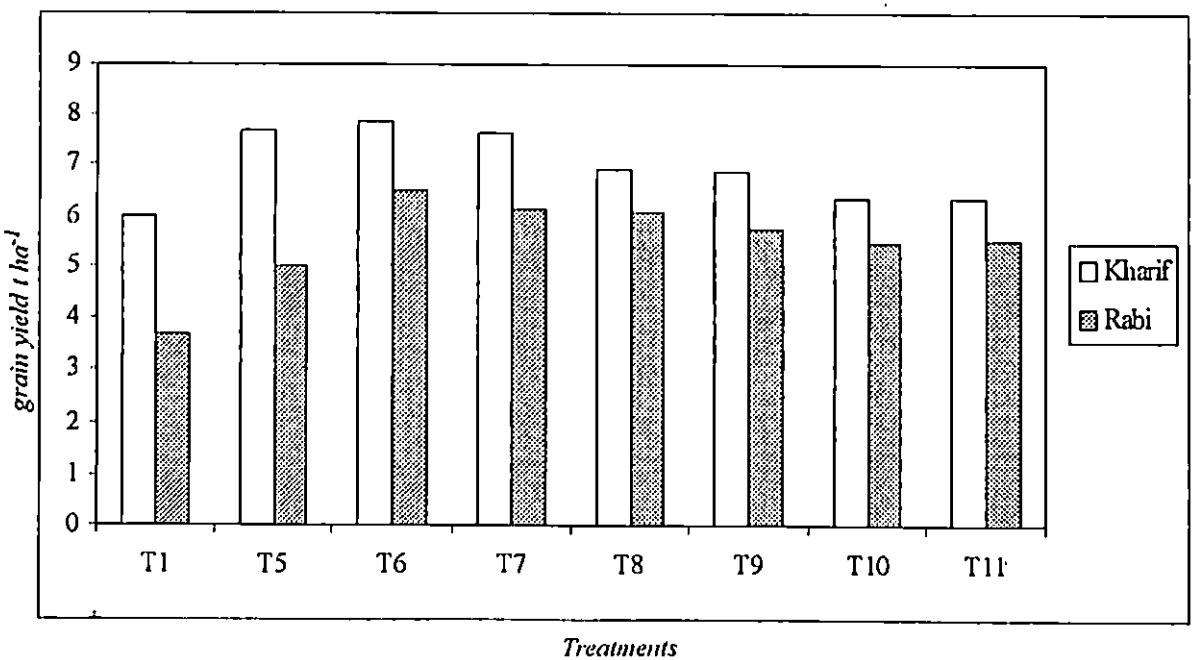
4.3.2. Straw yield

The straw yield in t ha^{-1} is presented in Table 4.

During kharif maximum straw yield was recorded from plots receiving 50 per centrecommended N through farm yard manure in kharif (9.58 t ha^{-1}). However this was found to be on par with all other treatments except control .In rabi all the treated plots recorded a significant increase in straw yield. Here also maximum straw yield was recorded from T6 (plots receiving. 50 per cent of recommended N through farm yard manure in Kharif followed by 100 per cent of recommended NPK through chemical fertilizers in rabi) and minimum in plots receiving chemical fertilizers alone in both seasons (T5). This was found to be on par with plots receiving 50 or 25 per cent recommended N through green manure in Kharif. The maximum straw yield recorded treatment (T6) was found to be on par with plots receiving 25 per cent of recommended N through farm yard manure (T7) and 50 per cent of recommended N through crop residue in Kharif(T8).

Plots which received organic manure in kharif was found found to be on par and produced better straw yield than treatment which received 100 per cent recommended NPK through chemical fertilizer in both seasons. The results clearly indicted that organic manure application in Kharif could increase straw yield in rabi. This is in confirmity with the results obtained by Subbiah *et al.* (1983)., Mahimiraja *et al.* (1985)., Sharma *et al.* (1987)., and Kavimandan *et al.* (1987).

Fig. 4. Effect of treatments on Kharif and Rabi straw yield



4.4 Nutrient uptake

The data on uptake of major nutrients by the crop at different growth stages are presented in Table 5a to 5c.

4.4.1 Nitrogen uptake

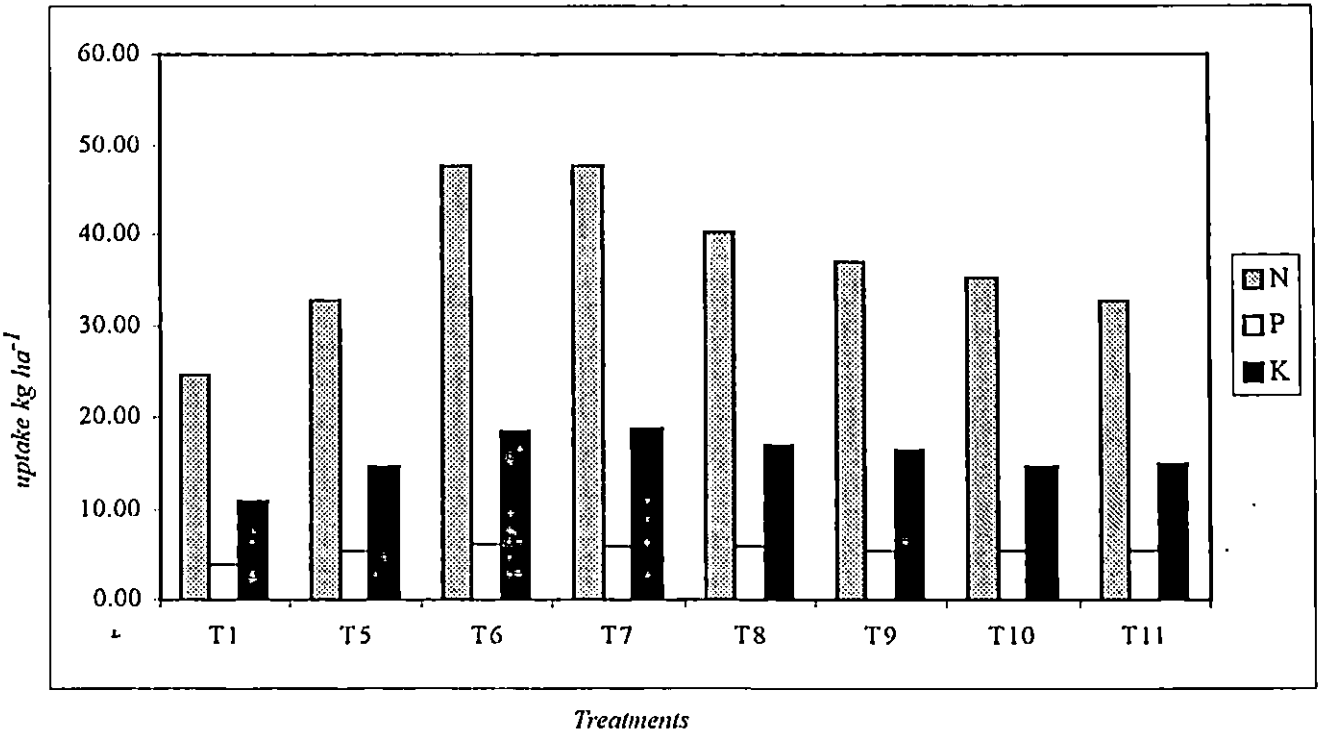
The data on uptake of nitrogen by the crop at different growth stages are presented in Table 5a. Significant variation was noticed in the uptake of N by plants at different growth stages and at harvest in rabi. Significant difference noticed in the dry weight of crop at different growth stages and at harvest was reflected on the uptake values. (Table.5a)

During rabi all the treated plots recorded a significant increase in the uptake of N at all stages of crop growth. At active tillering stage uptake of N by plant was maximum in treatment receiving 50 per cent recommended N through farm yard manure followed by 100 per cent recommended NPK through chemical fertilizers in rabi. While at panicle initiation stage, maximum being observed in treatments which received 25 per cent of recommended N through crop residue in Kharif followed by 75 per cent recommended NPK through chemical fertilizers in rabi. But it was on par with treatment receiving 50 per cent of recommended N through farm yard manure in Kharif followed by 100 per cent of recommended NPK through chemical fertilizers in rabi.(T6)

Table 5(a) : Effet of treatments on the uptake of nitrogen by plants at different growth stages (Kg ha^{-1})

Treatments	Kharif season			Rabi season				
	At Harvest			active tillering	panicle initiation	At Harvest		
	Grain	Straw	Total			Grain	Straw	Total
T1	31.52	17.18	48.92	18.09	31.66	24.61	25.69	50.30
T5	36.76	18.65	55.41	43.86	50.11	32.70	39.55	72.25
T6	37.88	25.19	62.56	51.12	66.02	47.71	48.90	96.61
T7	37.39	21.35	58.76	42.55	61.20	47.52	45.58	93.09
T8	36.93	18.32	55.25	45.32	60.57	40.29	43.17	83.47
T9	37.29	20.26	57.55	38.94	67.85	36.86	40.52	77.39
T10	36.19	16.53	52.73	38.80	52.53	35.17	41.5	76.53
T11	32.88	21.16	54.02	32.96	53.01	32.78	43.90	76.68
F	NS	NS	NS	9.440**	15.67**	18.176**	10.080**	25.53**
SE (m)	1.49	1.97	2.88	3.248	2.918	1.836	2.17	2.807
CD (0.05)	—	—	—	9.553	8.583	5.401	6.395	8.256

Fig. 5. Effect of treatments on NPK uptake in grain during rabi season



Though statistically not significant, during Kharif N uptake of plants at harvest was maximum in treatment receiving 50 per cent of recommended N through farm yard manure(T6). In the case of rabi N uptake of grain was also significantly high in all the treated plots but treatment receiving 50 or 25 per cent of recommended N through farm yard manure in Kharif recorded a significant increase in N uptake in comparison with other treatments. As far as N uptake in straw is considered, all the treated plot recorded significantly higher uptake than control. Treatments receiving 50 or 25 per cent of recommended N through farm yard manure, (T6 or T7), 50 per cent through crop residue (T8) and 25 per cent through green manuring in Kharif(T11) recorded more or less the same N uptake in straw. While treatments receiving 25 percent of recommended N through crop residue, (T9) 50 per cent through green manure (T10) and 100 per cent through chemical fertilizer in Kharif recorded less N uptake in straw. Total N uptake during rabi was significantly high in all the treated plots, the maximum being recorded for treatments receiving 50 per cent of recommended N through farm yard manure in Kharif followed by 100 per cent of recommended NPK through chemical fertilizers in rabi and all the remaining treatments were on par. The results thus clearly showed that treatments which received nitrogen through either organic manure or chemical fertilizer recorded higher uptake values as compared to control. Among the different treatments, treatments receiving,farm yard manure in Kharif showed better uptake values through out the growth

period of the crop. This is in conformity with the results obtained by Lal and Mathur (1989a). During the rabi season maximum N uptake was recorded where the rice crop received 100 percent of the recommended dose of fertilizer preceeded by the treatment receiving 50 per cent of fertilizer through organic source applied to Kharif crop.This could be due to the residual effect of the nutrients available through organic sources to the succeeding rabi crop. Beneficial effect of combined application of farm yard manure and inorganic source of fertilizer in rice crop supports the observation of Gill and Meelu (1982). The better drymatter yield, grain and straw yield noticed in the organic manured applied plots have resulted in higher uptake values. According to Pandey *et al.* (1995) N uptake in rice increases with inorganic source and through supplying it with organic manures. This was also reported by Singhania and Singh (1991).

4.4.2 Phosphorus

Phosphorus uptake at different growth stages are presented in Table 5b. In rabi season significant variation was noticed in the uptake of phosphorus by the crop at all growth stages.

P uptake of the crop was significantly higher in all the treated plots at active tillering and panicle initiation stages. At active tillering stage treatments receiving 25 per cent of recommended N through farm

Table 5 (b) Effect of treatments on the uptake of phosphorus by plants at different growth stages (kg ha^{-1})

Treatments	Kharif season			Rabi season				
	At Harvest			active tillering	panicle initiation	At Harvest		
	Grain	Straw	Total			Grain	Straw	Total
T1	7.76	7.13	14.89	1.36	4.12	3.81	3.65	7.46
T5	8.99	8.04	17.03	2.98	7.36	5.25	6.29	11.54
T6	8.55	9.52	18.07	3.70	10.68	5.98	7.51	13.49
T7	9.62	8.26	17.88	3.24	9.75	5.71	7.12	12.83
T8	9.52	6.92	16.44	3.24	9.75	5.71	7.12	12.83
T9	8.67	7.91	16.58	3.09	8.81	5.19	8.42	13.61
T10	9.03	8.05	17.08	2.92	8.42	5.21	6.46	11.69
T11	7.61	7.49	15.10	2.68	8.07	5.28	6.43	11.71
F	3.129*	NS	NS	12.393**	24.42**	3.647**	8.116**	9.35**
SE (m)	0.416	0.936	1.100	0.206	0.440	0.340	0.485	0.631
CD (0.05)	1.223	—	—	0.606	1.293	1.026	1.426	1.856

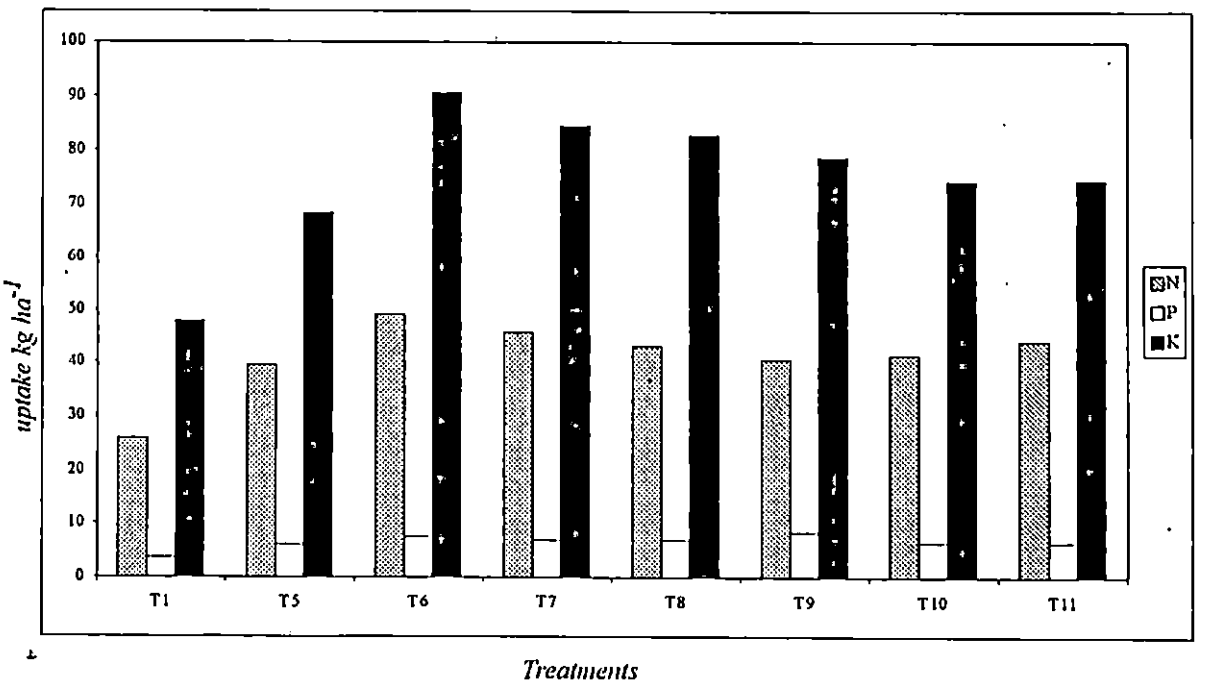
NS - Not significant; * - Significant at 5% level; ** = Significant at 1% .

yard manure (T7) or 50 per cent through farm yard manure (T6) or crop residue (T8) in Kharif followed by 75 or 100 per cent of recommended N through chemical fertilizer in rabi recorded more or less the same P uptake. Plots receiving green manuring in Kharif, and plots receiving chemical fertilizers alone in both the season recorded a significantly low uptake than plots receiving 50 per cent recommended N through farm yard manure in Kharif. (T6) At panicle initiation stage no significant difference was observed between plots receiving 50 per cent of recommended N through farm yard manure (T6) or crop residue (T8) and 25 per cent through farm yard manure (T7) in Kharif. Plots receiving farm yard manure in Kharif recorded a significant higher P uptake than all other treatments.

In Kharif season P uptake by grain was significantly high in all the treated plots except which received 25 per cent of recommended N through green manuring(T11). During kharif the P uptake by straw as well as total P uptake showed no significant influence by treatments.

In the case of rabi crop, P uptake by grain was significantly high in all the treated plots . But in straw, the plots receiving 25 per cent of recommended N through crop residue(T9) recorded the maximum P uptake which was on par with treatment receiving 50 per cent of recommended N through either farm yard manure (T6) or crop residue (T8) and significantly higher than the remaining treatments.

Fig. 6. Effect of treatments on NPK uptake in straw during rabi season



When the total P uptake was considered no significant difference was observed among the treated plots but were significantly higher than the control.

The increase in P uptake by plots receiving 25 per cent of recommended N through crop residue may be due to the increase in the P content in straw rather than by an increased drymatter yield. The increased mineralization of soil P as a result of production of organic acids during decomposition of organic manure may also be one of the reasons for increased P uptake by plants. P uptake was higher when N was applied in combination of organic and inorganic forms than all as inorganic form (Singhania and Singh, 1991). The increased P uptake observed in plants under different treatments was reflected in grain yield which was exhibited from the carryover capacity of the P source applied to the preceeding crop (Medhi *et al.*, 1995).

4.4.3 Potassium

The data on uptake of potassium by plants at different growth stages are presented in Table 5c. During rabi significant variation was observed in the uptake of K at all growth stages. All the treated plots recorded a significantly higher K uptake in comparison to control through out the growth stages and at harvest. Maximum K uptake was

observed in plots receiving 50 per cent of recommended N through farm yard manure in Kharif. In all these cases much differences were not observed in treated plots. At active tillering stage K status of plots receiving 50 per cent recommended dose of N through farm yard manure in Kharif (T6) was significantly higher than plots receiving chemical fertiliser alone and plots receiving 25 per cent of recommended N through either farm yard manure (T7) or green manure (T11). At panicle initiation stage plots receiving chemical fertiliser alone,(T5) 25 and 50 per cent of recommended N through green manure and 25 per cent through crop residue (T9) recorded smaller K uptake.

In the case of kharif crop, all the treated plots recorded a significanlty higher uptake at harvest stage. Result on the uptake of K by grains during rabi crop also showed the superiority of treatments receiving farm yard manure in kharif. Treatments receiving 50 per cent of recommended N through crop residue (T8) also recorded higher uptake value among the treatments. Treatments receiving 25 per cent recommended N through farm yard manure followed by 100 per cent recommended N through chemical fertiliser recorded maximum K uptake. Similar uptake pattern was observed in the case of straw also. The total K uptake by plants at harvest stage also showed similar pattern.

Table 5(c) Effect of treatments on the uptake of potassium by plants at different growth stages (Kg ha^{-1})

Treatments	Kharif season			Rabi season				
	At Harvest			a.t	p.i	At Harvest		
	Grain	Straw	Total			Grain	Straw	Total
T1	11.14	68.75	79.89	16.10	45.28	10.77	47.78	58.55
T5	14.27	88.39	102.66	35.82	79.24	14.73	68.37	83.10
T6	14.84	100.91	115.75	42.83	106.82	18.57	90.78	109.34
T7	15.27	86.04	101.31	35.09	102.81	18.83	84.57	103.69
T8	12.33	78.55	90.88	38.14	100.15	17.08	82.79	99.87
T9	12.71	75.24	87.95	38.48	90.01	16.55	78.79	95-34
T10	12.19	74.31	86.50	37.52	91.05	14.63	74.28	88.91
T11	12.15	82.72	94.87	33.15	85.06	15.02	74.56	89.58
F	4.602**	NS	2.770*	14.263**	43.404**	20.634**	41.953**	54.03**
SE (m)	0.691	6.665	6.896	2.130	2.949	0.574	2.027	2.130
CD (0.05)	2.033	19.604	20.286	6.270	8.670	1.687	5.961	6.260

NS - Not significant; * - Significant at 5% level; ** = Significant at 1% .

At panicle initiation stage the plots receiving 100 per cent inorganics both the seasons recorded comparatively lower uptake values. This may be due to the lower drymatter production in these treatments. Plots receiving crop residue in kharif also performed better K uptake at all growth stages. This may be due to better K availability due to straw decomposition. At all growth stages increased uptake of K was seen in treatments receiving farm yard manure in kharif Sharma and Mittra (1991) could observe maximum K uptake in rice at harvest stage due to organic manure applications.

4.5 Physical properties

4.5.1 Bulk density

As seen from table 6 the bulk density before the start of experiment was superior in treatments receiving 50 per cent of recommended N through farm yard manure (T6) or crop residue (T8). These treatments showed lower values for bulk density. Treatments which received 25 per cent of recommended N through farm yard manure (T7) or crop residue (T9) also showed lower bulk density values. Treatments which received 100 per cent recommended dose of nutrients through inorganic fertilizers (T5) showed maximum bulk density. and it was significantly higher than all the treated and untreated plots.

Table 6. Effect of treatments on physical properties of soil before and after experimentation

Treatments	Before rabi season		After rabi season	
	B.D ($g\ cc^{-1}$)	WHC (%)	BD ($g\ cc^{-1}$)	WHC (%)
T1	127	34.84	1.25	37.56
T5	1.30	34.46	1.31	36.53
T6	1.13	45.45	1.14	46.12
T7	1.16	44.41	1.18	44.60
T8	1.14	45.94	1.14	46.13
T9	1.19	46.39	1.18	46.35
T10	1.20	44.63	1.23	44.60
T11	1.21	41.73	1.21	41.20
F	58.217**	24.632**	45.843**	14.003**
SE (m)	7.609	0.985	8.327	1.079
CD (0.05)	0.0224	2.897	0.025	3.175

** = Significant at 1%.

The results thus clearly revealed that application of organic manures in combination with inorganic fertilizers continuously in kharif has resulted in improving the bulk density of soil. The influence of organic manures in improving the bulk density of soil is well known and widely reported. Bulk density of the soils decreases with increase in organic matter and clay content. The microbial decomposition products of organic manure such as polysaccharides and bacterial gums are known to act as soil binding agents (Dhoot *et al.*, 1974). These soil binding agents increased the porosity of soil and decrease its bulk density (Biswas *et al.*, 1971 and Bhatia and Shukla, 1982).

The analysis of post harvest soil samples showed a similar trend. Here also crop residue and farm yard manure incorporated plots in kharif followed by 100 per cent recommended NPK through chemical fertiliser in rabi improved the bulk density of the soil. The treatment which received 100 per cent inorganics in both seasons recorded maximum value. Lal and Mathur (1989b) also reported that the bulk density of soil decreases with organics applied either alone or in conjunction with inorganics where as it increased by the treatment inorganics alone.

4.5.2 Water holding Capacity

When the values obtained for water holding capacity in the present study were analysed from Table 6 it could be observed that the mean value obtained for various treatments were significantly different.

Water holding capacity of all the treated plots of Kharif season except the plots receiving chemical fertilisers alone was higher than untreated plots. The same trend was observed after the harvest of rabi crop. Maximum water holding capacity was recorded for plots receiving 25 per cent of recommended N through crop residue (T9) in Kharif before and after the experiment which showed no significant difference with treatment receiving 50 per cent of recommended N through farm yard manure(T6), crop residue (T8) and green manure (T10) in Kharif . However the treatment receiving 25 per cent of recommended N through green manure (T11) recorded a lower value than other organic manured plots.

The results clearly revealed that application of organic manure either farm yard manure or green manure or crop residue could definitely influence the water holding capacity. Before the experiment and after harvest of rabi crop, the analysis of soil showed that application of organic manure either as crop residue or farm yard manure or green manure in kharif could produce substantial increase

in the water holding capacity of the soil. Treatments receiving 25 or 50 per cent of recommended N through farm yard manure or crop residue were found to be on par.

Addition of organic matter from cover crops or applied through organic manures improved the water holding capacity, infiltration rate and soil aggregation as compared to chemical fertiliser alone. (Bhatia and Shukla) 1982 and Bhriguvanshi, 1988 had been inferred from experiments that the application of farm yard manure with chemical fertiliser played a definite role in improving the water holding capacity of the soil. Thus an increment of water holding capacity was affected to the extent of 34.6% in soil samples collected before the experiment. This resulted from increased organic carbon content and as well as improvement in soil characteristics in structural condition of soil. Similar observation was made by Bhriguvanshi (1988) and Dadhwal and Kathiyar (1989). The role of organic manure on the water holding capacity was mainly by its influence on porosity of soil. Organic manure addition either alone or in combination with inorganic fertilizers resulted in uniform addition of organic matter and higher water holding capacity, while treatments in which inorganic fertilizers alone were applied recorded the lowest values.The improvement in water retention characteristics of soil by organic manure addition were reported by several workers (Bhriguvanshi. 1988 and Sharma *et al.*, 1988).

4.6 Chemical Properties

4.6.1 Organic Carbon

As seen from Table 7,the organic carbon content of the soil before the start of Kharif crop was significantly higher in all the treated plots. Among the treated plots minimum was recorded in treatment receiving 50 per cent N as crop residue (T8) or green manure (T10) in Kharif. Maximum being recorded in plots receiving 50 percent recommended N through farm yard manure (T6) in Kharif which was on par with plots receiving 25 per cent of recommended N through farm yard manure (T7).

The organic carbon content after kharif crop was maximum in treatment which received 50 per cent of recommended N through farm yard manure (T6) or crop residue(T8). This was followed by treatments receiving 25 per cent of recommended N through farm yard manure (T7). Maximum value for organic carbon content was recorded by treatment which received 50 per cent of recommended N through farm yard manure (1.42%). Among the treated plots, minimum organic carbon content was recorded in plots treated with 50 per cent recommended N through green manure in Kharif(T10). This was found to be on par with untreated plots(T1).

Table 7. Effect of treatments on organic carbon status and CEC of soil before and after experimentation

Treatments	Before Kharif Season	Before rabi season		After rabi season	
	Org. C. (%)	Org.C. %	CEC C mol(+)Kg^{-1}	Org C (%)	CEC C Mol(+)Kg^{-1}
T1	0.92	1.16	5.6	1.22	5.03
T5	1.02	1.25	6.92	1.32	6.18
T6	1.12	1.42	10.08	1.49	8.92
T7	1.08	1.38	9.59	1.41	8.69
T8	1.06	1.40	6.83	1.41	5.41
T9	1.01	1.31	10.79	1.32	10.94
T10	1.06	1.22	5.32	1.17	5.85
T11	1.07	1.25	7.19	1.25	8.42
F	12.695**	24.82**	63.37**	48.73**	33.106**
SE(m)	0.0168	1.883	0.2580	1.544	0.1152
CD (0.05)	0.0493	0.0554	0.7588	0.0454	0.338

** = Significant at 1% .

At harvest stage of rabi crop, maximum organic carbon content of the soil was recorded from treatment which received 50 per cent of recommended N through farm yard manure in kharif and 100 per cent of recommended NPK as chemical fertiliser in rabi(T6). This treatment was found to be at par with plots which received 25 per cent of N through farm yard manure (T7) and 50 per cent of N through crop residue in kharif(T8). Among treatments lowest value of organic carbon content was obtained from treatments which received 50 per cent of recommended N through green manure in Kharif(T10). This was at par with treatment receiving 25 per cent of recommended N through green manure (T11) in Kharif and control plots.

The results clearly revealed the superiority of farm yard manure and crop residue in increasing the organic carbon content of soil. Similar results of increase in organic carbon content due to continuous application of farm yard manure was reported by several workers. (Kurumthottical, 1982 and Udayasoorian *et al.*, 1988). Except control the lowest value of 1.25 and 1.22 were recorded by treatments receiving 50 per cent of recommended N through green manure in kharif (T10) and 100 per cent of recommended NPK through chemical fertilisers (T5) respectively. This may be due to the fact that the treatment T5 is devoid of any kind of organic manure. The treatment green manure + NPK in all proportions has recorded comparatively lower organic carbon

content. The lower organic carbon content recorded may be attributed due to the rapid decomposition of the fresh glyricidia leaves.

The results thus clearly revealed that the treatment receiving farm yard manure gave higher organic carbon content. Similar results of increase in organic carbon content due to farm yard manure were reported by several workers (Shinde and Ghosh, 1971 and Udayasoorian *et al.*, 1988). Treatments receiving 50 per cent recommended N through crop residue in kharif and the rest through chemical fertiliser followed by 100 per cent of recommended NPK through chemical fertiliser in rabi also gave higher organic carbon content. This is in agreement with the findings of Sharma *et al.*(1987) and Dev and Bharadwaj (1993). The organic carbon status of the soil increased substantially in all the treatments compared with its initial level. Continuous flooding in rice-rice system is generally reported to increase the organic carbon status of soil (Nambiar *et al.*, 1992). Patnaik *et al.* (1989) found an increase in organic carbon status when organic sources were used to substitute a part of fertilizer N which is obviously due to the addition of organic matter.

4.6.2 Cation exchange capacity

The data on cation exchange capacity of the soil before the experiment and at harvest are presented in Table 7. The results showed

that before and after the rabi crop the values showed significant difference among treatments.

The values ranged from 5.6 to 10.79 C moles (+) Kg^{-1} before rabi crop. After rabi, the values ranged from 5.03 to 10.94 C moles (+) Kg^{-1}.

The analysis of soil collected after kharif clearly revealed the superiority of treatments which received either 25 per cent recommended N through crop residue (T9) and 50 per cent of recommended N through farm yard manure (T6). These treatment were at par. The treatments which received 50 per cent of recommended N through green manure (T10) recorded the lowest value. (5.32 C moles(+)Kg^{-1}) and was at par with T1 (Control). But after rabi, all the treated plots recorded a lower level of cation exchange capacity.

After the rabi crop the results showed the superiority of treatment which received 25 per cent of recommended N through crop residue (T9) in kharif followed by 75 per cent of recommended NPK through chemical fertiliser in rabi. This treatment recorded cation exchange capacity value of 10.94 Cmoles(+) Kg^{-1}. This was followed by treatments receiving farm yard manure in kharif. Lowest cation exchange capacity value was recorded in control plots (5.03 Cmoles (+) Kg^{-1}. Among the treatments , plots receiving 50 per cent of recommended N through green manure in Kharif recorded the lowest cation exchange

capacity. Plots receiving chemical fertilisers alone in both season recorded more ot less the same cation exchange capacity as that of plots receiving 50 per cent of recommended N through green manure in Kharif.

Continuous addition of one or other form of organic matter in kharif season in the soil produced significant difference in both the seasons. The significant difference obtained in the organic carbon content of the soil due to various treatments was reflected in the cation exchange capacity of the soil. The low values noticed in the cation exchange capacity may be attributed to the dominance of kaolinite content in the clay complex. Application of organic manure enriched the soil with total organic carbon, humic fraction on which cation exchange capacity of the soil is partially dependent as observed by sharma *et al.* (1988). Similar increase in cation exchange capacity of soils due to prolonged addition of organic matter has been reported by Kurumthottical, 1982 and Udayasoorian, 1988. Maurya and Ghosh (1972) had also reported a similar increase in cation exchange capacity due to the continuous application of organic manure and fertilizers.

4.6.3. Available Nutrients

4.6.3.1 Available nitrogen

Available nitrogen status of the soil before kharif and after rabi crop are presented in Table 8. The result showed significant difference among treated and untreated plots.

The analysis of the soil collected before the kharif crop showed significant difference between treated and untreated plots. Maximum being recorded in plots receiving 50 per cent of recommended N through farm yard manure in Kharif(T6). This treatment showed no significant difference with plots receiving 50 per cent of recommended N through crop residue(T8) and 25 per cent of recommended N through farm yard manure in kharif(T7). Plots receiving 50 per cent recommended N through crop residue or green manure recorded the same available nitrogen content. Among the treated plots minimum available nitrogen content was recorded from plots receiving chemical fertiliser alone in both seasons(T5).

The analysis of soil test data before rabi showed maximum value of available nitrogen content in treatment receiving 50 per cent recommended N through farm yard manure in kharif (284.2 Kg ha^{-1}). This was on par with treatment receiving 50 and 25 per cent of

Table 8. Effect of treatments on soil nutrient status before and after experimentation.

Treatments	Available nutrients (Kg ha^{-1})								
	Before Kharif season			Before rabi season			After rabi season		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1	168.22	25.18	110.40	156.87	25.15	110.15	155.84	25.31	116.25
T_5	185.60	25.78	119.85	191.01	30.22	121.83	242.09	24.81	122.00
T_6	203.88	30.82	124.63	284.20	34.19	126.73	285.47	37.85	129.75
T_7	197.48	28.40	121.88	263.85	27.64	125.83	255.17	37.85	129.75
T_8	193.82	27.83	123.48	274.40	30.11	116.702	257.91	30.48	117.25
T_9	183.77	26.80	112.43	275.03	26.11	119.85	196.91	31.81	115.5
T_{10}	193.82	28.96	116.08	229.49	28.11	119.85	196.91	31.81	115.5
T_{11}	195.45	26.44	117.9	237.5	23.90	115.98	216.70	26.25	109.25
F	12.91**	12.209**	19.027**	8.570**	6.100**	11.306**	4.728**	8.280**	20.891**
SE(m)	3.048	0.530	1.064	15.461	1.311	1.60	18.580	1.811	1.330
CD (0.05)	8.965	1.559	3.131	45.480	3.873	4.89	54.681	5.341	3.931

** = Significant at 1% .

recommended N through crop residue and 25 per cent through farm yard manure. The available nitrogen content of green manured plots were significantly lower than that of plots receiving 50 and 25 per cent of recommended N through green manuring. Control plots recorded a lower value of 156.87 Kg ha^{-1} and were found inferior.

The analysis of the soil samples collected after rabi crop also showed a similar trend in available N status. Here also the treatment receiving 50 per cent recommended N through farm yard manure in kharif was found to be superior (285.47 Kg ha^{-1}). The treatment which received 100 per cent recommended NPK through chemical fertilizer (T5) was on par with treatment which received 50 or 25 per cent recommended N through either crop residue or farm yard manure in kharif followed by 75 or 100 per cent of recommended NPK through chemical fertiliser in rabi. Among the treated plots minimum available nitrogen content was recorded from plots receiving 50 per cent of recommended N through green manure in Kharif followed by 100 per cent of recommended N through chemical fertilizer in rabi (T10).

Continuous application of N either as inorganic fertilizer or as partial substitution of organics to supplement the recommended dosage has resulted in significant variation in the available N content of the soil. There are reports of increase in available N content of soil due to application of either organics or inorganics (Chellamuthu *et al.*, 1989).

In general the availability of N associated with different treatments was low as the values ranged from 156.87 to 284.2 kg ha^{-1} before the experiment and 155.85 to 285 Kg ha^{-1} after the experiment. Sharma and Sharma (1994) reported the application of organic manure increased the available N content of soil. Higher quantities of available N after crop residue incorporation was reported by Tiwari *et al.* (1980a). Green manured treatments showed comparatively lower values of available N when compared to farm yard manure and crop residue treatments. Most of the green manure-N which has mineralized during the rice season was absorbed by rice itself. Since in wetland soils mineral-N is readily lost via leaching and denitrification, only a small quantity of residual green manure-N might have been left after the rice crop which in the presence of recommended dose could not produce higher yield. The application of farm yard manure either to rice or wheat in rice-wheat sequence resulted in significant increase in the chemical properties including available N as reported by Ganal and Singh (1988). Increase in available N content due to addition of organic manure was reported by Krishnamoorthy *et al.* (1994).

Under intensive cropping if the stubbles are ploughed back into the soil, significant quantities of nutrients could be returned to the soil which gradually become available to the subsequent crops on decomposition. Higher quantities of avialable N after incorporation of crop residue have been reported by Tiwari *et al.*, 1980b. Ponnamperuma

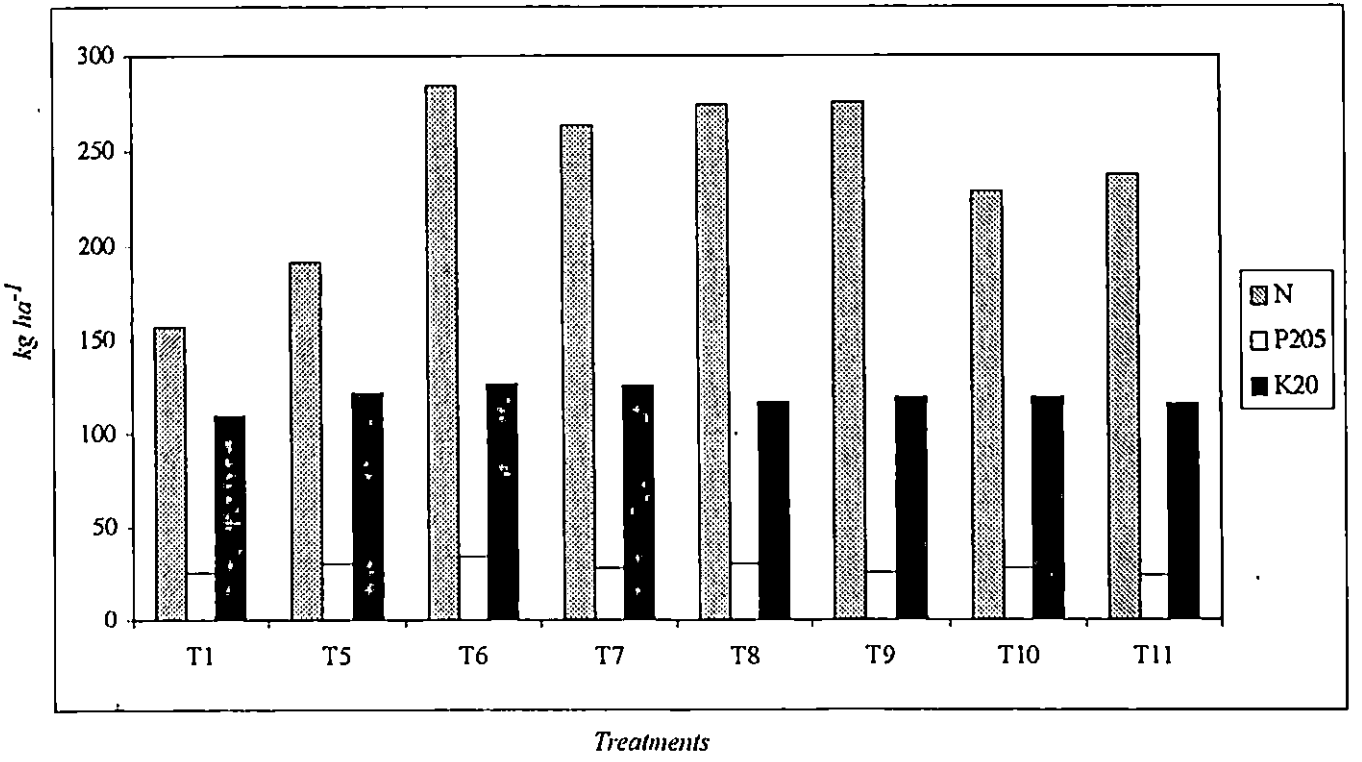
(1980) opined that rice straw has a positive effect on soil fertility and its continuous application increases the soil-N content.

4.6.3.2 Available Phosphorus

As seen from Table 8 the analysis of soil collected before the kharif crop showed the superiority of treatments receiving 50 per cent of recommended N through farm yard manure in Kharif(T6). Minimum being recorded in plots receiving chemical fertiliser alone in both seasons(T5). This treatment recorded more or less the same available P content as that of control plots. Plots receiving 50 per cent recommended N through either green manure (T10) or crop residue (T8) showed no significant difference with plots receiving 25 per cent recommended N through farm yard manure in kharif(T7).

The analysis of soil test data before rabi showed that the treatment which received 50 per cent of recommended N through farm yard manure recorded maximum value of 34.19 Kg ha^{-1}. This is found significantly superior to all other treatments. This was followed by treatments receiving 100 per cent NPK as chemical fertilizer(T5), 50 per cent recommended N through crop residue (T8) or green leaves (T10) and 25 per cent recommended N through farm yard manure(T7) or crop residue(T9). These treatments were on par. The lowest value of 23.91 Kg ha^{-1} was recorded in treatments receiving 75 per cent inorganics

Fig. 7. Effect of treatments on available NPK status before rabi season



and 25 Per cent recommended N through green manure. Control plot also recorded a low value of 25.15 $Kgha^{-1}$ and it was on par with the above treatment.

In general application of organic manure was found to increase the availability of P. The complementary use of chemical fertilizers and organic manures will augment the efficiency of fertilizers. This is because organic manure affect P availability in soil through mineralisation of organic P, liberation of Ca bound P through CO_2 formation and complexing of Al and Fe-P through microbial activity (Dalal, 1977 and Sharma and Mittra, 1991). sharma *et al.* (1988) found that incorporation of organic wastes improved the available p content by 20 per cent due to the release of P during decomposition and solublisation of P compounds by organic acids released during decomposition.

The analysis of post-harvest samples of rabi crop showed significant difference between treatments. The treatments which received 50 or 25 per cent of recommended N through farm yard manure in kharif recorded maximum available P (37.85 kg ha-1) and were on par. However plots receiving 50 per cent recommended N through green manure showed an increase in available phosphorus status in comparison with control . Among the treatments available P was minimum in treatment receiving 100 per cent inorganics in both seasons

(24.81 $Kgha^{-1}$) and found inferior to treated and untreated plots. In the cropping sequence, the 1st crop hardly utilises 10-20 per cent of the applied p and the rest remains in the soil for the subsequent crops (Kothari and Saraf,1987). The result clearly revealed the residual influence of organic matter treatment in kharif in improving the available P content of soil. The integration of organic matter in plant nutrients, increased the P supply to plants by direct enrichment, enhancing the solubilisation of native P, accelerating the mineralisation of added chemical P and by reducing the P fixation. (John Kutty and Anilakumar, 1991). The decline in available P status of the soil even with P application was probably due to high P fixation capacity of lateritic soils containing large quantity of soluble Al and Fe.

4.6.4.3. Available Potassium

The data pertaining to the available K content of the soil before the experiment and at harvest are presented in Table 8.Available potassium content of the soil collected before the kharif crop recorded maximum value in plots receiving 50 per cent of recommended N through farm yard manure in kharif. Minimum being recorded in plots receiving 25 per cent of recommended N through crop residue in kharif.

The available K status before the rabi crop was significantly higher in all the treated plots.The treatment which received 100 per cent inorganics were found to be at par with 25 (T7) and 50 (T6) per cent recommended N through farm yard manure in kharif. This was followed by treatments which received either 50 or 25 per cent of recommended N through crop residue or 25 per cent recommended N through green manures. Maximum available K content was recorded in treatment which received 50 per cent recommended N through farm yard manure (126.73 Kg ha^{-1}) and minimum in control (110.15 Kg ha^{-1}).

Analysis of post harvest samples of rabi crop indicated the superiority of treatment which received 25 per cent recommended N through farm yard manure in kharif followed by 75 per cent of recommended NPK in rabi. (129.75 kg ha^{-1}). Minimum available K content was recorded in plots receiving 25 per cent of recommended NPK through green manure in kharif and 75 per cent of recommended inorganics in rabi (109.25 kg ha^{-1}).

In general the availability of K was medium in most of the treatments, did not decrease even in the plots which received no K either by way of organic maures or chemical fertilizers. This may be due to constant supply of K from humus. Increase in the available K status of soil by application of organic manure was reported by several workers (Sharma and Sharma, 1994 and Krishnamoorthy *et al.*, 1994). Application

of farm yard manure improve the available K content as reported by Ganal and Singh (1990) and Rai *et al.* (1990). The increased availability of K in soil may be due to their easy decomposition of the mineral constituents, and their effect in dislodging the exchangeable K into the soil solution (Mahapatra and Jee, 1993). According to Tandon (1991) crop residues could be considered as an important source of K to soil, as it contained 75 per cent absorbed K.

Summary

SUMMARY

An experiment entitled "Integrated nutrient management in a rice-rice cropping system" was carried out to study the effect of long term application of organic manures in combination with inorganic fertilizers on the uptake, availability of nutrients and changes in the physico-chemical properties and finally growth and yield of rice at the Cropping Systems Research Centre, Karamana during the rabi season of 1995-96.

Observation on the growth and yield attributes of rice, nutrient uptake by the plant and changes in physico-chemical properties of soil before and after the experiment due to long term application of manures and fertilizers were studied. The data obtained were statistically analysed, the resutls presented and discussed in the foregoing chapter. The findings from the study are summarised below.

1. The tiller production was considerably influenced by all treatments at active tillering and panicle initiation stages. The number of tillers were maximum in treatment which received 50 per cent of recommended N as farm yard manure in kharif followed by 100 per cent recommended NPK through chemical fertilizers in rabi.

2. Root production in rice was highly influenced only at active tillering and panicle initiation stages by treatments which received 50 or 25 per cent of N as farm yard manure in kharif followed by 100 or 75 per cent of recommended NPK through chemical fertilizers in rabi. At harvest stage none of the treatment infleunced this character.

3. Though statistically not significant the number of productive tillers was maximum in treatment which received 25 or 50 per cent of recommended N throguh farm yard manure in kharif.

4. Thousand grain weight showed significant increase in all treatments. Maximum was observed in treatment receiving 50 per cent recommended N through farm yard manure in kharif.

5. Sterility percentage was significantly low in plots receiving 50 per cent of recommended N as farm yard manure in kharif. The treatment which received full quantity of NPK as chemical fertilizers during both kharif and rabi seasons recorded maximum sterility percentage.

6. Treatments receiving 50 per cent recommended N through farm yard manure in kharif recorded maximum grain yield during kharif and rabi seasons. During kharif, minimum grain yields

was recorded from plots receiving 25 per cent of recommended N through green manure. But during rabi minimum was observed from plots receiving chemical fertilizers alone in both seasons.

7. During rabi season maximum straw yield was observed in plots receiving 50 per cent recommended N through farm yard manure in kharif followed by 100 per cent recommended NPK through chemical fertilizers in rabi and the minimum was observed in plots receiving chemical fertilizers alone in both seasons.

8. During kharif nitrogen uptake was not influenced by treatments. During rabi the influence of treatment was significant at all growth stages of crop. Maximum N uptake by plants at active tillering and harvest stages was noticed in treatment receiving 50 per cent recommended N through farm yard manure in Kharif followed by 100 per cent recommended do so chemical fertilizers in rabi. But at panicle initiation stage in treatment receiving 25 per cent of recommended N through crop residue in Kharif followed by 75 per cent of recommended NPK through chemical fertilizers in rabi recorded maximum N uptake.

9. In the case of P uptake of rabi crop significant variation was noticed at all growth stages and at harvest. At active tillering

stage maximum uptake was noticed in treatment receiving 50 per cent recommended N through farm yard manure in Kharif while at panicle initiation stage maximum was observed in plots receiving 25 per cent of recommended N as farm yard manure in Kharif. At harvest stages maximum P uptake was noticed in plots receiving 25 per cent of recommended N as crop residue in Kharif. But during kharif, the uptake of phosphorus was significant only in grain and maximum was recorded by plots receiving 25 per cent recommended N through farm yard manure.

10. In the case of rabi crop significant variation was noticed in K uptake at all growth stages and at harvest. Maximum K uptake was observed in plots receiving 50 per cent of recommended N through farm yard manure in kharif. But during kharif, the uptake of K was significant only in grain.

11. The influence of long term application of manures and fertilizers on bulk density and water holding capacity of soil was significant. The results clearly revealed the beneficial effects of organic manure addition in improving bulk density and water holding capacity of the soil. Bulk density was found to be maximum in plots receiving chemical fertilizers alone in both seasons and minimum in plots receiving 50 per cent

recommended N through farm yard manure in Kharif. Water holding capacity of soil was found to be maximum in plots which received 25 per cent of recommended N as crop residue in Kharif.

12. Influence of long term application of manures and fertilizers on organic carbon content of soil was significant. Before experiment and at harvest maximum organic carbon content was observed in plots which received 50 per cent of recommended N through farm yard manure in Kharif.

13. Significant variation was noticed in the Cation exchange capacity of the soil before and after experimentation. Maximum cation exchange capacity was observed in plots receiving 25 per cent of recommended N through crop residue in Kharif.

14. Available N content of soil before the experiment and at harvest was maximum in plots receiving 50 per cent recommended N as farm yard manure in Kharif followed by 100 per cent of recommended NPK through chemical fertilizers in rabi. Plots receiving chemical fertilizers alone in both season and 50 per cent of recommended N through green manure supplied during kharif recorded minimum available nitrogen content before and after the experiment.

15. Available P content of the soil before and after experimentation was maximum in plots receiving 50 per cent recommended N through farm yard manure in Kharif followed by 100 per cent recommended N through chemical fertilizer in both seasons. Plots receiving 25 per cent of recommended N through green manure recorded minimum available P status before the rabi crop. After the rabi crop minimum available P was observed in plots receiving chemical fertilizer alone in both seasons.

16. Before Kharif and before rabi crops, availability of potassium was maximum in plots receiving 50 per cent of recommended N supplied through farm yard manure in Kharif but after rabi crop maximum available K was observed in plots receiving 25 or 50 per cent recommended N through farm yard manure in kharif.

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* *Originals not seen*

Appendix

Appendix I

Weekly Weather data during the cropping period from 1.10.95 to 11.2.95

Period		Average Max. temp °C	Average Min. temp °C	Average R.H. %	R.F mm.
From	To				
01.10.95	07.10.95	31.29	23.57	86.29	27
08.10.95	14.10.95	30.00	23.43	90.14	100
15.10.95	28.10.95	31.43	23.29	34.86	2
22.10.95	04.11.95	31.43	23.29	92.57	57
29.10.95	04.11.95	31.00	23.14	91.4	39
05.11.95	11.11.95	30.00	22.77	86.86	32
12.11.95	18.11.95	30.29	22.71	89.43	175
19.11.95	25.11.95	31.29	22.71	83.57	2
26.11.95	02.12.95	32.00	22.14	74.71	2
02.12.95	09.12.95	33.29	21.57	70.71	0
10.12.95	16.12.95	32.86	21.00	70.50	0
17.12.95	23.12.95	33.6	21.80	62.5	0
24.12.95	30.12.95	33.0	21.85	75.71	0
31.12.95	06.01.96	33.16	22.16	76.8	0
07.01.96	13.01.96	33.42	21.42	71.42	0
14.01.96	20.01.96	31.21	20.85	88.00	37
21.01.96	27.01.96	31.71	20.71	76.71	0
28.01.96	03.02.96	32.28	20.85	73.42	0
04.02.96	10.02.96	32.85	22.28	73.57	0
11.02.96	17.02.96	32.5	22.75	81.50	0

INTEGRATED NUTRIENT MANAGEMENT IN A RICE-RICE CROPPING SYSTEM

By

DEEPA S.

ABSTRACT OF A THESIS
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COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

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ABSTRACT

An experiment entitled "Integrated nutrient management in a rice-rice cropping system" was condcuted at Cropping Systems Research Centre, Karamana during the second crop season of 1995-96, to study the effect of long term application of manures and fertilizers on the availability and uptake of nutrients and changes in the physico-chemical properties of the soil for sustained productivity.

The experiment was laid out in randomized block design with twelve sets of treatments and four replications. The twelve sets of treatments incldued four treatments of different levels of recommended fertilizers, treatments of integration of chemical fertilizers with organic sources like farm yard manure, crop residues (rice straw) and green manure, along with one each of unfertilized control and farmers' practice of manuring.

Organic manure addition in different forms was found to have pronounced effect on various growth and yield attributing characters of rice when applied in combination with chemical fertilizers.When compared to other treatments, application of 25 or 50 per cent of recommended N through farm yard manure in kharif followed by 75 or 100 per cent of

recommended NPK through chemical fertilizers in rabi, gave higher tiller number, root production, productive tiller number, thousand grain weight, grain yield, and straw yield.

Integration of organic manures with inorganic fertilizers improved the N, P and K uptake by the plant at all growth stages and at harvest.Highest N and K uptake were recorded when 50 per cent N, supplied through farm yard manure in kharif season. Highest P uptake was recorded when 25 per cent of N supplied through crop residue in kharif.

In general the available N,P,K and organic carbon contents of the soil were slightly improved due to combined application of organic and inorganic sources of fertilizers. Application of farm yard manure to meet 50 per cent of N along with 100 per cent recommended dose of fertilizers recorded maximum available NPK and organic carbon

Bulk density was lowest under treatment receiving 50 per cent recommended N through farm yard manure in kharif. Incorporation of paddy straw, to meet 25 per cent N along with chemical fertilizers enhanced water holding capacity and cation exchange capacity of the soil.