YIELD MAXIMISATION THROUGH INTEGRATED NUTRIENT MANAGEMENT IN RICE

A THESIS
SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE

(AGRICULTURAL CHEMISTRY AND SOIL SCIENCE)

BY

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1992

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DEDICATED TO

MY BELOVED PARENTS

APPROVAL SHEET

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CERTIFICATE

This is to certify that this dissertation entitled **"YIELD MAXIMISATION THROUGH INTEGRATED NUTRIENT MANAGEMENT IN RICE"** submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (AGRICULTURE) IN AGRICULTURAL CHEMISTRY, SOIL SCIENCE AND BIOCHEMISTRY, is a record of bonafide research work carried out by Miss Rabeya Khanam under my guidance and supervision. No part of this dissertation has been submitted elsewhere for any other degree or diploma or published in any other form.

7.6.93

(G. N. Mitra)

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YIELD MAXIMISATION THROUGH INTEGRATED NUTRIENT MANAGEMENT IN RICE

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ABSTRACT

A field trial was conducted in the kharif season of 1992, at the Central Farm, Bhubaneswar, on an acid laterite soil with a medium duration semidwarf variety Lalat. The objective of the trial was to maximise grain yield of this variety through integrated nutrient management.

Itwas observed that about 45% yield increase over the recommended dose of 80 kg N as urea, 40 kg P_2O_5as SSP and 40 kg K_2O as MOP per ha could be achieved through the two treatments which consisted of in one case application of 80 kg N as USG, point placed one week after transplanting, 80 kg P_2O_5 as 1:1 mixture of SSP + RP applied to dhaincha crop which preceded the rice crop, 40 kg K_2O as MOP applied at the time of planting, incorporation of a 42 day old dhaincha crop one week before planting and application of BGA one week after transplanting. The second treatment which also gave similar yield consisted of liming with papermill sludge 6 weeks before planting, application of 80 kg N as PU in 3 splits, application of 80 kg P_2O_5 as SSP at the time of planting, application of 40 kg K_2O as MOP at the time of planting, incorporation of 42 days old dhaincha crop one week before planting and application of BGA one week after transplanting. Incorporation of dhaincha and application of BGA along with recommended dose of fertiliser increased grain yield by about 30%.

It was further observed that replacement of PU by USG at a dose of 80 kg N/ha along with 40 kg P_2O_5 and 40 kg K_2O decreased grain yield and increased straw yield. When the dose of P was increased to 80 kg P_2O_5/ha, there was significant increase in grain yield without any increase in starw yield.

It was further observed that replacement of SSP by DAP resulted in yield decrease. Application of N in the form of USG increased N content and uptake by the plants. The rice crop was found to remove considerable amount of Zn from the soil although Zn was not applied as a fertilizer.

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INTRODUCTION

There is a grave urgency to increase food production per unit area as the population of India approaches the 1 billion mark by the turn of the century and threatens to exceed this mark in the next 30 to 40 years before it can stabilise. There is now no scope to increase the area under cultivation since it has reached almost a saturation point. In fact there will be a shrinkage in this area as more and more cultivable land is diverted to accommodate new cities, industries or even multipurpose irrigation projects.

While aiming at higher productivity from unit area, one has to take into consideration the additional inputs which will be required for this purpose. Cost of these inputs will certainly increase as the energy and management costs become dearer. Prices of crops will however not increase as rapidly as the cost of inputs since food cost has to be kept low to make it available to all sections of the society, rich or poor. This makes investment in agriculture less profitable unless production per unit area is substantially increased. Aiming at yield maximisation is, therefore, a necessity not only to get more profit from agriculture but more urgently to meet food requirement of the country in the immediate future.

Maximum yield is a constantly moving target because of continuing technological advances. Maximum yield is slightly higher than maximum profit yield, but the latter can

be derived only after an economic analysis of the former. According to Wortman and Cummings (1978) "As part of their agricultural research, biological scientists in each country must continuously test the limits of available technology as well as their ability to put together new technological components to achieve highest yields. Maximum yields may not be economically practical, but agricultural scientists should not, for supposed economic reasons, fail to attempt to raise the limits on productivity imposed by technology".

The costs of inputs required for crop production are divided into fixed costs and variable costs. The fixed costs which include cost of land, building, machinery, labour etc., will remain the same irrespective of yield per unit area. The variable costs which include costs on fertilisers in addition to costs on pesticides, harvesting and handling will increase with the magnitude of total yield. There are, however, methods by which one may minimise the variable costs while aiming at maximum yield. Integrated nutrient management, integrated pest management, low cost devices for harvesting and handling are some of the methods which can minimise cost of production per unit area.

Integrated nutrient management has been used more often for low input sustainable agriculture (LISA) rather than for maximum yield research (MYR). In LISA, the components of integrated nutrient management such as organic manures and biofertilisers are utilised as partial replacements of inorganic fertilisers to cut down costs and to maximise the effects

of fertilisers at relatively lower doses to get an optimum yield. Some of the proponents of LISA also suggest a complete replacement of inorganic fertilisers by organic biofertilisers to get an optimum yield. As stated earlier it is the maximum rather than optimum yield which has to be aimed at to meet the food requirement of the country.

It has now been established that some of the components of Integrated nutrient management such as organic and biofertilisers can be used along with higher doses of inorganic fertilisers to maximise yield. Such conjunctive use can also minimise the adverse effects on ecology as apprehended from long term use of fertilisers.

An experiment was designed to maximise the yield of a rice variety in the kharif season through integrated nutrient management.

The objectives of this experiment were as follows:

1. To superimpose simultaneously on the recommended dose of fertiliser different components of integrated nutrient management such as green manuring, application of biofertilisers, use of nitrogenous fertilisers with higher apparent N recovery such as USG and application of mixtures of rock phosphate and superphosphate which increase P use efficiency in laterite soils and study their cumulative effect on yield maximisation of the rice variety used.

2. To find out the best way by which fertilisers, biofertilisers and soil amendments could be suitably mixed to achieve maximum yield.

3. To find out the maximum yield achievable under the existing agroclimatic conditions and soil fertility level with the most efficient use of integrated nutrient management technique.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Integrated nutrient management involves harmonious use of nutrients from inorganic and organic sources and measures to increase the availability of nutrients from different sources to the growing crop. It also envisages building up of soil fertility.

In the recent past after the introduction of high yielding varieties the use of organic manures and biofertilisers were abandoned due to their low nutrient supplying power which fell far short of nutrient requirements of HYV. It has now been established that organic manures and biofertilisers can be conjunctively used along with inorganic fertilisers not only to supply the nutrient requirement of HYV, but to even support maximum yield. They can also be blended into a suitable nutrient management system to maximise nutrient response.

Integrated nutrient management for nitrogen

Apart from various forms of organic manure, a number of organisms which are capable of biological nitrogen fixation can be used for integrated management of nitrogen. These alternate sources can be used as partial replacements of fertiliser N or to augment the effects of fertiliser N.

Effects of Blue Green Algae (BGA) in Nitrogen management

The biofertilisers which are of relevance in a rice based cropping system are Blue Green Algae (BGA) and azolla.

The technology for use of BGA is simpler and can be better adopted by farmers than Azola.

BGA are photosynthetic prokaryotic microorganism, some of which are capable of nitrogen fixation. Now over 125 strains of BGA are known to fix nitrogen. Since the discovery of nitrogen fixation by BGA in flooded rice soils (De, 1939), a large number of experiments have been conducted through both pot culture and field experiment to find out the amount of N added by BGA to the rice soils.

Venkataraman (1979) concluded from extensive field trials conducted in many parts of India that in areas where chemical N fertilisers are not used, BGA inoculation could give the farmers the benefit of applying 25-30 kg N/ha.

A few studies have been conducted with isotopes of nitrogen to study the availability of nitrogen fixed by BGA to rice.

Wilson et al. (1980) reported tht 39% of the N_2 fixed by ^{15}N labelled Aulosira sp., spread on the soil and 51% from the algae incorporated into the soil could be taken by the rice crop.

Tirol, Roger and Watanabe (1982) observed that the availability of ^{15}N from BGA incorporated into the soil was 23 to 28% for the first crop and 27 to 36% for the first and second crops. They further reported that after two crops 57% of ^{15}N from BGA and 32 to 40% of ^{15}N from $(NH_4)_2SO_4$ remained in the soil.

Miam (1985) from ^{15}N studies with Azolla, Anabaena and Nostoc observed that of the total ^{15}N applied at the start, 26%, 49% and 53% were released from Azolla, Anabaena and Nostoc respectively after 60 days, of the total N assimilated by the rice plant 48%, 61% and 62% were supplied by Azolla, Anabaena and Nostoc respectively.

BGA along with nitrogenous fertilisers are to be applied to high yielding varieties since BGA alone cannot meet the nitrogen requirement of these varieties.

Biological N_2 fixation is known to be suppressed in the presence of inorganic N. It is, therefore, expected that growth of N_2 fixation by BGA could be affected by application of fertiliser N.

Watanabe (1973) pointed out that inoculation with algae was generally fruitless where nitrogen fertilisers had been applied to the land.

Sankaran (1977) reported that application of nitrogenous fertilisers seemed to inactivate the algal N_2 fixation.

Aiyer (1965) observed a depressive effect on rice yield due to algalization with <u>Tolypothrix tenuis</u> in the presence of $(NH_4)_2SO_4$ and explained that this was due to a competition between algae and rice for nutrients.

There are, however, numerous report on the beneficial effects of algalization in the presence of fertiliser N.

Singh et al. (1972) conducted field trials with the rice variety Jaya and observed that application of BGA alongwith 60 kg N/ha as urea produced grain yield comparable to that obtained with 120 kg N as urea.

Similar observations have been made in pot and field experiment with $(NH_4)_2SO_4$ even at N levels as high as 120 kg N/ha. (Goyal and Venkataraman, 1970; Venkataraman and Goyal, 1963; Venkataraman and Goyal, 1969).

Venkataraman (1979) concluded from a large number of experiments carried out in India that application of high levels of N fertilisers complemented algal inoculations and resulted in yield increase from 2.2 to 28.9%.

Kanvaiyan et al. (1982) reported that application of BGA at 10 kg N/ha along with 60-120 kg N/ha significantly increased the paddy yields of 4 rice varieties.

Patel et al. (1984) reported from their trials on rice Cv. R 35-2752 that 10 kg BGA/ha inoculation produced grain yield equivalent to that with 25 kg N/ha.

Bhuiya et al. (1984) conducted field trials with rice Cv. BR-3 and observed that a combination of 40 kg N and 10 kg BGA/ha gave the highest grain yield (5.82 t/ha) which was 40% higher than untreated control (4.02 t/ha).

Arora et al. (1986) observed that with increasing rates of applied N, algal inoculation increased the yield, but decreased nitrogenase activity.

Tiwari, Lehri and Pathak (1987) reported from their trials on high yielding rice variety IR-8 and Saket-4 that inoculation with BGA can result in saving of upto 30% of fertilizer N and algal contribution remained unaffected even in presence of 120 kg N/ha.

Dar et al. (1989) reported that application of 15 kg N/ha or 10 kg BGA/ha or both gave average paddy yields of 4.5, 4.3 and 4.7 t/ha, respectively compared with N alone.

Singh and Srivastava (1990) conducted a field trial with rice Cv. JR. 3-756 and observed that mean grain yields were 2.6 and 2.8 t/ha with 10 kg Cyanobacteria and 10 kg Cyanobacteria + 25 kg N/ha, respectively.

Dar et al. (1990) reported from their trials on rice Cv. K39 that yields were highest with lime + Mo + BGA + 60 kg N, but the greatest yield increases were at 30 and 45 kg N from control.

Nitrogen management with green manuring

Research work has been recently initiated to include green manuring in the nutrient managment system for the high yielding rice varieties. Since green manuring alone cannot supply the nitrogen requirement of high yielding varieties, it has been used either to partially replace fertilizer N or to augment the effect of fertiliser N.

Beri and Meelu (1979) from their trials on S. cannabina, observed highest grain yields when dhaincha was

incorporated 0 or 10 days before puddling. It gave grain yields of 5.7 and 5.0 t/ha, respectively, equivalent to application of 120 kg N/ha.

Tiwari, Pathak and Ram (1980) observed from their experiments in alluvial soil that yields of N, P and K uptake by rice with green manuring (S. aculeata) + 40 kg N/ha were comparable to those given by 120 kg N/ha. Yields were not significantly affected by allowing time (15 days after ploughing) for the green manure crop to decompose before the rice was transplanted. Residual fertility from green manuring, nitrogen or their combination significantly increased subsequent wheat yield.

Beri and Meelu (1981) from their trials on s.aculeata as green manuring crop, observed that yields of rice with 60 kg N/ha + S. aculeata as green manure crop were at par with 120 kg N/ha applied as inorganic fertiliser. Ploughing in 2 months old S. aculeata 15,7 and 1 days before transplanting rice seedling yielded 4.86, 5.1 and 5.87 tonnes of rice/ha, respectively.

Rinaudo et al. (1981) in a field experiment compared 2 treatments PK fertiliser + inoculated S. rostrata ploughed in as green manure, PK fertiliser + uninoculated S. rostrata as green manure and concluded that the effects of these 2 treatments did not differ significantly from each other, but they both significantly increased the yield and N content of grain and straw.

Khind et al. (1982) studied efficiency of different green manuring crops as substitutes for nitrogen in rice. They

observed that nitrogen added by guar was less than dhaincha and cowpea. The combined use of 60 kg N/ha applied as urea and green manure (2 months old crop burried 1 day before transplanting) gave as high yield as the 120 kg N/ha as urea only.

Singh (1984) reported that 8 week old crop of Sesbania or Sunhemp might add 120 kg N/ha and compared quite well with chemical fertilizer. N substitution of 1/2 to 2/3 of usual dose of 120 kg N/ha were often recorded.

Bhardwaj and Dev (1985) reported that transplanting rice immediately after turning in S. cannabina (45 to 65 days old) gave yield equivalent to that obtained with 100-120 kg N/ha.

Khind, Josan and Beri (1985) observed from incubation studies that N was released from Sesbania aculeata soon after incorporation. Incorporation one day before transplanting released 60 to 120 kg N/ha depending on the amount of incorporation.

Joseph (1986) incorporated S. aculeata into the soil 50 days after sowing and flooded the soil for 0, 1 or 2 weeks before transplanting rice var. Jaya. The highest yield was recorded with 2 weeks of flooding after incorporation of green manuring crop before transplanting of rice.

Ramasamy et al. (1988) incorporated 60 day old dhaincha one week before transplanting rice and observed that dhaincha gave significantly higher grain yield than 40 kg N/ha. Dhaincha applied with 40 kg N was better than 80 kg N. The combined effects of dhaincha and azolla (1 t/ha on fresh

wt. basis) was equal to 80 kg N/ha.

Furoc et al. (1988) studied the residual N response taking 2 rice crops successively in a field trial incorporating green manure crop with or without N. Grain yield, N uptake and total dry matter yield of the first rice crop receiving 120 kg N/ha was at par with 60 kg N/ha + 45 days old green manure, S. rostrata. The second rice crop grain yields were highest with 45 day old S. aculeata with N (3.5 t/ha) or without N (3.6 t/ha).

Shukla et al. (1989) in a field trial taking 2 green manure crops S. aculeata and S. rostrata, concluded that best N use efficiency and apparent N recoveries were with 40 kg N from S. rostrata/ha (38 kg grain/ kg N applied and 75% respectively), 60 kg N from S. aculeata/ha (25 kg grain/kg N and 92% respectively) and Sesbania + 30 kg N as PU (24 kg grain/kg N and 73% respectively for S. aculeata and 29 kg grain/kg N and 86% respectively for S. rostrata). Yield of rice with Sesbania alone was at par with 90 kg N as PU.

Kalidurai et al. (1989) conducted field trial taking rice Cv. Co 43 and observed higher N uptake, grain and straw yields with S. rostrata + 60 kg N/ha as PU or NCU than 100 kg N/ha as PU or NCU applied without green manure.

Halepyati and Sheelavantar (1990) incorporated S. rostrata alone or with 25, 50, 75 or 100 kg N/ha and 100 kg N alcne and got mean rice grain yields of 4.6, 4.9, 5.3, 5.9 and 4.5 t/ha.

Sethy and Chanabasavana (1991) reported from a field

trial highest grain yield of rice Cv. Sonamasuri with 100 kg N/ha + S. aculeata (3.22 t/ha) followed by 100 kg N alone or with S. rostrata (2.8 t/ha) compared with 1.24 t without N or green manure.

Alexander et al. (1986) from a rice-rice green manure cropping system where S. speciosa was raised and incorporated before the kharif rice at 4.3 t/ha observed that with green manuring with treatment receiving 75% of the fertiliser dose of 90:45:45 kg NPK/ha in each season gave same yield as that receiving 100% fertiliser dose.

Experiments carried out at a number of locations under All India Coordinated Rice Research Project from 1985 to 1987 indicated that application of 80 kg N + 40 kg P_2O_5+ 40 kg K_2O/ha gave maximum grain yields invariable at all the locations. However, application of dhaincha or azolla in combination with 40 kg N, 20 kg P_2O_5 + 20 kg K_2O or dhaincha + 20 kg P_2O_5 + 20 kg K_2O and in some locations dhaincha + Azolla + 20 kg P_2O_5 + 20 kg K_2O did not differ significantly from the treatment receiving 80 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha.

Increasing Nitrogen use efficiency

An integrated nutrient management system has also to take into account the efficient utilization of applied fertilizers. Nitrogenous fertilisers are highly water soluble and almost 60-70% of applied nitrogen is lost due to leaching, volatilisation, denitrification and flooding under high rainfall conditions. When nitrogen is applied as a single

dose at the time of planting most of it is lost within a short time and the crop suffers from nitrogen deficiency at the latter growth stages. This results in substantial decrease in yield of the rice crop. A number of methods are adopted to make nitrogen available to the crop throughout the growth period. These methods include

1) Split application of nitrogen
2) Use of nitrification inhibitors and
3) Use of various forms of slow-release nitrogenous carriers.

Split application of nitrogen

Nitrogenous fertilisers have been applied in 2,3 or 4 splits in different quantities to ensure their efficient use by the rice crop.

Ojeda and Freyre (1980) in a field trial observed the effect of split application of nitrogen in 2 rice Cv. IR-800-C9 and Naylamp and concluded that N applied 25% at each of 4 growth stages i.e. at sowing, tiller initiation, full tillering and flowering gave maximum yield in both the varieties as compared to splitting N in 2 equal doses at sowing and flowering or splitting N in 3 equal doses at sowing, tiller initiation and full tillering stage.

Ghosh and Chatterjee (1981) reported significantly higher paddy yield with 60 kg N/ha applied in 2 equal split dressings at transplanting and the tillering stage than with N applied in a single dressing.

Petibskaya and Molokov (1983) in a lysimetric experiment observed increased biosynthesis of free aminoacids and their involvement in protein metabolism with application of N in equal split dressings before sowing, at the seedling, tillering and shooting stages, as compared to N applied fully before sowing or at seedling stage. They also observed that N applied at higher rates the tillering and shooting stages slightly decreased yield, but increased grain protein content.

Bacha and Lopes (1983) in a field trial taking rice Cv. BR-IRGA 409 observed significantly higher yield with 0, 30, 60, 90 or 120 kg N/ha applied 33% at tillering and remainder at flower initiation as compared to N applied 33% as basal dressing and rest at flower initiation.

Anil et al. (1985) observed that N applied in 3 equal split dressings at puddling or 7 DAT and at 21 and 42 DAT gave higher yields than when applied in 3 split dressings on other dates.

Sahoo, Mishra and Mohanty (1990) reported that applying N in equal split dressings was most effective in increasing N uptake and it's partitioning into stems, leaves and panicles.

Patra and Mishra (1990) from a field trial applying 15, 30 or 40 kg N/ha reported that with 45 kg N/ha, highest paddy yield was obtained with split dressings of 15 kg basal + 30 kg at tillering ; with 15 or 30 kg N/ha, a single dressing at the tillering stage was best.

Use of nitrification inhibitors

Denitrification is one of the important mechanism of N loss from waterlogged soils. Since rice prefers to take N in the form of NH_4^+, a number of chemicals have been used to inhibit conversion of NH_4^+ to NO_3^- by specifically inhibiting Nitrosomonas growth and activity.

Brandon et al. (1980) observed from a field trial that nitrification inhibitors significantly increased utilization efficiency of urea-N by reducing nitrification of NH_4 -N and denitrification of NO_3 -N through inhibition of Nitrosomonas.

Das and Chatterjee (1980) reported that the effects of the AM (2-amino-4-chloro-6 methyl pyrimidine) treated N were more pronounced at the higher N level than at the lower N level. Application of AM-treated N increased paddy yields from 5.48 to 5.84 t/ha in the day season and from 3.37 to 3.60 t/ha in the wet season.

Subiah et al (1980) from a field trial taking rice Cv. IR. 20 observed significantly higher yield with 90 Kg N/ha + neam seed crust as compared to 120 kg N/ha + neam seed crust.

Ramiah et al.(1986) reported that paddy yield with 80 kg N/ha as neem cake coated urea was at par with 80 kg N/ha as dicyandiamide-coated urea.

Wilson et al.(1990) studied the influence of dicyandiamide (DCD) on fertiliser N recovery from soil and rice when ^{15}N-labelled urea was applied preplant. Prior to flooding urea with

DCD reduced nitrification. With DCD, 51 and 8% of the applied N was recovered at flooding as NH_4^+ and NO_3^-, respectively, compared with 8 and 23% respectively without DCD. More fertiliser N was recovered in the shoots and roots when urea was applied with DCD, than when used alone. DCD, by maintaining more fertiliser N in the NH_4^+ form, appeared to cause greater immobilisation of the fertiliser N than when DCD was not applied.

Molletti, Fiore and Villa (1990) from a field trial reported significantly higher yield (7.03 t/ha) with Ca. cyanamide at sowing + 50 kg N as urea/ha 3 months later as compared to 100 kg N-serve (2-chloro-6(trichloro methyl) pyridine) applied before sowing + 50 kg urea/ha 3 months later (5.99 t/ha).

Use of various forms of slow release nitrogenous carrier

Among the nitrogenous fertilisers, urea has been treated or coated with different materials such as Neem cake coated urea (NCU), lac coated urea (LCU), sulphur coated urea (SCU), coaltar coated urea (CCU), etc. or formulated into different forms such as Urea supergranule (USG), Large granule urea (LGU), mud-ball urea etc. to impede it's rapid dissolution in soil water after it's application.

Reddy and Shinde (1979) conducted a field experiment growing rice under controlled irrigation (sunmergence 2-5 cm) or uncontrolled conditions (5-20 cm) and applied N as (a) Urea or (b) Urea blended with neem cake. Basally applied (b) gave significantly higher yield and returns/kg applied fertiliser under both controlled and uncontrolled irrigation as compared to urea alone.

Singlachar et al (1979) observed that grain yields were significantly increased by N applied as a basal dressing as mud balls, paper capssules, supergranules of SCU (Sulphur coated urea) compared with split application.

Singh and Kumar (1980) reported from a field trial with rice given 50-100 kg N/ha as urea and/or SCU in 1-3 split dressings that application of 50 kg N/ha as SCU at transsplanting + 25 kg N/ha as urea at tillering + 25 kg N/ha as urea at P.I. gave higher yield (7.33 t/ha) as compared to 100 kg N/ha as SCU in 3 split dressings (7.0 t/ha).

Chian and Yang (1980) observed that basal dressing SCU gave 17% higher yields than a basal dressing and 3 side dressing of urea.

Krishnarajan and Balasubramaniam (1981) reported that rice grain yield significantly increased with split applicastion of urea coated with coaltar and kerosene at sowing (25%), tillering (50%) and P.I. (25%).

Garcia and Vargas (1982) in field trial giving rice 45 or 90 kg N/ha as (a) Urea, (b) $(NH_4)_2 SO_4$, or (c) SCU applied before transplanting or in 3 equal broadcast application after transplanting, observed that grain yield with SCU (5.42 t) was significantly higher than with Urea or $(NH_4)_2 SO_4$ (4.80 and 4.76 t, respectively).

Sahu and Mitra (1989) conducted field trial to test the efficiency and method of application of LGU (large granule urea) in wetland rice cultivation and obsrved that application of LGU in 2 splits i.e. 2/3rd of the dose at 7 DAT of rice and 1/3rd of the dose at P.I. stage gave significantly higher yields at 60 and 90 kg N/ha compared to PU when applied in a similar manner or even in 3 splits. The apparent N recovery and N use efficiency were also higher for LGU than those for PU.

Patra and Padhi (1989) reported from a field trial applying to rice Cv. IR. 36 0, 30, 60 or 90 kg N/ha as urea or LGU in split applications at transplanting and tillering or at transplanting, tillering and P.I. or as USG placed at 8-10 cm deep between rows 8 DAT and observed that grain yields so also returns were highest with 90 kg N/ha as LGU and lowest with 30 kg N/ha as USG. The number of tillers/hill, panicles/hill, panicle length and 1000 grain weight were lowest with USG because concurrent irrigation encouraged percolation and volatilisation losses.

Joseph et al. (1991) observed from a field trial on rice given 29, 58 or 87 kg N/ha in 4 forms as SCU, PU, USG or Mussoriephos coated urea that SCU, PU or USG gave yields of 2.91-2.96 t compared with 2.65 t for N as Mussoriephos coated urea. N use efficiency was highest at 58 kg N/ha as SCU.

Urea-Supergranules (USG)

Meelu and Rekhi (1983) in a field study with SCU, USG, LGU, NCU (all applied in a single dose at transplanting)

and PU (applied in 3 equal splits) on rice grown on typic Ustipsamment soil, obtained highest mean grain yield of 6.36 t/ha with SCU followed by 5.65 t/ha with split application PU; and lowest yield of 4.06 t/ha was obtained with USG.

Saha and Mitra (1984) reported that rice given 54 kg N/ha gave similar yield with N applied both as urea at 10-12 cm depth at transplanting and USG placed 10 cm deep at centre of 4 hills of each alternate row and column. Yields with 54 kg N as USG/ha was at par with that obtained with 81 kg N as SCU, applied broadcast and incorporated at transplanting.

Reddy and Mitra (1985) also observed the superiority of USG and SCU under intermediate deep water conditions with water depths of 15-35 cm during most part of the growth period. Placement of USG and SCU produced 23-25% higher grain yields as compared to PU.

Sen, Gulati and Mohanty (1985) observed 46% increase in average yield from USG placement compared with urea alone in 3 split dressing.

Manickam and Ramaswami (1985) reported that 37.5 kg/ha USC applied at 8-10 cm depth gave significantly higher yield as compared to 112.5 kg/ha PU applied in 3 split application.

Singh, Tan and Hong (1985) concluded from a field trial taking rice CV. OM 33 that 29 kg N/ha as SCU or USG gave a yield response similar to that with 87 kg N/ha as PU. At 58, 67 and 116 kg N/ha as PU, SCU and USG did not produce

significantly different yields. This reduced grain yield with SCU and USG at higher N levels was caused by a higher % of unfilled spikelts.

Singh and Verma (1989) reported from a field trial on rice Cv. Jaya taking 120 kg N/ha as urea (applied in 3 splits) or as SCU, NCU, Lac/gypsum coated urea, USG applied 7 DAT that highest grain, straw yield and 1000-grain weight were obtained with USG which were slightly superior to SCU.

Singh et al.(1989) from a field trial with rice Cv. Jaya, reported that grain and straw yields were highest by placement of USG at 10 cm depth followed by that at 15 cm and 5 cm.

Tomar and Verma (1990) observed that paddy yields with 80 kg N/ha as USG was at par with 120 kg N/ha as urea.

Raju and Reddy (1990) conducted a field trial with rice Cv. Prabhat and observed that grain yield with 37.5 kg N/ha as USG (5.2 t/ha) was slightly lower than that obtained from 112.5 kg N/ha as plastic-coated urea (5.43 t/ha).

Juang (1990) studied on point and deep placement of USG under field conditions in many countries and concluded that superior performance of USG in increasing rice yields and fertilizer N efficiency (40-50% more efficient than urea alone) has shown USG to be highly suitable for paddy rice in many Asian countries, where urea is already a common fertilizer for rice.

N uptake and % recovery have often been observed to be higher when N is applied in form of USG rather than as PU.

Cao and De Datta (1983) observed that losses of N were lower with uniform placement of PU or point placement of USG than with split or band application of Urea + NH_4^+ - N. At harvest, recovery of ^{15}N fertiliser in grain + straw was upto 73% in the dry season and 65% in the wet season with point placement of USG.

Mohapatra et al. (1983) evaluated recovery of N applied as USG, NCU and FYM + Urea in an alluvial soil. Efficiency of N was higher with the last 2 sources. The recovery of N ranged from 29 to 40% with different N sources and USG showed the highest recovery. Concentration of NH_4^+ - N in flood water and soil was less with USG compared to other sources while NO_3^- - N in soil was in general 2 ppm.

N loss by NH_3-volatilisation measured in a closed curite system reduced from 24% with surface application of PU and 20% with surface application of USG to approximately 2% with deep placement of USG. The total N loss measured in an open cuvette system was about 38% with the surface application of USG whereas this loss was reduced to 10% with deep placement of USG. (Eriksen et al., 1985).

Chalam, Chakravorti and Mohanty (1989) observed that yields, N uptake and N recovery % were higher with N as USG than N as urea.

Singh et al.(1989) from a field trial with rice Cv. Jaya reported that protein harvest and N uptake were highest under 10 cm deep placement of USG followed by that at 15 cm and 5 cm.

Bharat and Srivastava (1989) reported from a field trial with rice Cv. Jaya that yield, N use efficiency and N recovery % were higher with USG than N as urea.

Dubey and Bisen (1989) from a field trial taking 4 levels of N 0, 38, 76 or 114 kg N/ha as urea or USG, broadcast in 2 splits 8 and 25 DAt or placed near plants 8 DAT, concluded that N content and U uptake increased with N applications and was highest with USG using the placement method.

Phosphorus management in rice

Dash et al.(1982) concluded from a field trial that application of different acidulated RP to moist aerobic soils 2 weeks prior to flooding gave higher Olsen P, dry weight and P uptake during initial growth stages and higher grain yield and P uptake compared with when the P carriers are applied at flooding. RP acidulated to the extent of 50% gave optimum P availability in soil, grain yield and P uptake by rice.

Marwaha (1989) reported that among the indigenous phosphate rocks, Mussorie RP appears to be the most reactive and agronomically suitable as measured in terms of it's crystallite size, crop response, P uptake and in the ameliorating liming action in the acid soil.

Marwaha and Sood (1989) observed that application of 10 to 20% acidulated RP exhibited favourable effect on the P-fixing capacity of the soil as compared to highly water soluble sources as expressed in terms of AEC, available P status and extractable Al content of the soil. They also suggested that soils rich in extractable Al and/or having higher degree of exchangeable acidity may be better adopted to the use of RP or partially acidulated RP.

Pattnaik and Mishra (1989) studied on total P content of 12 acid soils in Orissa and observed that inorganic P increased on submergence. Submergence decreased reductant soluble P (Red-S-P) and Ca-P and increased the Al-P and Fe-P fractions, the highest increase being in Al-P. About 53 to 90% of added P (200 ppm) as fertilizer was recovered as inorganic, a large % of which was in Al-P and Fe-P form.

Subramanian and Kumaraswamy (1989) studied on phosphate adsorption isotherm in acid soils varying in fertility from a long term fertilizer trial that P fixation capacities varied widely (332-268 ppm). The fixation of applied P as saloid-P or Al-P or Ca-P followed almost similar trend in soils under different treatments.

Effect of P on yield and Residual effect of P

Verma, Sharma and Singh (1981) studied on the residual effect of P in rice Cv. Cauvery on a sandy clay loam soil with 10 kg available P/ha and reported that grain yield were not affected by P application in the first year, but were

increased in subsequent years to give average yield of 2.0, 2.2 and 2.4 t/ha with 9, 18, 27 kg P_2O_5/ha respectively.

Sarkar and Sarkar (1982) conducted a field experiment to assess the direct or residual effect of MRP in an acid soil of Assam and observed that the direct effect was not statistically significant, residual effect and direct + residual effects as judged by grain yield and total P uptake, were significant.

Sahu and Pal (1983) conducted a field trial with rice Cv. Parijat on acid soils of Orissa in 2 consecutive years given 0, 40, 80 or 120 kg P as (a) 100% MRP, (b) 100% superphosphate or 75:25, 50:50 or 25:75, MRP:Superphosphate mixtures. Following the harvest of rice crop wheat Cv. Sonalika was sown. They reported highest P uptake, grain yield and P content of grain and straw with 80 kg P_2O_5 applied as 50:50 mixture of MRP and superphosphate. Grain yields of rice were 2.71 and 3.44 t/ha following application of this mixture in first and second year and the grain yields of the following wheat crop reached 2.07 and 2.26 t/ha, respectively in these 2 years.

Sundaresan and Aiyer (1983) observed from a pot experiment with rice Cv. Jaya on 6 different acid soils from Kerala given 45 or 90 kg P_2O_5/ha as (a) superphosphate or (b) MRP that there was no significant difference between 1000 grain wt., grain and straw yields in response to (a) and (b).

More and Kadrekar (1983) studied the effects of 50 kg P_2O_5/ha applied as MCP, DAP, Uramphos, DCP or RP on the yield

and P uptake of rice in pot of medium black or lateritic soil and observed that grain yield and P uptake were significantly increased by all P sources in both soils and were highest with Uramphos in medium black soil and with DCP in lateritic soil.

Mathur and Lal (1987) studied on the response of rice to RP as compared to SP, and reported that sources of P significantly differed in increasing the yield of rice in 2 out of 4 years, but no significant difference in yield was noticed among the levels of P of the same source.

Mongia et al.(1988) from a pot experiment in acid soil containing 0, 25, 50, 75 and 100 kg P_2O_5/ha as MRP or superphosphate reported that yields increased with increasing P levels and ranged from 14.7 to 23.7 and from 9.9 to 23.5 gm/pot over all P levels of RP and superphosphate respectively, compared with 0.4 gm/pot for untreated control.

Bandyopadhyay (1988) observed that application of RP could not improve soil pH, but it increased dry matter yield of dhaincha as compared with application of limestone. Grain yield of rice taken after dhaincha increased significantly by application of RP.

Sharma and Sinha (1989) studied on the residual effect of P sources in a Rice-gram rotation in acid soil and reported that superphosphate significantly increased the residual available P content of the soil over the P fertilisers. Significantly higher P uptake by rice was found due to application of superphosphate followed by RP. More availability

of P from superphosphate application was due to it's containing water soluble P. The residual available soil P also increased in case of RP because of its long contact with the soils.

Potassium management in rice

Potassium management under wetland rice conditions involves applications of one of the potassic fertilisers such as Muriate of Potash or K_2SO_4, either in a single dose at the time of planting or in split doses at different stages of growth. Split application has generally given higher response in light textured soil since most of the applied K at planting is either leached or washed away due to flooding under wetland rice cropping conditions.

Bacha et al.(1980) reported from field trial that application of potassium in 2 equal split as basal and side dressing at booting stage, gave significantly higher yield than K applied either as basal or side dressing at booting stage.

Lopes et al.(1981) conducted a field trial at Uruguaina soil rich in K and observed that rice Cv. BR/IRGA 409 gave yield of 7.57, 8.57 and 8.01 t/ha with all K applied at sowing, at flooding or 50% at sowing and 50% at flooding respectively.

Das and Sarkar (1981) reported that a foliar spray of 0.25 to 1% KNO_3 at the ear emergence stage or 15-30 days later increased paddy grain and straw yield. The treatments increased the retention of chlorophyll in the flag leaf and

delayed senescence during the active grain filling stage.

Chen (1987) studied the K uptake and loss in rice in relation to N and K status in paddy soil and reported that application of K reduced the flux of K uptake in rice and N inhibited K flux in rice on soils with low K content whereas it promoted the K flux in rice on the soil with high K content. When exchangeable and K in soil was below the critical value 2-4 mg/100 gm in paddy soil on red earth, loss of K occurred in the rice plant at an early stage at the rate of 0.9-7.7 x 10^{-3} M/cm^2.

Patiram and Prasad (1987) observed that paddy yields of rice grown on K-deficient low lands were significantly increased with 60 kg K_2O/ha, especially when applied in 2-3 split dressings.

Sehthilvel and Palaniappan (1989) conducted a field trial by applying NK granules to rice Cv. IR 50 (wet season) and Cv. CO 43 (dry season) as a basal dressing or as topdressing at tillering or at tillering + PI stage or KCl applied as basal. K uptake was highest with basal application of KCl and highest yields were with basal application of KCl or NK granules applied at tillering + PI.

Kolar and Grewal (1989) reported that yield of rice responded significantly to split application of 50 kg K/ha (1/2 at transplanting + 1/2 at active tillering). Split application of K at transplanting and PI; at active tillering and PI also significantly increased yield. Applying 100 kg K

at transplanting was as efficient as split application. K helped increase panicle bearing tillers and grain weight.

Krishnappa et al.(1990) from a field trial observed that K applied in 2 equal split dressings at transplanting and PI or 3 split dressings, 50% at transplanting, 25% at tillering and 25% at P.I. significantly increased paddy yield than when applied at transplanting alone.

Liming

Lime is the first step in any sound soil management programme and broadcast application in accordance with soil and soil and plant requirements are essential for greatest return from fertilisers.

Machado (1980) from a field trial giving all combinations of 0, 2.4 or 4.8 t limestone/ha and 0, 60 or 120 kg N/ha as urea to rice Cv. Bluebell observed that grain yields ranged from 3.9 to 4.4 t/ha and were not significantly affected by the treatments, but increasing rates of N and especially limestone increased the growth duration leading to an increase in sterility as a result of the critical stage occurring later.

Machado et al.(1980) conducted a field trial applying all combinations of 0, 100, 200 or 300 kg P_2O_5/ha and 0, 0.8, 1.6 and 2.4 t dolomitic limestone/ha. Average grain yields ranged from 6.6 to 7.0 t/ha and the highest yield of 7.2 t/ha was given by 100 kg P_2O_5 + 2.4 t limestone/ha.

Lee et al.(1989) conducted a field trial giving 0, 150 or 300 kg N/ha and 0, 2.33 or 4.66 t lime/ha and observed

that total flag leaf sugar and starch content at heading decreased with increasing lime rate. Liming reduced lodging at higher N rates. Lignin, hemicellulose and cellulose content, cell wall thickness increased with increasing lime rate.

Mamaril et al.(1990) studied the phosphorus-lime interactions in rice grown on strongly acid upland soil and reported that grain yields were significantly higher when P and lime were applied. Upland rice responded more to P during the initial yers, but the benefits of lime increased with time.

Rosmini and Sarwani (1991) conducted a field trial using 4 lime levels (0, 0.5, 1.0 and 2.0 t/ha) on acid sulphate soil, applied 15 days before transplanting and reported that yields in the plots with 2.0 t/ha lime were significantly higher than those at other levels.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted in the 'C' block of Central Research Station of the Orissa University of Agriculture and Technology, Bhubaneswar during Kharif, 1992 in a medium land soil classified as Aeric Haplaquept with the following physical and chemical characteristics of the surface soil (0-15 cm).

1.	Sand	76%
2.	Silt	20%
3.	Clay	40%
Textural Class		Sandy loam
1.	pH (1:2)	5.9
2.	Organic carbon	0.368%
3.	Available Nitrogen (alk. $KMnO_4$)	225
4.	Available P_2O_5 (Olsen)	11.6
5.	Available K_2O (Amm. acetate)	290
6.	Lime requirement (woodruff)	2 t/ha

The chemical composition of the soil indicated that the soil was low in nitrogen, phosphorus and high in potassium and medium in organic carbon with acidic reaction.

Experimental Details

Design and Layout:

The experiment was carried out in a randomised block design with 10 treatments and 3 replications.

Treatment description:

T_1	N_{80} P_{40} K_{40}
T_2	N_{80} P_{40} K_{40} + FYM 5 t/ha
T_3	N_{80} P_{40} K_{40} + GM
T_4	N_{80} P_{40} K_{40} + GM + BGA
T_5	N_{80}(USG) P_{40} K_{40} + GM + BGA
T_6	N_{80}(USG) P_{40} (SSP + RP) 1:1 K_{40} + GM + BGA
T_7	N_{80}(USG) P_{80} (SSP + RP) 1:1 K_{80} + GM + BGA
T_8	Liming + N_{80} P_{80}(SSP) K_{40} + GM + BGA
T_9	Liming + N_{80} P_{80}(DAP) K_{40} + GM + BGA
T_{10}	Liming + Gypsum + 80:40:40 (DAP) + BGA

Twentyfive day old rice variety Lalat (125 days) was transplanted on 21st July, 1992 at a spacing of 16 cm x 16 cm in a plot size of 30 m^2 .

N was applied in all the treatments @ 80 kg/ha. Treatment no.1, 2, 3, 4, 8 received N in form of urea which was applied in 3 splits; 25% at the time of transplanting, 50% 17 days after transplanting (DAT) and 25% 18 days before heading (DBH). Treatment No.5, 6, 7 received N in form of Urea super granules (USG) which was point placed in between 4 hills at alternate rows 7 DAT at 5-7 cm depth. Treatment

No.9, 10 received N in form of DAP which was applied in 3 splits. At transplanting, N was applied first calculating the P dose of rice. Tr. No.9 received 31 kg N from DAP (i.e. 174 kg DAP ws applied to provide 80 kg P). Rest of N (i.e. 49 kg) was applied as urea in 2 equal split doses viz. 17 DAT and 18 DBH. Tr. No.10 received N in form of DAP to provide 15.7 kg N and 40 kg P_2O_5 at transplanting (i.e. 87 kg DAP). To provide 20 kg N (i.e. 25% of 80 kg N) at transplanting to rice, rest 4.3 kg N ws supplemented with urea. Rest 60 kg was applied in 2 splits, 40 kg at 17 DAT and 20 kg at 18 DBH. Tr.No.1, 2, 3, 4, 5, 8 received P in form of SSP and Tr.No.6 and 7 received P as mixture of SSP and RP at the ratio of 1:1. Rock phosphate was given in form of Udaipur rock phosphate (URP) which contains 14.65% P_2O_5. All treatments received K in form of Muriate of Potash (MOP) at the time of transplanting except Tr.No.7 where K @ 80 kg/ha was applied in 2 equal splits, 50% at the time of transplanting and 50% at 25 DAT.

FYM @ 5 t/ha was given at the time of transplanting in Tr.No.2. Source of green manure was dhaincha (S.cannabinus). Tr.No.3 to 8, where GM was used, the P requirement of rice was given to the dhaincha crop. This practice was not followed in Tr.No.8 where DAP was used. All other treatments (Tr. No.1, 2, 9, 10) received all P at transplanting. Soil based BGA was applied one week after transplanting @ 12 kg/ha. Gypsum was applied (Tr.No.10) at the time of transplanting @ 250 kg/ha. Liming was done with papermill sludge (Tr..No.8, 9 and 10) at 0.5 LR 42 days before transplanting at the time of land preparation.

The chemical composition of papermill sludge is as follows:

Total SiO_2	2.90%
Water soluble SiO_2	0.51%
CaO	47.21%
MgO	0.39%
$CaCo_3$ equivalent	85.2%

42 days old dhaincha plants were uprooted, chopped and incorporated into the field and rice was transplanted 7 days after incorporation of dhaincha into the soil.

At the time of incorporation dry matter yield of dhaincha plants were recorded and analysed for N, P and K content.

At maximum tillering stage rice plant samples were collected for chemical analysis. Yield and yield attributing characters were recorded and plant and grain samples were collected for chemical analysis at harvest.

After harvest of rice crop (27th Oct., 1992) soil samples were collected from individual treatments and analysed for pH, organic carbon, available nitrogen, phosphorus and potassium.

Methods of Analysis

1) Soil Analysis:

Chemical constituents	Methods used
i) Mechanical analysis	Bouyoucos Hydrometer method. (Piper,1950)
ii) pH	1:2 (Soil:Water) in Elico pH meter.

iii)	O.C.	Walkley Black rapid titration method(Piper, 1950)
iv)	Available nitrogen	Alkaline $KMnO_4$ method (Subbbiah and Asija, 1956)
v)	Total nitrogen	Macrokjeldahl method (A.O.A.C., 1965)
vi)	Available P_2O_5	Olsen method (Jackson, 1967)
vii)	Available K_2O	Extracted by 1N ammonium acetate and determined by Elico Flame Photometer.
viii)	Lime requirement	Woodruff's buffer method.

2) Plant Analysis:

The plant samples were ovendried at 80°C for 48 hours, ground and passed through 20 mesh sieve and analysed for N, P and K.

i)	Estimation of nitrogen	Microkjeldahl method (A.O.A.C., 1965)

ii) Estimation of plant samples for P, K, Ca, S and Zn.

(a) Digestion of plant samples for P, K, Ca, S and Zn.

The dried and ground plant sample (1 gm) was digested with HNO_3 and $HClO_4$ (60%) at the ratio of 3:2 and volume was made upto 100 ml with distilled water. From this stock solution P, K, Ca, S and Zn were estimated.

(b) Estimation of phosphorus

Phosphorus was determined by Vanado Molybdate Yellow colour method in a Spectro pohotometer at 420 mm (Chapman and Pratt, 1961).

(c) Estimation of potassium

Potassium was determined by Elico Flame photometer (Champman and Pratt, 1961)

(d) Estimation of calcium

Calcium was determined by Elico Flame photometer (Wells and Corey, 1960).

(e) Estimation of sulphur

Sulphur was determined by turbidity development. (Bethge, 1956).

(f) Estimation of zinc.

Zinc was determined by Atomic Absorption Spectrophotometer.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

A field experiment was carried out for Kharif season 1992, in a laterite soil (Aeric Haplaquept) in the Central Farm of O.U.A.T at Bhubaneswar. A medium duration rice variety Lalat (125 days), which is photoinsensitive, semi-dwarf and moderately nitrogen responsive was grown. There were in total 10 treatments which were replicated thrice in a randomised block design.

The details of the treatments are given under Materials and Methods.

The treatments were designed to find out the cumulawtive effects of different nutrient management systems sometimes superimposed upon one another on yield maximisation.

N was applied to all the treatments at a saturation dose of 80 kg N/ha, maximum tolerated by the rice variety used, in the kharif season. P and K applied as SSP @ 40 kg P_2O_5/ha and as MOP @ 40 kg K_2O/ha respectively along with the saturation dose of N constituted the control (T_1). In the other treatments this basic dose of N, P, K as applied to the control was supplemented by addition of different nutrient carriers, amendments and management practices etc. to study their cumulative effects on yield.

In addityion to the grain and straw yield, the effects of different treatments on some of the yield attributing chara-

cters and on the contents and uptakes of N,P,K, Ca, S and Zn were dtermined. The results are presented from Table 1 to Table 13 in the following pages.

Nutrient added through FYM and green manuring

The nutrient contents of FYM and 42 day old dhaincha crop is given in Table 1. Except T_9 and T_{10}, the phosphatic fertiliser was added to the dhaincha crop and not to the rice crop.

It is observed from table 1 that the NPK content and the amount of N,P,K added through the dhaincha crop to rice was higher when 80 kg P_2O_5/ha was added to it as compared to 40 kg. The total amount of N,P,K, added through the addition of FYM was N = 25 kg/ha, P = 10 kg/ha, K = 22 .5 kg/ha and through green manuring due to application of 40 kg P_2O_5/ha N = 28.54 kg/ha, P = 2.89 kg/ha, K = 29.18 kg/ha and with 80 kg P_2O_5/ha N = 39.97 kg/ha, P = 4.11 kg/ha, K = 35.81 kg/ha.

Effect of integrated nutrient management on some yield attributing characters and grain and straw yield

Some of the yield attributing characters such as ear bearing tillers/m^2, panicle length, panicle weight and % filled grains were recorded. The data are presented in Table 2.

It is observed from table 2 that except for panicle length, other parameters were significantly affected due to different treatments. Grain filling however, was affected in a highly significant manner by the treatments. Application of organic manure (FYM) or biofertilisers (GM and BGA) (T_2, T_3 & T_4) significantly increased per cent filled grains as compared to the

Table 1. Nutrient composition and nutrient added by FYM and green manure (*S. cannabinus*).

Name of the saource	% N	% P	% K	Added N (kg/ha)	Added P (kg/ha)	Added K (kg/ha)
FYM @ 5 t/ha	0.50	0.20	0.45	25.00	10.00	22.5
Green manure (40 kg P_2O_5/ha)	2.758	0.28	2.82	28.54	2.89	29.18
Green manure (80 kg P_2O_5/ha)	3.304	0.34	2.96	39.97	4.11	35.81

Table 2. Effect of integrated nutrient management on some yield attributing characters of rice.

Tr.No.	Treatments	EBT/m^2	Panicle length(cm)	Panicle weight(gm)	Total No. of chaffy grains/ panicle	Total No.of filled grains/ panicle	% filled grains
T_1	80:40:40	301	24.52	2.12	36	46	56.09
T_2	80:40:40 + FYM 5 t/ha	319	25.06	2.17	33	53	61.62
T_3	80:40:40 + GM	327	24.42	1.85	28	53	61.62
T_4	80:40:40 + GM + BGA	326	26.78	2.11	32	59	64.83
T_5	80:40:40 + GM + BGA (USG)	313	23.13	1.78	21	60	74.07
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	322	25.06	1.85	23	63	73.25
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	295	22.66	1.75	12	65	84.41
T_8	Liming + 80:80:40 +GM+BGA (SSP)	324	23.96	1.85	12	66	84.61
T_9	Liming + 80:80:40 +GM+BGA (DAP)	297	22.86	1.59	15	61	80.26
T_{10}	Liming + Gypsum +80:40:40 + BGA (DAP)	302	24.18	1.84	18	59	76.62
SE(m) ±		10.683	0.681	0.235	1.922	1.595	
C.D. at 5% level		N.S.	2.021	N.S.	5.706	4.735	

the control (T_1) which consisted of N_{80} P_{40} K_{40} applied in the form of inorganic fertilisers. Significant increases in % filled grains over these treatments were observed when PU was substituted by USG (T_5, T_6). Increasing the dose of P from 40 to 80 kg did not have any significant effect in grain filling (T_5 vs. T_6). However, when the dose of K was doubled there was again a significant increase in grain filling (T_6 vs. T_7). Similarly liming also significantly increased grain filling (T_8). There appears to be a decrease in grain filling when SSP was replaced by DAP as a P source (T_8 vs.T_9 and T_{10}).

The above observations indicate that addition of organic matter or biofertiliser improve grain filling and consequently the yield of rice. This is probably due to the better utilisation of nutrients by their regulated release at later stages of growth which results in higher protein and carbohydrate synthesis and consequently better grain filling. The effect of USG which is a slow release N fertiliser also has similar effects. The effect of potassium is due to its known role in translocation of carbohydrate and of Ca in the synthesis of carbohydrate.

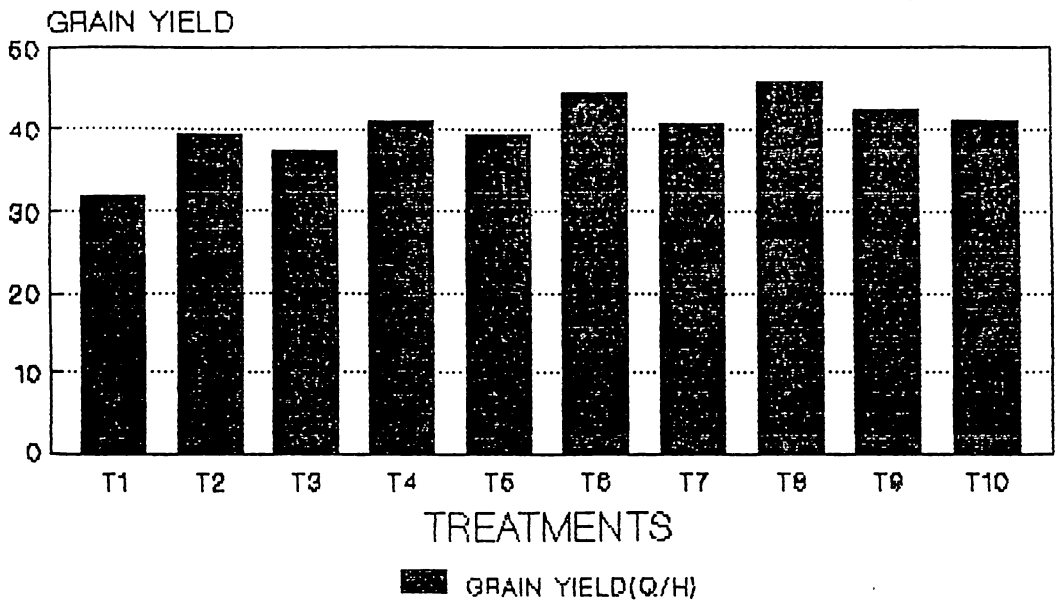
Grain yield, straw yield and 1000-grain weight (filled grains) at harvest are given in table 3. The effects of different treatments on grain yield is also presented in Fig.1.

It is observed from table 3 that 1000 grain wt. (filled grains) was not significantly affected by the different treatments. There were significant variation in grain and

Table 3. Effect of integrated nutrient management on 1000 grain weight, grain and straw yield of rice.

Tr.No.	Treatments	1000 grain weight	Grain yield(q/ha	% decrease or increase over std.treatment	Straw yield (q/ha)	% decrease or increase over std.treatment
T_1	80:40:40	27.85	31.72	-	36.36	-
T_2	80:40:40 + FYM 5 t/ha	27.67	39.37	+24.11	41.88	+15.18
T_3	80:40:40 + GM	28.18	37.24	+17.40	38.87	+6.90
T_4	80:40:40 + GM + BGA	28.09	41.12	+29.63	43.13	+18.61
T_5	80:40:40 + GM + BGA (USG)	27.96	39.24	+23.70	45.01	+23.78
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	28.99	44.51	+40.32	45.26	+24.47
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	28.05	40.75	+28.46	42.00	+15.51
T_8	Liming + 80:80:40 +GM+BGA (SSP)	28.64	45.89	+44.67	50.15	+37.92
T_9	Liming + 80:80:40 +GM+BGA (DAP)	26.10	42.38	+33.60	46.84	+28.82
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	26.41	40.87	+28.84	42.63	+17.24
SE(m) ±		0.831	1.271		1.442	
C.D. at 5% level		N.S.	3.773		4.281	

FIGURE 1



EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GRAIN YIELD (Q/H) OF RICE

T1 = 80:40:40

T2 = 80:40:40 + FYM 5 T/HA

T3 = 80:40:40 + GM

T4 = 80:40:40 + GM + BGA

T5 = 80:40:40 (USG) + GM + BGA

T6 = 80:80:40 (USG) + GM + BGA + P as(SSP+RP)

T7 = 80:80:80 (USG) + GM + BGA + P as(SSP+RP)

T8 = Liming +80:80:40 (SSP) + GM +BGA

T9 = Liming +80:80:40 (DAP) + GM +BGA

T10= Liming +Gypsum+80:40:40 (DAP) +BGA

straw yield at harvest. Application of FYM along with recommended dose of fertilisers (T_2) increased both grain and straw yield significantly over the control (T_1). Application of green manure (GM) or GM + BGA along with fertilisers also significantly increased grain and straw yield over control (T_3 and T_4 vs. T_1). The yields with GM + BGA (T_4) was significantly higher than GM alone (T_3). It was further observed that FYM, GM and BGA application increased grain yield more than the straw yield. When USG replaced PU (T_5), without changing the other components of T_4, grain yield decreased and the straw yield increased significantly though the yields of both the treatments were significantly higher than the control. Increase only in the dose of P fertiliser from 40 kg/ha in T_5 to 80 kg/ha in T_6 without changing any other components resulted in a significant increase in grain yield, but straw yield was not affected (T_6 vs. T_5). Doubling the dose of potassic fertiliser significantly decreased grain and straw yield (T_7 vs. T_6). When the plots were limed and N_{80} $P_{80(SSP)}$ K_{40} were applied along with GM and BGA, there were significant increases in grain and straw yield (T_8) as compared to control (T_1). Grain and straw yield decreased significantly when SSP was replaced by DAP (T_9 vs. T_8) There were further significant decrease in grain and straw yield when DAP was used to supply 40 kg P_2O_5/ha and gypsum was applied to supply 30 kg S/ha.

The observations as recorded above indicate that application of organic or biofertilisers (T_2, T_3 and T_4) increase grain yield rather than the straw yield due to their

effects on better utilisation of P fertilisers for grain production. The role of P in increasing fertilisation and consequently seed formation is well known. The observed decrease in grain yield with significant increase in straw yield due to replacement of PU by USG was probably due to the higher availability of N since 80 kg USG was applied as a single dose which supported more of vegetative growth at the early growth stages of the crop. According to Yoshida (1981), N absorbed at early growth stages is used to produce more straw than grain. This is evident from the significant increase in grain yield, but not the straw yield when the dose of P was doubled in the next treatment in T_6 along with USG application. The significant decrease in grain and straw yield due to doubling of the dose of K (T_7) as compared to previous treatment (T_6) was probably due to nutrient imbalance created by this treatment. The effect of liming on significantly increasing grain and straw yield was partly due to its effect on P availability in acid laterite soils, it's effect on reducing higher concentration of Fe and Mn present in laterite soils and the beneficial effect of Ca on an acid laterite soil on the general growth of the plants. The significant decreases in grain and straw yield due to replacement of SSP by DAP (T_9) were probably due to decrease in S availability in this treatment. Application of gypsum along with DAP and liming did not improve grain or straw yield as the needed S requirement of the crop could not be met from gypsum at higher pH values caused by liming (T_{10}). Further the significant decrease in yield in this treatment might be partly due to omission of G.M. in this treatment.

N, P, K content and uptake at maximum tillering stage

N, P, K contents and uptake by the plants at maximum tillering stage are given in Table 4. Effect of different treatments on N content and uptake, P content and uptake and K content and uptake are presented in Fig. 2, 3 and 4, respectively.

It is observed from table 4 that there were considerable variationsin the N content of the plants though the dose of N for all the treatments was same (80 kg N/ha). The highest N content was observed in T_5 where PU was replaced with USG and the lowest in T_{10}, where N was supplied partially as DAP and partially as urea and GM was excluded from the treatment. All the USG treated plots (T_5, T_6 and T_7) had relatively higher N contents which were significantly higher than the control (T_1). Application of GM + BGA (T_4) also significantly increased N content of the plants as compared to control (T_1). All the 3 treatments which received liming (T_8, T_9, T_{10}) had significantly lower N content than the control.

Effect of USG on increasing N content of plants at maximum tillering stage is already known. According to Mitra, Sahu and Rout (1989), there was increased uptake of N by rice when USG was point placed as compared to application of prilled urea in three splits. The significant decrease in N content of the plants due to liming was not due to N loss at higher pH as liming was done sufficiently ahead (42 days before transplanting) of N application and pH of the soil was

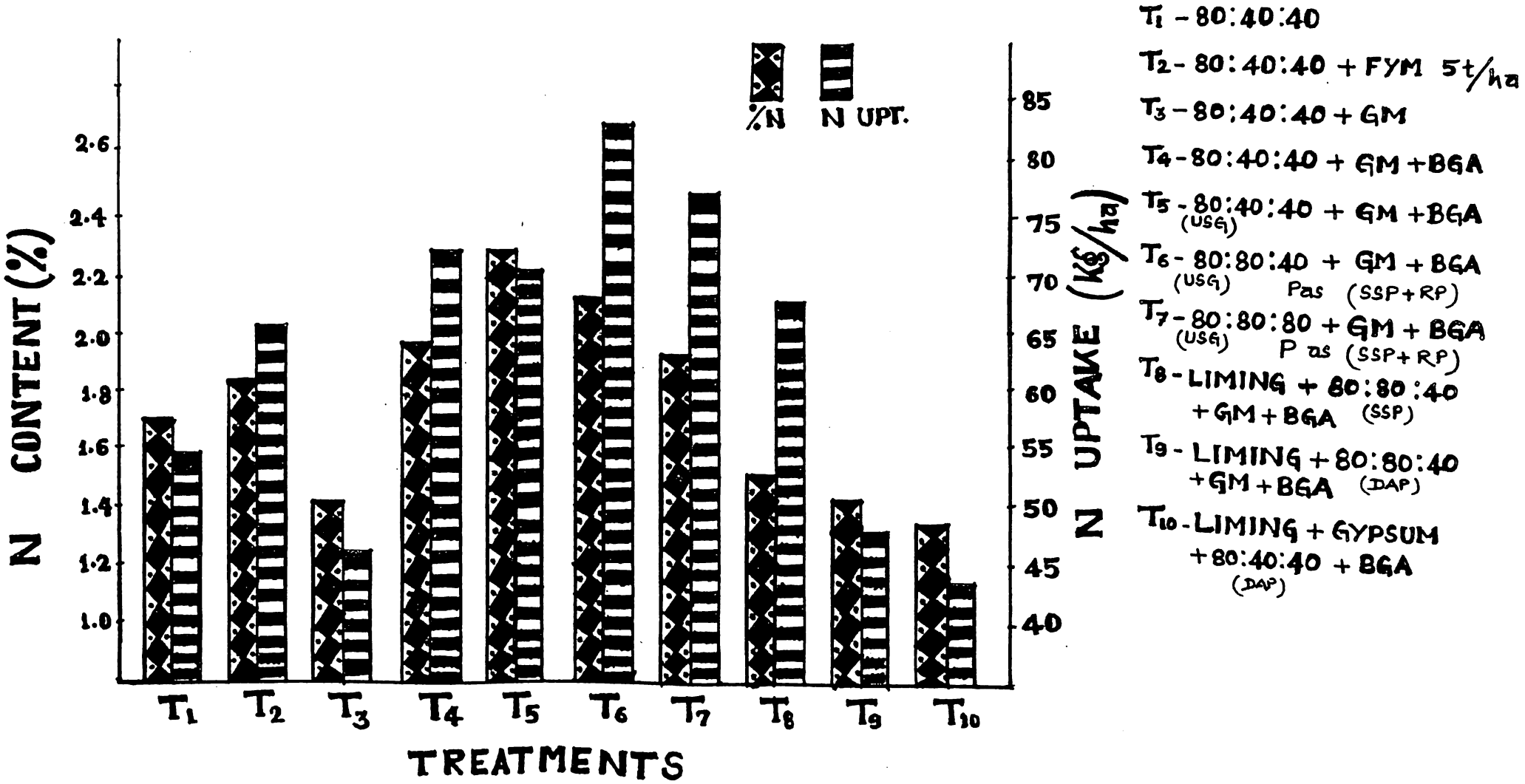


FIG.2. EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON N CONTENT(%) AND UPTAKE (kg/ha) AT MAXIMUM TILLERING STAGE

Table 4. Effect of integrated nutrient management on N, P, K, caontent and uptake of plant at maximum tillering stage.

Tr.No.	Treatments	% N	% P	% K	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T_1	80:40:40	1.72	0.26	2.31	54.70	8.20	73.38
T_2	80:40:40 + FYM 5 t/ha	1.83	0.28	2.09	65.98	10.05	75.29
T_3	80:40:40 + GM	1.41	0.26	2.07	46.01	8.46	67.38
T_4	80:40:40 + GM + BGA	1.97	0.29	2.06	72.41	10.62	75.44
T_5	80:40:40+ GM + BGA (USG)	2.29	0.31	2.01	70.69	9.53	61.72
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	2.13	0.26	2.00	83.37	10.31	79.34
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	1.94	0.26	1.96	77.16	10.39	78.02
T_8	Liming + 80:80:40 +GM+BGA (SSP)	1.4					
T_9	Liming + 80:80:40 +GM+BGA (DAP)	1.4					
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	1.3					
SE(m) ±		0.0					
C.D. at 5% level		0.2					

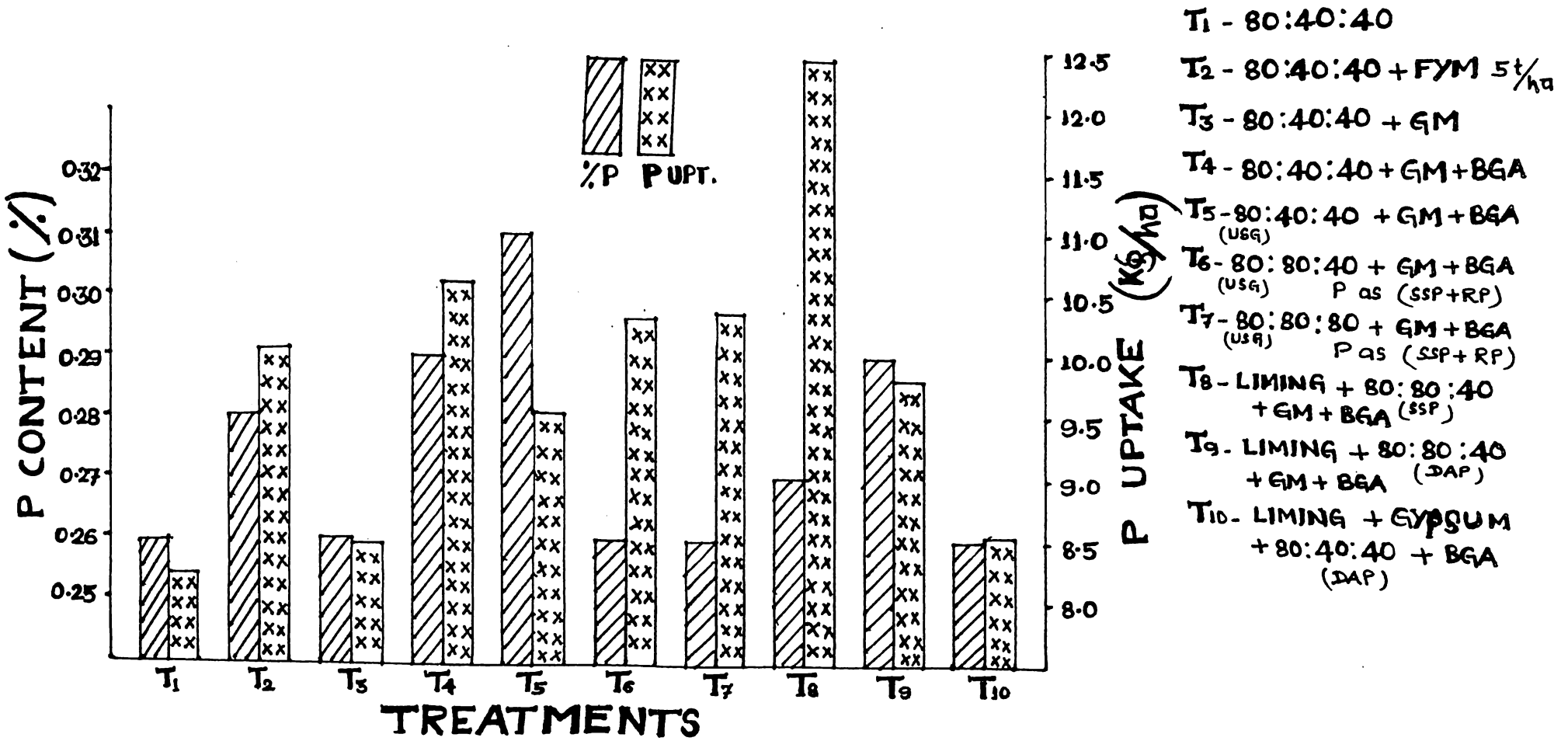


FIG.3. EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON P CONTENT (%) AND UPTAKE (Kg/ha) AT MAXIMUM TILLERING STAGE

below neutral after liming. This effect was probably due to interaction between Ca^{++} and NH_4^+ ion which is the preferred form of N taken up by the rice plant. The rate of Ca uptake is dependant on presence of counter ions (Mengel and Kirkby, 1978). Conversely the higher availability of Ca^{++} ion due to liming affected the uptakes of positively charged NH_4^+ ion.

The P and K content of the plants due to various treatments did not vary significantly.

The uptake of N was governed partly by N content and partly by vegetative growth, whereas P and K uptakes were mainly governed by vegetative growth since the P and K contents did not vary significantly among the treatments. The highest N uptake was observed in T_6 which consisted of N_{80}(USG) P_{80}(SSP + RP) K_{40} + GM + BGA. Both yield and N content of this treatment were significantly higher than the control. The N uptakes of USG treatments (T_5, T_6, T_7) and of T_4, N_{80} P_{40} K_{40} + GM + BGA were significantly higher than the control due to higher N content and relatively higher dry matter yields than the control.

Ca, S and Zn content and uptake at maximum tillering stage

The Ca, S and Zn contents and their uptakes by the plants at the maximum tillering stage are given in Table 5.

It is observed from table 5 that the Ca content of the plant did not differ significantly among the treatments. The S content was lowest for S-free treatment (T_9) which was significantly lower than most of the other treatments. The differences among the other treatments was not significant.

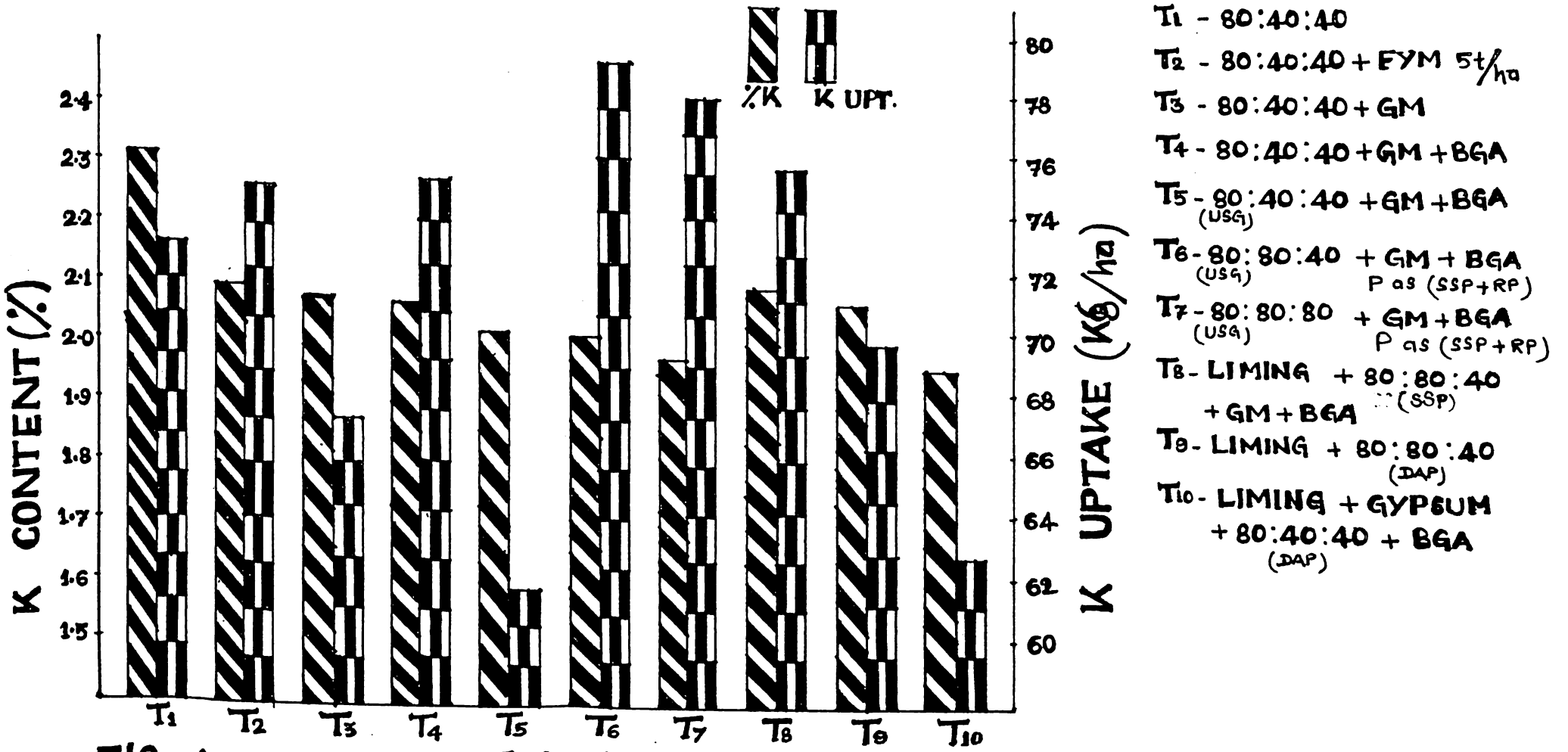


FIG.4. EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON K CONTENT(%) AND K UPTAKE (Kg/ha) AT MAXIMUM

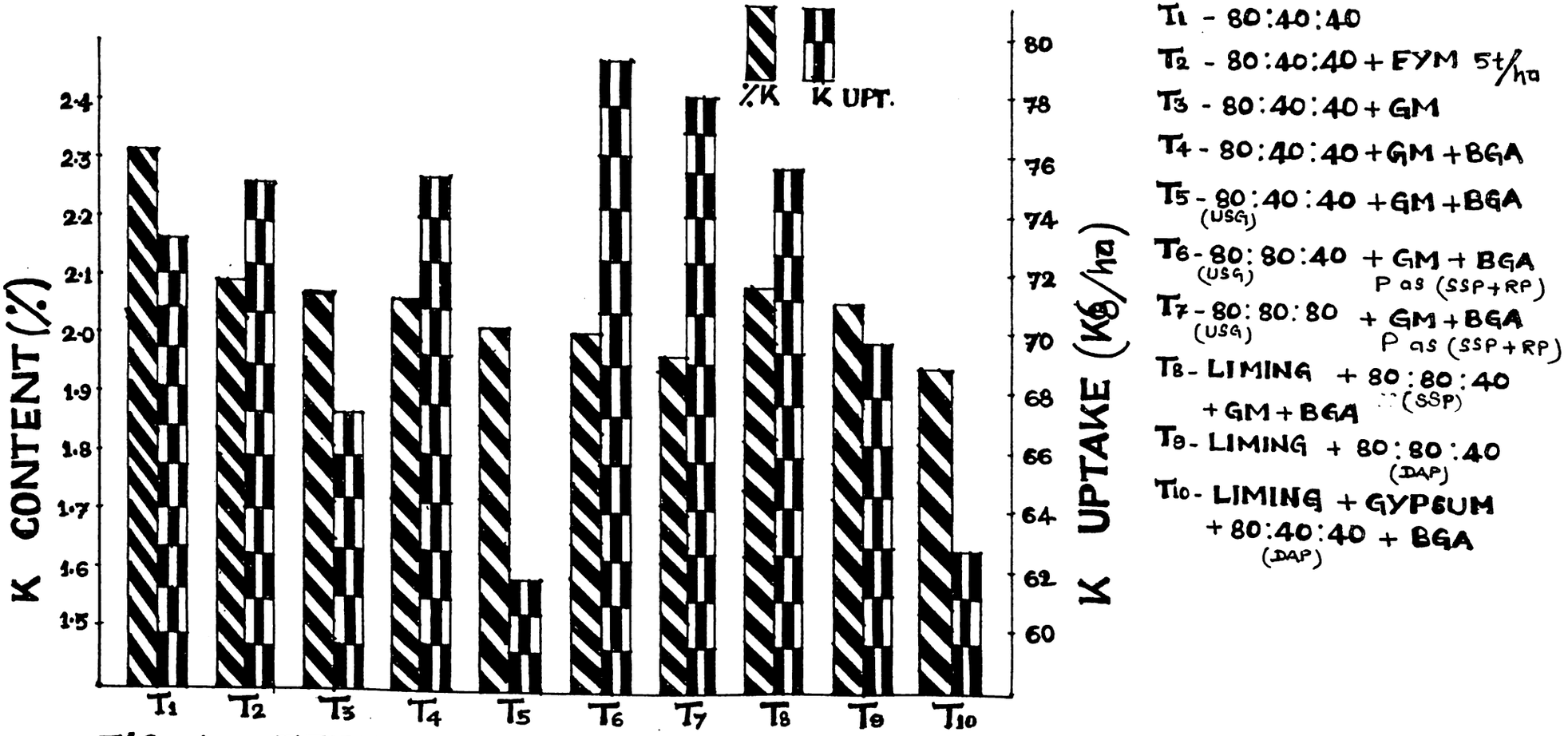


FIG.4. EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON K CONTENT(%) AND K UPTAKE (Kg/ha) AT MAXIMUM TILLERING STAGE

Table 5. Effect of integrated nutrient management on Ca, S, Zn content and uptake by plant at maximum tillering stage.

Tr.No.	Treatments	% Ca	% S	Zn(ppm)	Ca uptake (kg/ha)	S uptake (kg/ha)	Zn uptake (gm/ha)
T_1	80:40:40	0.25	0.13	28.66	7.75	4.11	89.95
T_2	80:40:40 + FYM 5 t/ha	0.31	0.14	47.66	11.18	5.04	171.64
T_3	80:40:40 + GM	0.30	0.13	31.66	9.78	4.23	103.26
T_4	80:40:40 + Gm + BGA	0.30	0.15	29.33	11.13	5.41	107.71
T_5	80:40:40 + GM + BGA (USG)	0.25	0.15	24.66	7.77	4.74	75.94
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	0.31	0.13	34.00	12.07	5.24	132.60
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	0.31	0.11	43.33	12.31	4.32	175.90
T_8	Liming + 80:80:40 +GM+BGA (SSP)	0.30	0.14	25.66	13.79	6.61	118.37
T_9	Liming + 80:80:40 +GM+BGA (DAP)	0.30	0.09	24.33	9.94	3.01	81.40
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	0.28	0.12	23.00	9.17	3.87	74.41
SE(m) ±		0.019	0.011	3.088	0.694	0.492	14.823
C.D. at 5% level		N.S.	0.032	9.16	2.06	1.460	44.00

The Zn content was highest for the FYM treated plot (T_2) and significantly higher than most of the treatments. Since Zn was not applied to any of the treatments, it was the mobilisation of soil Zn which controlled the Zn content and uptake by the plants. GM + BGA application did not have any significant effect on Zn content of the plants. The only other treatment where Zn content was found to be significantly higher than the other treatments was T_7 (N_{80}(USG) P_{80}(SSP + RP) K_{80} + GM + BGA). Higher K level somehow or other mobilised Zn uptake by the rice plant. Since the experiment was conducted in a laterite soil with high Fe content, a higher dose of K reduced Fe-uptake by the plant which resulted in an increase in Zn-uptake.

The uptakes of Ca was dependent on the DM yield since Ca content did not differ significantly among the treatments. According to Mengel and Kirkby (1978), Ca uptake is genetically controlled and is low for cereals. The S uptake was lowest for S free treatments (T_9 and T_{10}) and was controlled more or less by dry matter yield.

N, P, K content and uptake by straw at harvest

N, P, K content and uptake by straw at harvest are given in Table 6.

It is observed from table 6 that there were significant differences between N and P contents of different treatments, but the differences with respect to K content were not significant. Highest N contents were observed in the three treatments T_5, T_6 and T_7 which received USG as the N source. The organic manure/biofertiliser applied

Table 6. Effect of integrated nutrient management on N, P, K content and uptake by straw at harvest.

Tr.No.	Treatments	% N	% P	% K	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T_1	80:40:40	0.66	0.10	2.35	23.99	3.64	85.74
T_2	80:40:40: + FYM 5 t/ha	0.75	0.11	2.39	31.41	4.61	100.09
T_3	80:40:40 + GM	0.75	0.11	2.23	29.15	4.27	86.68
T_4	80:40:40 + GM + BGA	0.79	0.12	2.38	34.07	5.17	102.64
T_5	80:40:40 + GM + BGA (USG)	0.83	0.10	2.41	37.35	4.05	108.47
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	0.84	0.11	2.33	38.01	4.97	105.45
T_7	80:80:80 + GM + BGA (USG) P as (SSR+RP)	0.86	0.10	2.32	36.12	4.20	97.44
T_8	Liming + 80:80:40 +GM+BGA (SSP)	0.73	0.12	2.35	36.60	6.01	117.85
T_9	Liming + 80:80:40 +GM+BGA (DAP)	0.72	0.13	2.19	33.72	6.08	102.57
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	0.68	0.10	2.37	28.98	4.26	101.03
SE(m) ±		0.023	0.005	0.083	1.710	0.232	5.082
C.D. at 5% level		0.068	N.S.	N.S.	5.076	0.688	15.088

treatments (T_2, T_3 and T_4) had significantly higher N content in their straw as compared to control (T_1). Liming also increased N content, but the differences were not significant.

The effect of USG in increasing N content of the straw even at harvest is due to the higher uptake of N at the initial stages of growth(Table 3). Application of biofertiliser/organic matter increased the N use efficiency and resulted in higher N uptake. Even in T_3 where N content was low at maximum tillering stage (probably due to locking up of some of the available N in organic form in the soil), the N content at harvest was significantly higher than the control due to release of this locked up N at the later growth stages. The effect of liming on increasing N content of the straw was probably due to the favourable influence of liming on microbial growth.

N uptake of the straw was governed both by the N content and yield of straw at harvest. The highest uptake was observed in T_6 which consited of N_{80} (USG) P_{80} (SSP + RP) K_{40} + GM + BGA. All the treatments which received additions of biofertilisrs, organic manures or other forms of N and P had significantly higher N uptake than the control (T_1). P and K uptakes were also similarly affected and most of the treatments had significantly higher P and K uptakes than the control (T_1). Split application of double the dose of K in T_7 did not increase in the K content or K uptake by the crop at harvest. Senthilvel and Palaniappan et al. (1989) did not observe higher K uptake due to split application of K to rice as compared to basal application.

Ca, S, Zn content and uptake by straw at harvest

Ca, S and Zn content of straw and their uptakes at harvest are given in Table 7.

It is observed from table 7 that the Ca content and Ca uptake were not significantly different for most of the treatments except T_{10} where Ca content and uptake were very low. Since this treatment did not include GM but received gypsum along with DAP, the acidifying effect of gypsum was probably responsible for low Ca content and uptake. The S cosntent and uptake did not vary much among the treatments although the highest S content and uptake were observed in T_8 which received 80 kg SSP along with liming. S available from SSP appears to be more readily available to the rice plant than gypsum (T_{10}). With respect to Zn content and uptake, the highest values were observed in T_7 which received highest dose of K in addition to other nutrients. At maximum tillering stage, this treatment also had the highest values. As stated earlier Zn was not applied to any of the treatments and hence the higher uptake was due to better mobilisation of native Zn. As explained earlier application of higher dose of K in this treatment counteracted Fe uptake and facilitated uptake of Zn since Fe and Zn have antagonistic effect on one another.

N, P, K content and uptake by grain at harvest

N, P, K content and uptake by grain at harvest are given in Table 8.

Table 7. Effect of integrated nutrient mangement on Ca, S and Zn content and uptake by straw at harvest.

Tr.No.	Treatment	% Ca	% S	Zn(ppm)	Ca uptake (kg/ha)	S uptake (kg/ha)	Zn uptake (gm/ha)
T_1	80:40:40	0.27	0.06	23.66	9.81	2.18	85.96
T_2	80:40:40 + FYM 5 t/ha	0.24	0.07	23.00	10.05	2.93	96.83
T_3	80:40:40 + GM	0.28	0.06	26.00	10.88	2.33	101.32
T_4	80:40;40 + GM + BGA	0.26	0.06	28.66	11.21	2.58	123.38
T_5	80:40:40 + GM + BGA (USG)	0.26	0.06	23.33	11.70	2.70	104.95
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	0.27	0.06	28.33	12.22	2.71	127.43
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	0.25	0.09	36.33	10.5	3.78	152.41
T_8	Liming + 80:80:40 +GM+BGA (SSP)	0.26	0.09	22.66	13.03	4.51	111.75
T_9	Liming + 80:80:40 +GM+BGA (DAP)	0.25	0.05	22.33	11.71	2.34	105.08
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	0.16	0.07	26.66	6.82	2.98	113.60
SE(m) ±		0.018	0.0005	1.95	0.923	0.371	9.34
C.D. at 5% level		0.053	0.014	5.789	2.74	1.101	27.73

Table 8. Effect of integrated nutrient management on N, P, K content and uptake by grain at harvest.

Tr.No.	Treatments	% N	% P	% K	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T_1	80:40:40	1.57	0.23	0.85	49.80	7.29	26.96
T_2	80:40:40 + FYM 5 t/ha	1.66	0.23	0.79	65.35	9.05	31.10
T_3	80:40:40 + GM	1.32	0.24	0.99	49.15	8.93	36.86
T_4	80:40:40 + GM + BGA	1.82	0.21	0.86	74.83	8.63	35.36
T_5	80:40:40 + GM + BGA (USG)	2.01	0.19	0.89	78.87	7.45	34.92
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	1.94	0.19	0.91	86.34	8.45	40.50
T_7	80:80:80 + GM+BGA (USG) P as (SSP+RP)	1.83	0.19	0.85	74.57	7.74	34.63
T_8	Liming + 80:80:40 +GM+BGA (SSP)	1.34	0.21	0.82	61.49	9.63	37.62
T_9	Liming + 80:80:40 +GM+BGA (DAP)	1.34	0.22	0.90	56.78	9.32	38.14
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	1.23	0.20	0.80	50.27	8.17	32.69
SE(m) ±		0.049	0.008	0.047	3.377	0.477	2.150
C.D. at 5% level		0.145	0.023	N.S.	10.026	1.416	6.383

It is observed from table 8 that N and P content of the grains and N, P and K uptake by the grains were significantly different among the different treatments. It is observed from this table that the highest N content and N uptake were observed in the USG treatments, (T_5, T_6 and T_7) and T_4 where inorganic fertiliserswere supplemented with GM + BGA. The FYM treated plot (T_2) had also significantly higher N content and N uptake by the grains as compared to the control. Lime treated plots had lower N content in their grains. The N uptakes were relatively higher due to higher grain yields in these treatments as compared to the control. The P and K uptake by the grains were more or less governed by the grain yield since P and K contents of the grains did not vary much among the treatments.

Ca, S content and uptake by grain at harvest

Ca and S content and uptake by grain are given in Table 9.

It is observed from table 9 that Ca and S content of the grains were not significantly different among different treatments though Ca and S uptakes differed significantly. Ca and S uptake were found to be dependant on grain yield as affected by the treatments. The treatments T_6 and T_8 where highest grain yields were obtained also had highest Ca and S uptakes.

Total N,P,K, Ca and S uptake (removal) by rice plant (grain + straw)

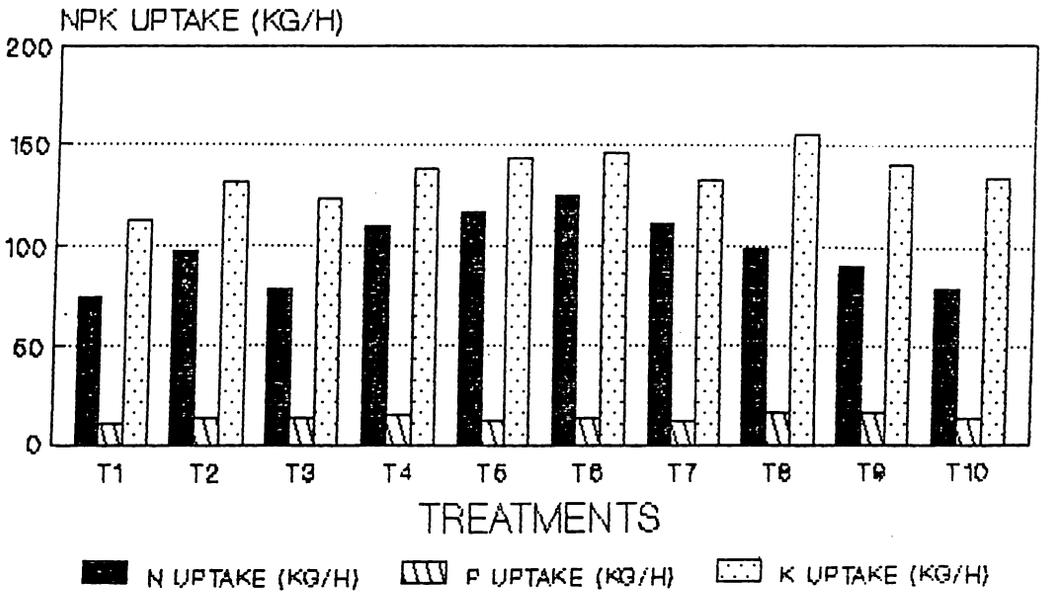
The total uptakes (removal) of N,P,K, Ca and S are given in Table 10 and illustrated in Fig.5,6.

Table 9. Effect of integrated nutrient management on Ca, S content and uptake by grain at harvest.

Tr.No.	Treatments	% Ca	% S	Ca uptake (kg/ha)	S uptake (kg/ha)
T_1	80:40:40	0.74	0.01	23.47	0.31
T_2	80:40:40 + FYM 5 t/ha	0.75	0.02	29.42	0.78
T_3	80:40:40 + GM	0.71	0.03	26.44	1.11
T_4	80:40:40 + GM + BGA	0.75	0.02	30.84	0.82
T_5	80:40:40 + GM + BGA (USG)	0.76	0.02	29.82	0.78
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	0.81	0.03	36.05	1.33
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	0.75	0.02	30.56	0.81
T_8	Liming + 80:80:40 +GM+BGA (SSP)	0.76	0.04	34.87	1.83
T_9	Liming + 80:80:40 +GM+BGA (DAP)	0.75	0.03	31.78	1.27
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	0.75	0.03	30.65	1.22
SE(m) ±		0.018	0.008	1.217	0.237
C.D. at 5% level		N.S.	N.S.	3.613	0.703

It is observed from table 10 that the highest N uptake by the plant at harvest was observed in T_6 which consisted of N_{80}(USG) P_{80}(SSP+RP) K_{40} + GM + BGA followed by 2 other USG treated plots T_5 and T_7. Except T_3 and T_{10}, all the other treatments removed significantly higher N than the control. As usual, all the USG treated plots had relatively higher N uptakes followed by T_4 which consisted N_{80} P_{40} K_{40} + GM + BGA. Highest P uptake was observed in T_8 and T_9 which were limed plots and received 80 kg P_2O_5 as SSP (T_8) or DAP (T_9). All the treatments except T_5, T_7 and T_{10} had significantly higher P uptakes than the control. T_5 was a USG treated plot with 40 kg P_2O_5, T_7 also was a USG treated plot with 80 kg P_2O_5 and 80 kg of K_2O and T_{10} did not have green manuring and received 40 kg P_2O_5 as DAP. As discussed earlier when N was applied in the form of 80 kg of USG, there was a higher P requirement for the crop. Application of 40 kg of P_2O_5 as SSP was not sufficient. When dose of P was increased to 80 kg as (SSP+RP), both N and P uptakes as well as grain yield increased significantly, though there was no increase in straw yield. In other words, there was a better balance among N, P, K which resulted in higher utilisation of nutrients for grain production. However, when the dose of K was increased to 80 kg K_2O/ha, a nutrient imbalance was again created resulting in significant decrease in N,P and even K uptakes along with significant decrease in grain yield. The K uptake was highest in the limed plot(T_8) mainly due to the highest yield obtained in this treatment.

FIGURE 5



EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON TOTAL NPK UPTAKE (KG/H) BY RICE PLANT

T1 = 80:40:40

T2 = 80:40:40 + FYM 5 T/HA

T3 = 80:40:40 + GM

T4 = 80:40:40 + GM + BGA

T5 = 80:40:40 (USG) + GM + BGA

T6 = 80:80:40 (USG) + GM + BGA + P as(SSP+RP)

T7 = 80:80:80 (USG) + GM + BGA + P as(SSP+RP)

T8 = Liming +80:80:40 (SSP) + GM +BGA

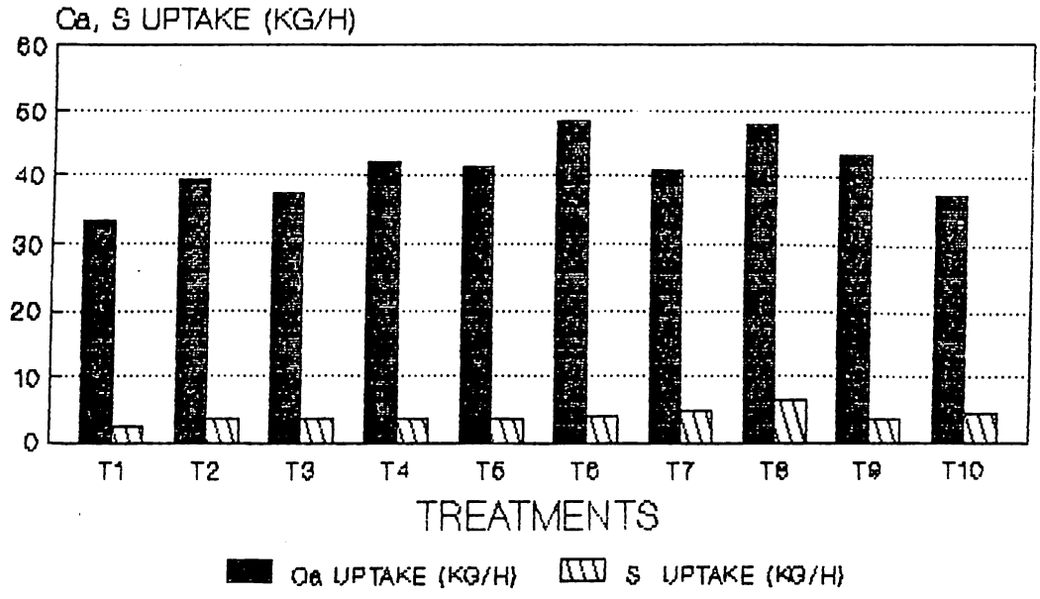
T9 = Liming +80:80:40 (DAP) + GM +BGA

T10= Liming +Gypsum+80:40:40 (DAP) +BGA

Table 10. Effect of integrated nutrient management on total N,P,K, Ca and S uptake by the rice plant.

Tr.No.	Treatments	N uptake (kg/ha)	P uptake (kg/ha)	Ca uptake (kg/ha)	K uptake (kg/ha)	S uptake (kg/ha)
T_1	80:40:40	73.79	10.93	33.28	112.43	2.49
T_2	80:40:40 + FYM 5 t/ha	96.76	13.66	39.57	131.19	3.71
T_3	80:40:40 + GM	78.30	13.20	37.32	123.54	3.44
T_4	80:40:40 + GM + BGA	108.90	13.80	42.05	138.00	3.40
T_5	80:40:40 + GM + BGA (USG)	116.22	11.50	41.52	143.39	3.48
T_6	80:80:40 + GM + BGA (USG) P as (SSP + RP)	124.35	13.42	48.27	145.95	4.04
T_7	80:80:80 + GM + BGA (USG) P as (SSP + RP)	110.69	11.94	41.06	132.07	4.59
T_8	Liming + 80:80:40 +GM+BGA (SSP)	98.09	15.64	47.90	155.47	6.34
T_9	Liming + 80:80:40 +GM+BGA (DAP)	90.51	15.40	43.49	140.71	3.61
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	79.25	12.43	37.47	133.72	4.20
SE(m) ±		4.206	0.607	1.716	5.679	0.289
C.D. at 5% level		12.487	1.802	5.094	16.860	0.858

FIGURE 6



EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON TOTAL Ca ,S UPTAKE (KG/H) BY RICE PLANT

T1 = 80:40:40

T2 = 80:40:40 + FYM 5 T/HA

T3 = 80:40:40 + GM

T4 = 80:40:40 + GM + BGA

T5 = 80:40:40 (USG) + GM + BGA

T6 = 80:80:40 (USG) + GM + BGA + P as(SSP+RP)

T7 = 80:80:80 (USG) + GM + BGA + P as(SSP+RP)

T8 = Liming +80:80:40 (SSP) + GM +BGA

T9 = Liming +80:80:40 (DAP) + GM +BGA

T10= Liming +Gypsum+80:40:40 (DAP) +BGA

Highest Ca uptake was observed in T_6 followed by T_8 where yield also was highest. S uptake was highest in T_8 which received 80 kg of P_2O_5 as SSP.

The N removal for different treatments varied between 73.70 to 124.35 kg/ha, P removal from 10.93 to 15.64 kg/ha, K removal from 112.43 to 154.47 kg/ha, Ca removal from 33.28 to 48.27 kg/ha and S removal from 2.49 to 6.34 kg/ha. The lowest removal rate for all the nutrients was observed in control, N_{80} P_{40} K_{40} which received the nutrients in form of frtilisers. The highest removal for N and Ca was in T_6, P, K and S in T_8. These two treatments also produced highest grain and straw yield as compared to other treatments.

Relative concentrations of other nutrients as compared to N at different stages of growth

N/P, N/K and N/S ratios were calculated for the plant at maximum tillering and for straw and grain at harvest. These ratios are given in Table 11.

It is observed from table 11 that for different treatments, the N/P ratio at maximum tillering stage varied between 4.89 to 7.46, N/K ratio between 0.68 to 1.13 and N/S ratio from 10.50 to 15.77. At harvest, the N/P, N/K and N/S ratios for straw were between 5.50 - 8.60, 0.28-0.37 and 8.11-14.40 respectively. The N/P and N/K ratios for grains were 5.50 - 10.57 and 1.33 - 2.25 respectively. The N/S ratio for grain was not calculated since S content of grain was very low as compared to N content and the ratios were highly magnified so as to include a large amount of error as well.

Table 11. Relative concentration of other nutrients as compared to N at different stages of growth.

Tr.No.	Treatments	Maximum tillering			Harvest				
					Straw			Grain	
		N/P	N/K	N/S	N/P	N/K	N/S	N/P	N/K
T_1	80:40:40	6.61	0.74	13.23	6.60	0.28	11.00	6.82	1.80
T_2	80:40:40 + FYM 5 t/ha	6.53	0.87	13.07	6.81	0.31	10.71	7.21	2.10
T_3	80:40:40 + GM	5.42	0.68	10.84	6.81	0.33	12.50	5.50	1.33
T_4	80:40:40 + GM + BGA	6.79	0.95	13.13	6.58	0.33	13.16	8.66	2.11
T_5	80:40:40 + GM + BGA (USG)	7.38	1.13	15.26	8.30	0.34	13.83	10.57	2.25
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	8.19	1.06	16.38	7.63	0.36	14.00	10.21	2.13
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	7.46	0.98	17.63	8.60	0.37	9.55	9.63	2.15
T_8	Liming + 80:80:40 +GM+BGA (SSP)	5.44	0.70	10.50	6.08	0.31	8.11	6.38	1.63
T_9	Liming + 80:80:40 +GM+BGA (DAP)	4.89	0.69	15.77	5.53	0.32	14.4	6.09	1.48
T_{10}	Liming + Gypsum +80:40:40+ BGA (DAP)	5.15	0.69	11.16	6.80	0.28	9.71	6.19	1.53

The N/P ratio in the plant did not vary much from maximum tillering to harvest for the different treatments, due to proportionate translocation of both N and P from the straw to the panicle for grain formation. However, N/K and N/S ratio decreased in the straw from maximum tillering to harvest due to a relatively higher rate of translocation of N than K or S to the grain. According to Yoshida (1981), 20% of K absorbed by the plant is translocated to the panicles for grain formation. The N/P, N/K and N/S ratios of the plants either at maximum tillering or at harvest did not correlate with the grain yield. There were wide variations between T_6 and T_8 which produced maximum grain yield with respect to these 3 ratios at both the growth stages.

Nutrient uptake efficiency

This was defined as follows:

$$\text{Nutrient uptake efficiency} = \frac{\text{grain yield (kg/ha)}}{\text{total nutrient uptake(kg/ha)}}$$

This was calculated by dividing grain yield (Table 2) of different treatments by the total uptake of N, P or K (Table 9) for each treatment. The data are given in Table 12.

It is observed from table 12 that grain produced per kg of N absorbed varied from 33.76 in T_5 (N_{80} (USG) P_{40} K_{40} + GM + BGA) to 51.57 in T_{10} (Liming + Gypsum + $N_{80}P_{40}$(DAP)K_{40} + BGA). Grain produced per kg of P absorbed varied from 275.19 in T_9 (Liming + N_{80} P_{80}(DAP) K_{40} + GM + BGA) to 341.28 in T_7 (N_{80} (USG) P_{80} (SSP + RP) K_{80} + GM + BGA). Grain produced per kg of K absorbed varied from 27.36 in T_5 to 30.85 in T_7. However if the 2 treatments which produced

Table 12. Effect of integrated nutrient management on nutrient uptake efficiency (kg of grain produced/ kg weight of nutrient absorbed).

Tr.No.	Treatments	Grain produced per kg of N absorbed	Grain produced per kg of P absorbed	Grain produced per kg of K absorbed
T_1	80:40:40	42.98	290.21	28.21
T_2	80:40:40 + FYM 5 t/ha	40.68	288.21	30.00
T_3	80:40:40 + GM	47.56	282.12	30.14
T_4	80:40:40 + GM + BGA	37.75	297.97	29.79
T_5	80:40:40 + GM + BGA (USG)	33.76	341.21	27.36
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	35.79	331.66	30.49
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	36.81	341.28	30.85
T_8	Liming + 80:80:40 +GM+BGA (SSP)	46.78	293.41	29.51
T_9	Liming + 80:80:40 +GM+BGA (DAP)	46.82	275.19	30.01
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	51.57	328.80	30.56

maximum grain yield are compared (T_6 vs. T_8), it is observed that N uptake efficiency was higher for T_8 than T_6 and P and K uptake efficiencies were higher for T_6 than T_8. It can further be concluded from these data that K uptake efficiency varied within a very narrow range in all the treatments.

Nutrient status of soil after harvest

Nutrient status of the soil after harvest of the crop for different treatments are given in Table 13.

It is observed from table 13 that pH of the soil increased from the initial status. Organic carbon did not increase substantially except for the FYM treated plot. While available P increased to some extent for most of the treatments from the initial P status of the soil, there was a uniform decrease in available K status in all the treatments including T_7 where highest dose of K was applied.

Table 13. Effect of integrated nutrient managment on nutrient status of soil after rice harvest.

Tr.No.	Treatments	pH	O.C. %	Total N (%)	Available P (kg/ha)	Available K (kg/ha)
T_1	80:40:40	6.04	0.30	0.057	14.40	127.00
T_2	80:40:40 + FYM 5 t/ha	6.55	0.47	0.062	18.03	133.00
T_3	80:40:40 + GM	6.43	0.34	0.055	13.20	118.66
T_4	80:40:40 + GM + BGA	6.57	0.41	0.058	13.93	132.00
T_5	80:40:40 + GM + BGA (USG)	6.38	0.44	0.061	14.93	118.66
T_6	80:80:40 + GM + BGA (USG) P as (SSP+RP)	6.46	0.35	0.057	16.43	116.00
T_7	80:80:80 + GM + BGA (USG) P as (SSP+RP)	6.94	0.37	0.060	16.36	144.33
T_8	Liming + 80:80:40 +GM+BGA (SSP)	6.97	0.30	0.059	18.26	116.00
T_9	Liming + 80:80:40 +GM+BGA (DAP)	6.88	0.57	0.059	13.46	121.66
T_{10}	Liming + Gypsum +80:40:40+BGA (DAP)	6.22	0.43	0.057	16.03	116.00
SE(m) ±		0.231	0.05	-	1.143	3.741
C.D. at 5% level		N.S.	0.148	-	3.393	11.107
Initial status		5.9	0.368	225 (available N)	11.6	290

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

A field trial was conducted in the kharif season of 1992 at the Central Farm, Bhubaneswar on a laterite soil under medium land conditions. The soil was loamy sand with acidic pH (5.9) and low N,P and high K status. The rice variety used was Lalat, a medium duration (125 days), semi-dwarf photoinsensitive moderately nitrogen responsive and fine grained variety. The objective of this trial was to maximise grain yield of this variety through integrated nutrient management, since this variety has become popular with the farmers in large parts of Orissa.

The details of different treatments are given under Materials and Methods (Page 31-36). These treatments were designed to elicit informations on the cumulative effects of different nutrient management systems sometimes superimposed on each other in increasing grain yield of the rice variety used over the recommended dose of N_{80} P_{40} $K_{40}(T_1)$ which served as the control. N dose was kept at 80 kg/ha (maximum for this variety for kharif) for all the treatments and applied either as PU in three splits, point placed 7 DAT or applied partly as PU and partly as DAP. The doses of other nutrients such as P and K were increased from 40 kg to 80 kg in some of the treatments. All the treatments received either FYM, GM or GM + BGA along with NPK as fertilisers. Liming was superimposed additionally on some of the treatments. The cumulative effects

of different nutrient management systems as described above on yield attributing characters, grain and straw yield at harvest, N,P,K, Ca, S and Zn contents and uptakes by the plants at maximum tillering and harvest were determined.

Except for DAP treatments, P required by the rice crop was applied to the green manure crop as a part of the P management system. It was observed that with increase in P dose from 40 kg to 80 kg P_2O_5/ha (table 1), N added through green manure crop increased from 28.54 to 39.97 kg/ha, P from 2.89 to 4.11 kg/ha and K from 29.18 to 35.81 kg/ha. This was expected since the soil of the experimental plot was low in available P (11.3 kg Olsen P/ha).

One of the important yield attributing character presented in table 2 is % filled grains. There was an improvement in grain filling in all the treatments as compared to control (N_{80} P_{40} K_{40}). As stated earlier the N dose in the control was almost the maximum amount tolerated by this variety. This tended to increase vegetative growth and low partitioning of nutrients from vegetative parts to the grains. With the addition of organic manure/biofertilisers this adverse effect of N was neutralised and there was increased movement of nutrients to the grains which resulted in better grain filling. Liming along with application of P @ 80 kg/ha (T_8, T_9) and application of higher dose of P and K along with N (T_7) increased grain filling to about 80% as compared to 56% in control.

Grain and straw yield along with 1000 grain wt. are given in table 3. Thousand grain wt. was not significantly

affected by the different treatments. Grain yield, however,could be increased to about 45% and straw yield to about 38% over the control. More than 40% grain yield was observed in the treatments, N_{80}(USG) P_{80}(SSP + RP) K_{40} + GM + BGA (T_6) and liming + N_{80}(PU) P_{80}(SSP) K_{40} + GM + BGA (T_8) (Fig.1). Around 30% yield increases over control were observed in the treatments N_{80}(PU) P_{40}(SSP) K_{40} + GM + BGA(T_4) N_{80}(USG) P_{80}(SSP + RP) K_{80} + GM + BGA (T_7), liming + N_{80}(PU) P_{80}(DAP) K_{40} + GM + BGA (T_9) and Liming + gypsum + N_{80}(PU+DAP) P_{40}(DAP) K_{40} + GM + BGA (T_{10}). Among the above tratments T_4 appears to be more economic to get a 30% yield increase. Rest of the treatments (T_2, T_3, T_5) gave around 20% yield increase over the control (Fig.1). This table also shows (Table 3) that USG applied at 80 kg N/ha (T_5) induces more vegetative growth than grain yield, unless it is supplemented with a higher dose of P (80 kg P_2O_5/ha). Similarly replacement of SSP (T_8) by DAP (T_9) results in a decrease in grain and straw yield probably due to S deficiency.

N, P, K content of the plants and their uptake at maximum tillering stage are given in Table 4. The USG treated plot (T_5, T_6, T_7) were found to have highest N contents in the plants as has been reported by other workers (Dubey and Bisen, 1989; Chalam, Chakravorty and Mohanty, 1989) However the N content of these treatments decreased progressively as the doses of P and then K were increased while keeping all other components unchanged.

Application of FYM (T_2) or GM + BGA (T_4) also increased N content. N uptake was highest in the USG treated

plot which produced higher grain and straw yield (T_6). However N uptake was governed by both N content and dry matter yield rather than yield alone (Fig.2). P and K content of the plants did not differ much among the treatments. The P and K uptakes were goverened more or less by the dry matter yield (Fig. 3 & 4).

Ca, S and Zn content and their uptakes given in table 5 indicated that Ca content did not vary much among the treatments due to low Ca requirement of the treatments due to low Ca requirement of the cereals. S content was generally higher in treatments receiving S containing fertilisers than those receiving S free fertiliser. Zn contents of the plants were found to vary considerably due to different treatments though Zn was not applied as a fertiliser. This was mainly due to mobilization of native Zn. (DTPA Zn = 1.1 ppm) by the different treatments. Highest Zn content and uptakes were observed in the treatments receiving FYM (T_2) and 80 kg K_2O/ha (T_7). While effect of FYM in mobilizing native Zn was due to its chelating property, the effect of K was probably an indirect one. The experiment was carried out in an Fe rich laterite soil where considerable antagonism between Fe and Zn was expected. A higher dose of K probably reduced Fe uptake by the plant and helped in higher uptake of Zn.

N, P, K, content and uptake by the straw at harvest are given in table 6. As compared to the maximum tillering stage (table 4), the N and P content of straw substantially decreased but the K content increased at harvest. This was due to higher rate of movement of N and P to the grains as

compared to K. According to Yoshida (1981) about 20% of K absorbed by the plant was transported to the grain and the rest ramained in the vegetative part at maturity. As in the maximum tillering stage, the N content of the USG treated plots were higher in the straw as compared to other treatments. The P and K content of the straw did not differ significantly among the treatments. N uptake was generally higher for USG treated plots and was governed partly by N content and partly by straw yield. P and K uptake also were similarly affected.

Ca, S and Zn content and their uptakes by straw at harvest are given in table 7. As compared to table 5, it was observed that while S and Zn content of the plants dsecreased from maximum tillering to harvest stage, the effect on Ca content was not so evident. The uptake of these nutrients and their contents were in the similar pattern as at the maximum tillering stage.

N, P, K content and uptake by grain at harvest are given in table 8. It was observed from this table that similar to straw, grains also had relatively higher N content in the USG treated plots which decreased with increase in doses of P and K. The uptakesof N for these treatments also were relatively higher.

Ca and S content of the grain varied within a very narrow range due to differenttreatments and their uptakes by the grains were more or less governed by yield (table 9).

Total crop removal of different nutrients at harvest (table 10) indicated that higher nutrient uptakes were not

always associated with higher yield. The two treatments where more than 40% yield increases were recorded, removed in one case 124 kg N/ha (T_6) and the other (T_8) with a slightly higher yield than T_6 98 kg N/ha. Similarly P removal was 13.4 and 15.64 kg P_2O_5/ha, K 145.95 and 155.47 kg K_2O/ha, Ca 48.27 and 47.9 kg/ha and S removal 4.04 and 6.34 kg/ha in the two treatments T_6 and T_8 respectively. It was the efficient utilisation of nutrients for grain production rather than nutrient uptake which was found to govern the grain yield.

The N/P, N/K and N/S ratios given in table 11, showed that the N/P ratio remained more or less similar in plants from maximum tillering to harvest, but there were substantial decreases in N/K ratio and a slight decrease in N/S ratio. This was mainly due to the relative translocation of these nutrients from vegetative parts to the grains after flowring. While N and P translocated almost at similar rate from vegetative parts to the grain, there were higher rates of translocation of N relative to K and S to the grains. This resulted in a lowering of N/K and N/S ratio in the straw at harvest. These ratios in the plants were not found to be realted to yields since higher yields were obtained at completely different values for these ratios.

Calculation of relative nutrient uptake efficiency (kg of grain produced/kg of nutrient absorbed)(table 12) showed that these figures were not related to grain yield produced. Among the two treatments which produced maximum grain yield (T_6 and T_8), T_8 had the most effective nutrient uptake efficiency since maximum amount of nutrient absorbed

were utilised for grain production in this treatment.

Analysis of the soil at the end of the experiment showed (table 13) an increase in pH values, almost no change in organic carbon, an increase inavailable P, but a decrease in available K as compared to the initial soil test values.

The following conclusions can be drawn from this study.

1. Through suitable integrated nutrient management practice, yield of a moderately N responsive semidwarf variety (Lalat) could be increased by about 45% over the recommended dose in the kharif season. The two best treatment combinations which resulted in about 45% yield increase over the recommended dose (T_1) were N_{80}(USG) P_{80}(SSP+RP) K_{40}(MOP) + GM + BGA (T_6) and liming + N_{80}(PU) P_{80}(SSP) K_{40}(MOP) + GM + BGA (T_8).

2. Application of green manure + BGA along with the recommended dose of fertiliser increased grain yield by about 30%.

3. When the N dose is high, replacement of PU by USG supplemented by biofertilisers resulted in decreased grain yield and increased straw yield. This trend could be reversed and a significant yield increase could be achieved when the high dose of USG was supplementd by a high dose of P, keeping every thing else unchanged (T_5 vs. T_7).

4. Increase in dose of K along with higher dose of

N (as USG) and P supplemented by GM + BGA resulted in a significant yield decrease (T_6 vs. T_7).

5. Liming along with application of N_{80}(PU) P_{80}(SSP) K_{40}(MOP) + GM + BGA resulted in a significant yield increase (T_8). When SSP was replaced by DAP in this treatment, there was a substantial yield decrease (T_9).

6. When N was applied in form of USG, the plants either at maximum tillering or at harvest as well as grains contained relatively higher amount of N. The uptakes of N also were higher.

7. Plants removed considerable amount of Zn even when Zn was not applied to the crop. This may lead to Zn depletion and future Zn deficiency in the soil.

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CHAPTER VI

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