SEASONAL VARIATIONS IN THE NUTRIENT TRANSFORMATION IN THE LATERITIC ALLUVIAL RICE SOILS OF PERMANENT MANURIAL TRIALS

BY

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

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DECLARATION

I hereby declare that the thesis entitled "**Seasonal variations in the nutrient transformation in the lateritic alluvial rice soils of permanent manurial trials**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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We, the undersigned members of the Advisory Committee of **Mr.K.K.Dineskumar**, a candidate for the degree of **Master of Science in Agriculture** majoring in **Soil Science and Agricultural Chemistry** agree that the thesis entitled "Seasonal variations in the nutrient transformation in the lateritic alluvial rice soils of permanent manurial trials" may be submitted by K.K.Dineskumar in partial fulfilment for the degree.

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K.K. DINESKUMAR

Dedicated to
my loving parents

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Introduction

INTRODUCTION

Rice is one of the major cereal crops in the world and forms the staple food for millions. The exploding population in South-East Asia, which incidentally is the major rice growing portion of the world, has forced countries like India to increase production and productivity of rice. For this, use of heavy doses of inorganic fertilizers was recommended. With the introduction of high yielding, fertilizer responsive varieties, still higher doses of fertilizers began to be used by the farmers replacing organic manaures.

The continuous use of chemical fertilizers in heavy doses will tell upon the overall soil health. On the other hand, use of organic manures has been proved to improve soil conditions. The permanent manurial trials were started to study the deleterious effects of continuous application of fertilizers, the exhaustion of nutrients in soil by continuous cultivation and also the beneficial effects of organic manures.

In 1961, a permanent manurial experiment was laid out in Regional Agricultural Research Station, Pattambi. The varieties used were tall indica varieties PTB 2 and PTB 20 during the first and second crop seasons respectively. There are eight treatments and four replications. The treatments included application of cattle manure, green leaves and ammonium sulphate individually and in combination with and without P and K fertilizers. The trial was aimed to find out the effect of continuous use of inorganic fertilizers and organic manures and to work out the judicious and economic combination of organic and inorganic fertilizers for formulating recommendations to farmers. A second trial was started in 1973, with the same objectives but with high yielding variety, Jaya in both the seasons. The treatments were the same, but the dose of manures and fertilizers varied based on the nutrient requirements for high yielding varieties.

A phenomenon noticed with rice cultivation in Kerala is the difference in yield between the first crop season (virippu) and the second crop season (mundakan). Generally higher yields are obtained during the second season. The case with permanent manaurial trials is also not different. During most of the years, higher grain yields were recorded in the second season, compared to the first.

Many reasons have been attributed to the higher yield during second crop. Lesser incidence of pests and diseases and more sunshine hours are some of them. But whether seasonal differences in nutrient availability in soil exist, has not yet been studied. So the present study was initiated to find out the seasonal variations in nutrient transformations in the two permanent manurial trials. It was also aimed, to find out the influence of various treatments on the nutrient availability in both the seasons. Along with these, seasonal differences in nutrient content and uptake by the crop were also included in the objectives.

Review of Literature

REVIEW OF LITERATURE

1 Seasonal variations in nutrient content of soil and plant and factors affecting it

1.1 Nutrient content in soils

1.1.1 Organic carbon

In a slightly gleyed soil, the organic carbon content showed a maximum in the month of May-July, coinciding with increase in root mass and minimum in October (Sauerlandt and Tiekjen, 1971).

Analysis of soils from a forest reserve in Gujarat showed that the organic carbon content was highest in summer (Pandit and Thampan, 1988).

1.1.2 Nitrogen

Drouineau *et al.* (1952) observed that wide seasonal variation occurred in the content of mineralizable N in differently treated Mediterranean calcareous soils. They found that mineralizable N was inversely correlated with temperature. There was a highly significant correlation between mineralizable N of variously fertilized plots at the end of March and their maximum content of mineral N in summer.

In a field planted with wheat, analysis of soil samples, taken at monthly intervals showed that after harvest in March, N was high. During rains in July-September, excessive leaching was almost counter-balanced by ammonification and nitrification. After planting wheat in October, during the subsequent months, N level was low because of uptake by the crop (Pathak, 1953).

The availability of nitrogen in flooded soil is higher than in non flooded soils. Eventhough organic matter is mineralised at a slower rate in anaerobic soils than in aerobic soils, the net amount mineralised is greater because less nitrogen is immobilised (Ponnamperuma, 1965).

Ponnamperuma (1977) reported that soil properties, duration of submergence and temperature strongly influence the concentration of water soluble NO_3, exchangeable and water soluble NH_4^-.

1.1.3 Phosphorus

In a field planted with wheat, analysis of soil samples taken at monthly intervals showed that P was low after harvest, high in the rainy season and low during early growth period (Pathak, 1953).

The availability of phosphorus is closely related to the degree of soil reduction. In a Taiwan soil, the contents of available phosphorus increased proportionately with decrease in Eh (Chiang, 1963).

Concentrations of P were found to be constant in heavy clayloam soils, seasonal variations occurring only where dung or P fertilizers were applied during the year. But these variations did not alter the general classification of the P status into low, medium and high (Blackmore, 1966).

Soil P levels under most crops, were greatest in spring and lowest after harvest, according to Garbouchev (1966). They increased again in winter. He also reported that P in 0.01 M $CaCl_2$ equilibrium extracts fell to a lower level in NPK than in PK treated plots because of the better growth induced by N.

Available P_2O_5 in soil has been reported to be lower in summer and higher in winter. Summer decline was accounted as due to increased uptake by plants (Pelisek, 1977).

In a glasshouse experiment with an acidic and red soil, it was observed that available P in soil increased during the tillering stage of the rice crop, which was due to decrease in the Fe-P and Ca-P fractions in red soil, subsequent decreases in available P were due to transformation of the fixed P fractions (Singh and Ram, 1977).

Martel and Zizka (1978) observed that there was significant decrease in P values from May to October in a sandy soil. Field heterogeneity was a greater factor of variation than sampling time.

The availability of soil phosphorus increases after soil submergence, mainly due to reduction of ferric phosphate to ferrous phosphate, although other changes such as hydrolysis of aluminium phosphate are also involved. The increase in solubility of phosphorus, however is low in ultisols and oxisols high in active iron (De Datta, 1981).

Analysis of soils from a forest reserve in Gujarat showed that there was an increase in P from summer to winter (Pandit and Thampan, 1988).

1.1.4 Potassium

In a field planted with wheat, K was high in the soil after harvest in March. After planting wheat in October, K level went low because of uptake by the crop (Pathak, 1953).

Blackmore (1966) observed that in a heavy clay loam soil, concentrations of soluble K varied more than those of P during the season, but the variation did not alter the general classification of the K status into low, medium and high.

Garbouchev (1966) has reported that soil K levels under most crops were greatest in spring and lowest after harvest, they increased again in winter.

In an experiment to find out the effect of time of sampling on soil test K values, it was observed that in 28 unfertilized plots, months of sampling significantly affected K soil test values, which were highest in May and declined as the growing season progressed (Liebhardt and Ted, 1977).

Pelisek (1977) observed that available K_2O in soil was lower in summer and higher in winter. Summer decline was due to increased uptake by plants.

In a sandy soil, there was significant difference in K values from May to October. Field heterogeneity was a greater factor of variation than sampling time (Martel and Zizka, 1978).

The period of intensive reduction, production of ammonia, build up of high concentration of CO_2, Fe^{2+}, Mn^{2+} and organic reduction products occurs in the first 2-6 weeks after flooding. During this period, the availability of potassium to rice increases markedly (De Datta, 1981).

1.1.5 Calcium and Magnesium

Garbouchev (1966) has reported that seasonal changes in $CaCl_2$ extractable Mg of soils under most crops were small.

In a sandy soil, Martel and Zizka (1978) observed that there was a significant variation in Mg values, from May to October.

Analysis of soils from a forest reserve in Gujarat showed that there was an increase in soil Ca and Mg from summer to winter (Pandit and Thampan, 1988).

The benefits of submergence of rice soils is that it increases the availability of many nutrients including Ca (De Datta, 1981).

1.2 Changes in soil nutrient contents of soil due to application of manures and fertilizers

1.2.1 Organic carbon

In two permanent manurial trials, one with wheat-fallow-wheat rotation, started in 1946-47 and the other with cotton-fallow-cotton, started in 1951-52, the surface 6" soil samples of the manured and fertilized plots maintained the organic carbon at higher levels than the control (Kanwar and Prihar, 1962).

In a long term experiment with application of organic manures and ammonium sulphate in a mulberry field in West Bengal, Mandal and Pain (1965) have observed that the organic carbon content of soils increased with continuous application of cowdung for 15 years. In another experiment, long term effect of four rotations and application of farm yard manures and fertilizers on chemical and physical properties of soil was studied. The farm yard manure application increased the organic carbon content of soil (Havanangi and Mann, 1970).

In another long term experiment conducted at Pusa, farm yard manure and green manure with phosphate have resulted in higher contents of organic carbon.

Also use of NP and NPK fertilizers indicated noticeable increases (Maurya and Ghosh, 1972). Singh *et al.* (1980) also have reported an increase in organic carbon content in a Sierozem soil in Haryana, due to continuous application of farm yard manure.

Significant increase in organic carbon content was observed in plots receiving cattle manure alone and cattle manure + green leaves when compared to those receiving inorganic fertilizers, in the permanent manurial experiment being conducted at Pattambi with tall indica rice varieties. The same trend was observed in the case of permanent manurial trials with dwarf indica also. But in an experiment conducted in sandy soils of Kayamkulam, continuous application of organic matter for 31 seasons failed to increase organic carbon level (Kurumthottical, 1982). But Singh *et al.* (1983) have reported an increase in organic carbon status of a sandy loam soil due to continuous application of farm yard manure to a wheat-maize rotation.

Carbon content of soil increased from 0.911 to 1.584 per cent by continuous application of organic manures. Farm yard manure had significant influence on its contents (Udayasoorian, 1988).

In a long term fertilizer experiment, which is in progress since 1972 at Coimbatore, 100 per cent optimum NPK + organic manure treatment raised the organic carbon status of the soil. The lowest content of organic carbon was noticed in cropped unmanured treatment and this has been attributed to very poor crop growth and naturally poor root residues (Subramanian and Kumaraswamy, 1989).

Schwab *et al.* (1990) reported that continuous application of N and P fertilizers for 40 years resulted in significant changes in organic matter content. It was found to be unaffected by P fertilization, but increased with increasing N rate.

Based on the studies conducted in the permanent manurial experiment on dwarf indica rice at Pattambi, Padmam (1992) reported that the beneficial effects of cattle manure in the first crop season is mainly due to the increase in the contents of organic carbon. She has also reported that application of high dose of organic manure at the rate of 18 t ha^{-1} for a continuous period of 34 seasons has increased the organic carbon content of soil significantly over application of inorganic fertilizers but the values were low ranging from 1.07 to 1.43 per cent. The inability of organic manures to enhance the organic carbon content of soil considerably may be due to the high rate of decomposition during the summer season when the fields pass through a summer fallow.

After 3 years of continuous application of manures and fertilizers in an inceptisol, manure increased the organic content of the soil (Patiram and Singh, 1993).

1.2.2 Available nitrogen

Application of cattle manure continuously for 40 years has resulted in a two fold increase in the available N content, compared to control in the permanent manurial experiment at Coimbatore (Raju, 1952). Long term use of compost and cowdung caused an increase in available nitrogen content of soil in an experiment conducted with Jute in West Bengal. Use of ammonium sulphate did not increase the available N content of the soil (Mandal and Pain, 1965).

Maurya and Ghosh (1972) noted that application of farm yard manure along with phosphate to a rotation of cereals and pulses has resulted in the highest content of nitrogen in soil, in a permanent manurial experiment conducted at Pusa.

Muthuvel *et al.* (1977) have found that the available N content of soil was positively influenced by organic matter addition in the permanent manurial experiment at Coimbatore, under rainfed condition. On the other hand, continuous application of organic matter, along with chemical fertilizers had no effect on the available nitrogen content of soil under irrigated condition.

There was an increase in available N content of soil at Hyderabad with intensive manuring and cropping. The improvement in N status of soil at Barackpore was more pronounced in 100 per cent NPK + farm yard manure and 150 per cent NPK treatments and least in unfertilized control (Patnaik *et al.*, 1980).

In the permanent manurial experiment on dwarf indica at Pattambi, significant variation was noticed in the available N content of soils receiving various treatments. Higher value of 106.2 kg ha^{-1} was observed in treatment where 90 kg N ha^{-1} was supplied through organic and inorganic sources together with P_2O_5 and K_2O. Lowest amount of available N was noticed in treatment which received only NPK fertilizers (Kurumthottical, 1982). But Yaduvanshi *et al.* (1985) observed no influence of various treatments on the available N status of soils in a long term experiment initiated in 1972-73 in Himachal Pradesh.

Kapur *et al.* (1986) observed that the increase in available N, even by continuous application of 120 kg N ha^{-1} was very little when compared to initial status. But supplementary N fertilizer with P fertilizer increased the available N content considerably.

Analysis of samples taken from plots under long term experiment which is in progress since 1972 in Coimbatore has revealed that available N status was highest under 100 per cent optimum NPK + organic manure treatment and lowest under cropped but unmanured treatment (Subramaniam and Kumaraswamy, 1989).

In the permanent manurial experiment going on at Pattambi, continuous application of N either in organic or inorganic form or a combined application of both forms has not resulted in any significant variation in the available N content of the soil (Padmam, 1992).

1.2.3 Available phosphorus

The availability of phosphorus in a soil is closely related to the degree of soil reduction (Chiang, 1963).

Kanwar and Prihar (1962) while analysing the soils from plots receiving continuous application of organic and inorganic fertilizers, found that plots receiving ammonium phosphate treatment had built up available P to a much greater extent than farm yard manure. But in an experiment with long term application of manures and fertilizers, NP fertilizers as well as farm yard manure application increased the available P_2O_5 status of the soil (Haranangi and Mann, 1970).

In the permanent manurial experiment on dwarf indica at Pattambi application of phosphatic fertilizer in combination with organic manures had resulted in higher content of available P as compared to inorganic fertilizers alone. The available P content in soil ranged from 210.5 kg ha^{-1}, recorded by the treatment which received application of ammonium sulphate alone to 318.5 kg ha^{-1}, recorded by treatment which involved application of green leaves along NPK fertilizers (Kurumthottical, 1982).

In another experiment to study the influence of long term application of manures and fertilizers to a wheat-maize rotation on soil properties, it was seen that farm yard manure significantly increased the available P status of the soil. Phosphorus treatments increased P status only in combination with farm yard manure (Sharma *et al.*, 1983). But Yaduvanshi *et al.* (1985) have noted that long term P fertilization with maize-potato-wheat cropping sequence resulted in pronounced build up of available P.

In a trial to find out the response of wet land rice to nitrogenous fertilizers in soils ammended with organic manures, it was found that organic manures exhibited residual effect in terms of available P (Maskina *et al.*, 1988).

Build up of available P status was significant under 100 per cent optimum NPK + organic manure treatment in the long term fertilizer experiment, which is in progress since 1972 in Coimbatore. Available P status in other treatments also increased over the initial values, but was not as conspicuous as the above one. Appreciable build up of available P status in NPK + organic matter treated plots was attributed to the influence of organic matter in increasing the labile P in soil through complexing of cations like Ca^{2+}, Mg^{2+}, Fe^{2+}, Al^{3+} etc. which are responsible for P fixation (Subramaniam and Kumaraswamy, 1989).

In the permanent manurial experiment on dwarf indica rice at Pattambi, cattle manure application showed a tendency to increase available P content of soil (KAU, 1991). In the same experimental fields, Padmam (1992) has reported that application of green leaves decreased the availability of P in the soil. She also noted that continuous application of cattle manure alone or in combination with NPK fertilizers has increased the available P content of soil significantly.

1.2.4 Available potassium

Kanwar and Prihar (1962) reported that continuous application of farm yard manure increased the exchangeable K in soil. Water soluble K was increased by farm yard manure, but decreased by ammonium phosphate. On the contrary, continuous application of P fertilizers caused an increase in available K content in a Seirozem soil in Haryana (Singh *et al.*, 1980).

Continuous application of potassic fertilizers did not influence available K level of the soil in a wheat-maize rotation in a sandy soil (Sharma *et al.*, 1983). Increase in available K status of soil by application of farm yard manure was reported in an experiment with paddy-wheat rotation (Kaushik *et al.*, 1984).

In a long term fertilizer experiment being conducted at Coimbatore since 1972, it was seen that the available K status in soils depleted even in treatments receiving K fertilizers, under continuous cropping (Subramaniam and Kumaraswamy, 1989).

Lal *et al.* (1990) in an investigation to find out the effect of long term use of farm yard manure, fertilizer and lime found that after 28 years exchangeable

K decreased in the absence of K fertilizers or manures. All forms of K were found to be significantly correlated with organic carbon content.

1.2.5 Exchangeable calcium and magnesium

Mandal and Pain (1965) noted in a long term manurial experiment with jute in West Bengal that use of ammonium sulphate and cowdung resulted in a decrease in exchangeable calcium. Prasad and Singh (1980) also noted that long term use of ammonium sulphate alone as the N source markedly reduced the exchangeable calcium content of soil by about one-half but exchangeable magnesium content was unaffected by the treatment. The initial status of exchangeable Ca was increased or retained in the plots which received application of farm yard manure and NPK fertilizers.

Continuous application of farm yard manure to a Seirozem soil in Haryana was also found to increase the exchangeable Ca and Mg contents of the soil (Singh *et al.*, 1980).

In the permanent manurial experiments on paddy being conducted at Pattambi and Kayamkulam, exchangeable Ca and Mg contents were higher in the treatments which received organic manure alone or in combination with phosphate fertilizer. The values of exchangeable Ca and Mg in the new permanent manurial experiments at Pattambi varied from 0.277 to 0.592 and from 0.118 to 0.283 cmol(+) kg^{-1} respectively. In both cases, application of cattle manure along with green leaves and NPK fertilizers recorded the maximum values and minimum values were recorded by the treatment which received NPK fertilizers alone (Kurumthottical, 1982).

Muthuvel *et al.* (1983) noted that Ca content was lower in plots receiving nitrogen application, in a long term fertilizer trial. They attributed the reason to the enhanced uptake of Ca by crops, induced by N treatment.

In a long term manurial trial conducted at Coimbatore, Udayasoorian (1988) found that continuous application of compost improved the status of exchangeable Ca, but lowered that of exchangeable Mg.

Padmam (1992), while studying the soils from the permanent manurial trial on dwarf indica rice varieties at Pattambi, observed that the exchangeable Ca content was uninfluenced by continuous application of manures and fertilizers. But she noted significant variation in the exchangeable Mg content of soil due to various treatments. All treatments which involved cattle manure application showed significant increase in exchangeable Mg status. Patiram and Singh (1993) also have observed that three years of manure application increased the exchangeable Ca and Mg status of an inceptisol in Sikkim.

2 Effect of flooding on crop growth

Flooding a soil causes chemical reduction of iron and manganese as well as other elements in the soil. Various acids such as butyric and gases such as carbon dioxide, methane and hydrogen sulphide are produced. All except methane, when present in large amounts may retard root development, inhibit root absorption and cause root rot (De Datta, 1981).

3 Nutrient contents and uptake in plants

3.1 Effect of seasons

The K content in the above ground parts of winter wheat was low during the winter months, but increased from March onwards. The content of P tended to be lowest between December and March (Zimowska, 1976).

Mc Coll (1980) observed that little retranslocation of Ca or Mg in leaves of trembling aspen occurred during the growing season in contrast to K and N, whose concentrations in leaves increased in the early spring, but decreased in summer.

Low temperature during the late growth phase of sugarcane has been found to depress leaf N whereas high rainfall increased it. A similar trend was noted with regard to P. High rainfall had an adverse effect on sheath K content (Srinivasan and Morachan, 1980).

Intrigliolo (1986) has reported that the leaf K content of orange fell during the summer and N values decreased from June to September.

3.2 Efect of manures and fertilizers

Kanwar and Prihar (1962) have noted that continuous application of ammonium phosphate increased the P and K content of the grains, compared to others, in a long term manurial experiment.

A study has revealed that absorption of N, P and K increased with increasing amounts of farm yard manure applied. Increase in K was highest, followed by those in N and P (Yamashita, 1964).

Application of nitrogen and phosphorus fertilizers influenced their concentration in plants (ragi) positively, in an experiment to study the effect of continuous application of fertilizers and manures on the yield and composition of ragi. It was seen that potash application increased P absorption (Perumal *et al.*, 1969).

In a long term fertilizer cum manurial trial on paddy-wheat cropping sequence, application of N and farm yard manure increased the uptake of N, P and K (Kaushik *et al.*, 1984).

In the permanent manurial experiment with dwarf indica rice varieties, at Pattambi, the N contents in grain and straw were maximum in the treatment receiving a combination of cattle manure and NPK fertilizer and minimum in that receiving cattle manure alone (KAU, 1991).

In a long term field experiment involving rice-wheat cropping sequence and NPK fertilizers at karnal, fertilizer N reduced the P content in rice (Swarup and Chillar, 1986.)

Chellamuthu *et al.* (1988), in a study to find out the effect of farm yard manure and ammonium sulphate on Ca and Mg contents and uptake by ragi, noted that their contents increased markedly by application of N sources of fertilizers. Combined application of farm yard manure and ammonium sulphate registered the highest total uptake of Ca.

In the permanent manurial experiment on dwarf indica at Pattambi, Padmam (1992) observed that the N content in plants was not affected by various treatments. But highly significant differences were noted in the P contents, whereas K content was not influenced.

4 Nutrient absorption and tranlocation in rice

Nitrogen may be lost from plants through root exudation, the flushing action of dew or rain and natural or mechanical loss of plant parts (De Datta, 1981).

In general, for any varietal type, nitrogen response is higher during the summer dry season than in the wet season. There is an important interaction between light intensity and nitrogen response. When light intensity is low, the optimum nitrogen level is low. Under reduced light intensity, photosynthetic rate is reduced, starch accumulation is decreased, root development is retarded and nitrogen uptake slows down (Tanaka, 1969).

The rate of dry matter production of the rice plant, the proportionate weight of each plant part, and the mineral content of a given plant part change as the plant develops. The causes are changes in the physiological status of the plant with the development of growth phases and changes in environmental conditions. The accumulation of nitrogen in the vegetative organs is high during the early growth stages and decreases with growth. After flowering, translocation of nitrogen from the vegetative organs to the grains becomes significant. Nitrogen, phosphorus and sulphur, which are components of proteins, are absorbed rapidly during vegetative stage and translocated from the vegetative organs to the grain after flowering. Potassium and calcium, which regulate various metabolic processes are absorbed at a rate almost parallel to dry matter production but there is no marked translocation of these elements from vegetative organs to the grains during ripening. Magnesium is absorbed most actively during the reproductive stages, and its translocation after flowering occurs to some extent (De Datta, 1981).

Materials and Methods

MATERIALS AND METHODS

The soil and plant samples to be analysed for the present study were collected at pre-determined stages during the period from harvest of second crop of 1991 to harvest of second crop of 1992 from the two ongoing permanent manurial trials at the Regional Agricultural Research Station, Pattambi. The station is located at an altitude of 25 m above mean sea level on 10° 48' N latitude and 76° 12' E longitude.

1 Details of the field experiments

The soil in the experiment field is of the textural class sandy loam, Fluventic Tropofluent. There are two permanent manurial trials, one on tall indica and the other on dwarf indica rice varieties. The one on the tall indica was started in 1961 and the other in 1973. The lay out of the experiments are given in Fig.1 and 2. The details of the experiments are given below.

1.1 Permanent manurial experiment on tall indica

The design adopted for the experiment is RBD, with 8 treatments and 4 replications. The treatments are

1. Cattle manure 8 t ha^{-1} (40 kg N ha^{-1}) - (CM alone)
2. Green manure 8 t ha^{-1} (40 kg N ha^{-1}) - (GL alone)
3. Cattle manure 4 t ha^{-1} (20 kg N ha^{-1}) + Green leaves 4 t ha^{-1} (20 kg N ha^{-1}) - (CM + GL)
4. Ammonium sulphate alone to supply 40 kg N ha^{-1} - (AS alone)

Fig.1. Layout of Field Experiment (Tall indica)

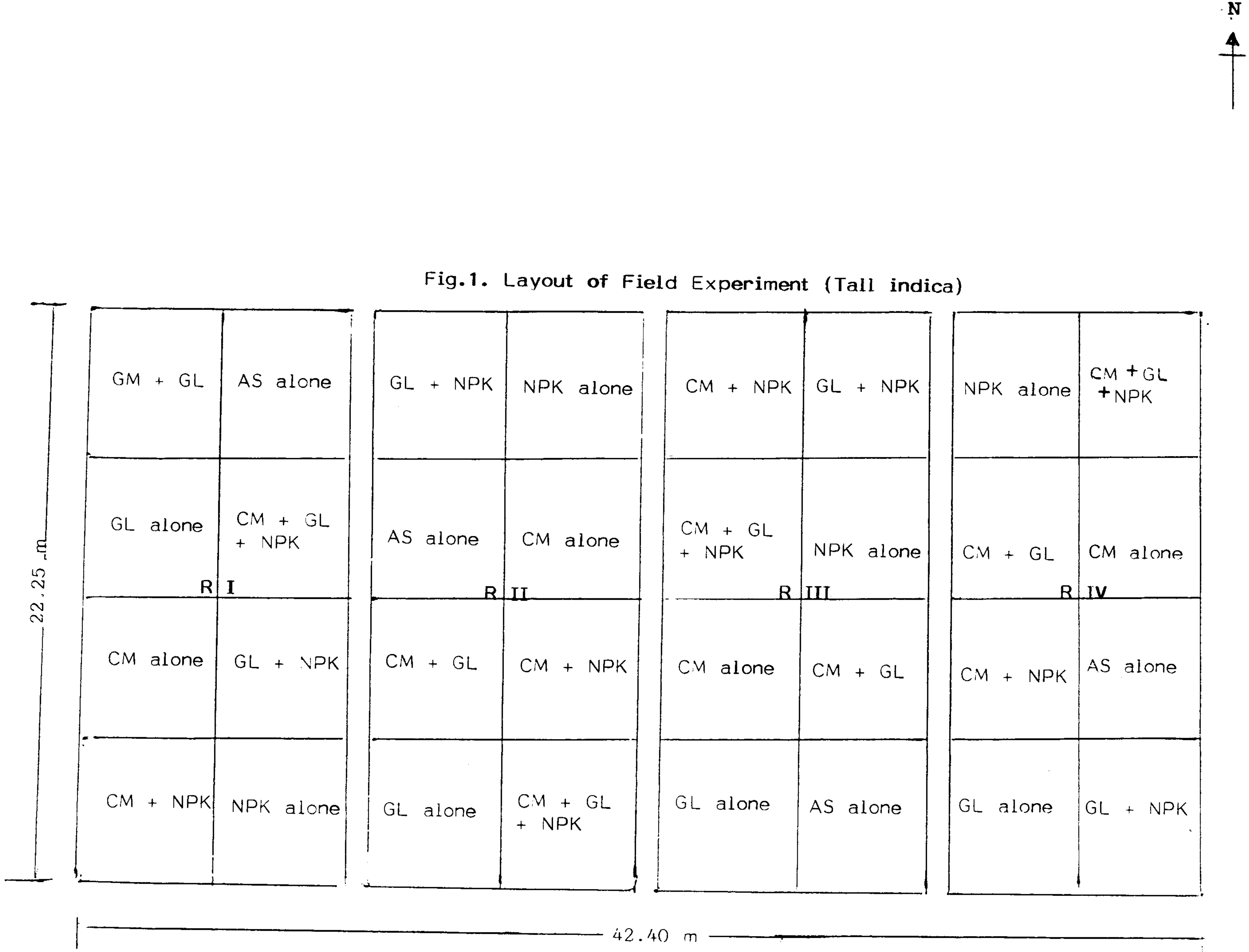
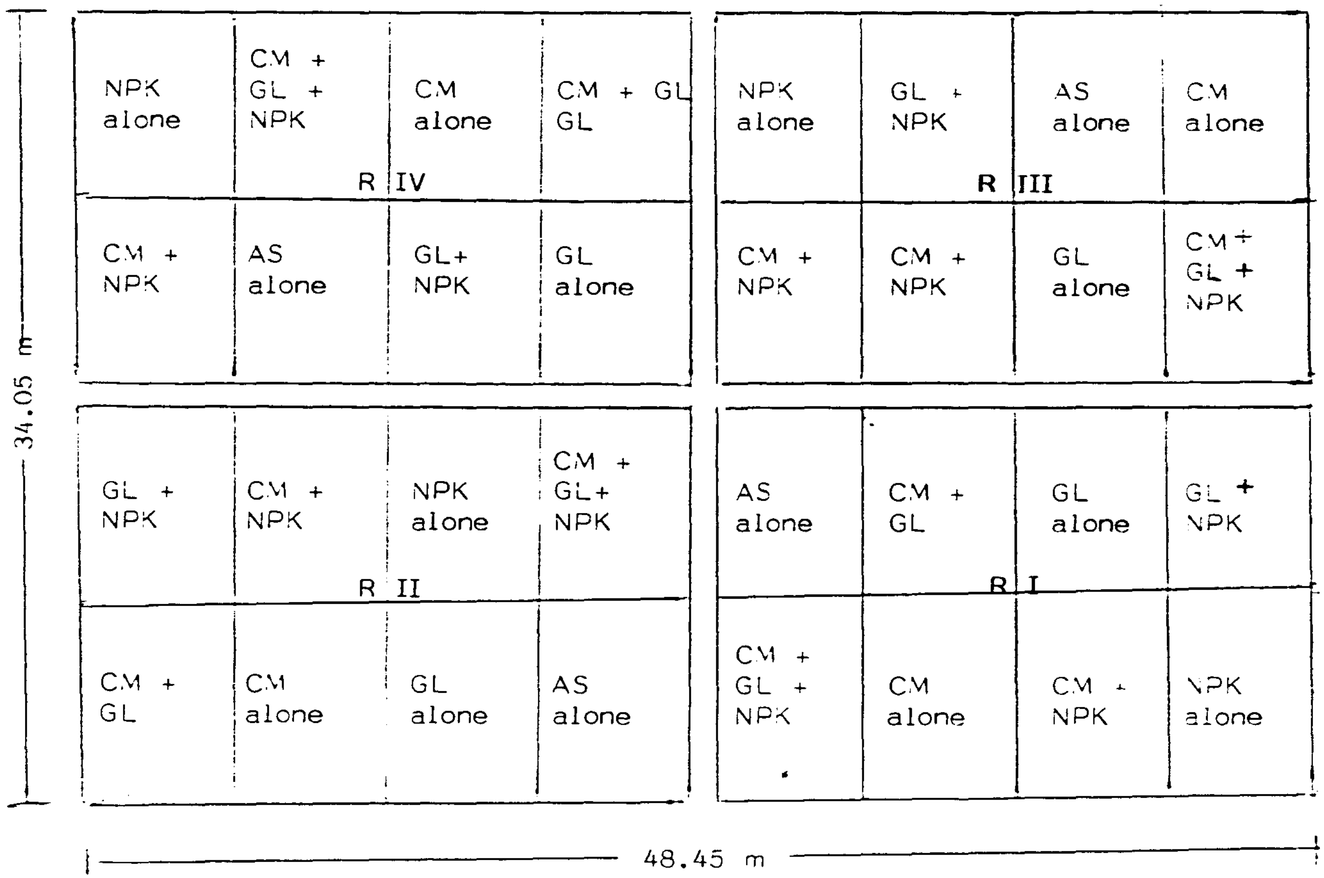


Fig.2. Layout of Field Experiment (Dwarf indica)



5. Cattle manure 4 t ha^{-1} (20 kg N ha^{-1}) + NPK fertilizers to supply 20:20:20 kg N, P and K ha^{-1} (CM + NPK)
6. Green leaves 4 t ha^{-1} (20 kg N ha^{-1}) + NPK fertilizers to supply 20:20:20 kg N, P and K ha^{-1} (GL + NPK)
7. Cattle manure 2 t ha^{-1} (10 kg N ha^{-1}) + Green leaves 2 ha^{-1} (10 kg N ha^{-1}) + NPK fertilizers to supply 20:20:20 kg N, P and K ha^{-1} (CM + GL + NPK)
8. NPK fertilizers alone to supply 40:20:20 kg N, P and K ha^{-1} (NPK alone)

The N dose is kept constant (40 kg N ha^{-1}) for all the treatments, taking the N content in cattle manure and green leaves as 0.5 per cent. P_2O_5 and K_2O were applied in the form of superphosphate and muriate of potash respectively as basal application. The entire quantity of ammonium sulphate was applied at the time of tillering. Variety PTB-2 was grown during the first crop season and PTB-20 for the second crop season.

1.2 Permanent manurial experiment on dwarf indica

In this experiment also, the design adopted is RBD, with 8 treatments and 4 replications. Variety Jaya is grown during both the seasons. The treatments are:

1. Cattle manure 18 t ha^{-1} (90 kg N ha^{-1}) - (CM alone)
2. Green manure 18 t ha^{-1} (90 kg N ha^{-1}) - (GL alone)
3. Cattle manure 9 t ha^{-1} (45 kg N ha^{-1}) + Green leaves 9 t ha^{-1} (45 kg N ha^{-1}) - (CM + GL)
4. Ammonium sulphate alone to supply 90 kg N ha^{-1} - (AS alone)

5. Cattle manure 9 t ha^{-1} (45 kg ha^{-1}) + NPK fertilizers to supply 45:45:45 kg N, P and K ha^{-1} (CM + NPK)
6. Green leaves 9 t ha^{-1} (45 kg N ha^{-1}) + NPK fertilizers to supply 45:45:45 kg N, P and K ha^{-1} (GL + NPK)
7. Cattle manure 4.5 t ha^{-1} (22.5 kg N ha^{-1}) + Green leaves 4.5 t ha^{-1} (22.5 kg N ha^{-1}) + NPK fertilizers to supply 45:45:45 kg N, P and K ha^{-1} (CM + GL + NPK)
8. NPK fertilizers alone to supply 90:45:45 kg N, P and K ha^{-1} (NPK alone)

N, P and K were applied as ammonium sulphate, superphosphate and muriate of potash respectively. The entire quantity of superphosphate was applied as basal dose at the time of transplanting. Half the dose of ammonium sulphate and muriate of potash was applied as basal dose and the remaining quantity applied at the time of panicle initiation. The percentage of N in cattle manure and green leaves is taken as 0.5 per cent.

2 Collection of samples

Soil samples from both the experiments were collected from all the plots at the following periods.

1. Harvest of the second crop of 91-92
2. Before application of manures for the first crop of 92-93
3. Transplantation of the first crop
4. Tillering of the first crop
5. 50 per cent flowering of the first crop
6. Harvest of the first crop

7. Before application of manures for the second crop
8. Transplantation of the second crop during 92-93
9. Tillering of the second crop
10. 50 per cent flowering of the second crop
11. Harvest of the second crop

Soil samples were collected from the surface (0-15 cm) of the soil using metallic soil sampler.

Plant samples also were collected at tillering, 50 per cent flowering and harvest of the two crops. The whole plants were washed in running water. Roots also collected, washed well and kept separately for analysis.

3 Laboratory studies

3.1 Soil samples

3.1.1 Preparation of the samples

The soil samples were spread in the shade for air drying. After air drying they were powdered gently and sieved through a 2 mm sieve. Then they were kept in polythene bags and labelled.

3.1.2 Analysis of the samples

Walkley and Black's rapid titration method was followed to determine the organaic carbon content (Piper, 1942). Cation exchange capacity was determined by the neutral normal ammonium acetate method described by Piper (1942).

Available nitrogen was estimated using the alkaline permanganate method developed by Subbiah and Asija (1956).

Bray No.1 extractant was used to extract the available phosphorus. Blue colour was developed using the ascorbic acid method (Watanabe and Olsen, 1965) and read in a Klett-summerson colorimeter.

Available K was extracted using normal ammonium acetate and read in an EEL flame photometer (Jackson, 1958). Exchangeable Ca and Mg were extracted using normal ammonium acetate and the contents determined by EDTA titration method (Hesse, 1971).

3.2 Plant samples

3.2.1 Preparation of the samples

The samples were dried in a hot air oven at 70°C and dry weights recorded. They were powdered and kept in labelled brown paper cover for analysis. Roots were also dried, powdered and kept separately.

3.2.2 Analysis of the samples

The nitrogen content in the samples was estimated by micro-kjeldahl distillation after digestion in sulphuric acid (Jackson, 1958). For the estimation of P, K, Ca and Mg, the samples were first digested using tri-acid mixture (HNO_3, $HClO_4$ and H_2SO_4 in the ratio 10:4:1). Phosphorus content was estimated by developing yellow colour using vanado-molybdo phosphoric acid yellow colour method and then reading the colour intensity in a Klett-summerson colorimeter (Jackson, 1958).

Potassium in the digest was determined using EEL flame photometer. Calcium and Magnesium were determined by EDTA titration method (Cheng and Bray, 1951).

4 Statistical analysis

Analysis of variance for RBD was done for the results obtained to see whether there existed any difference between the treatments. Paired 't' test was done to check whether there is variation in nutrient status between the two seasons (Panse and Sukhatme, 1985).

Results and Discussion

RESULTS AND DISCUSSION

The results obtained in the study are presented and discussed in this chapter.

1 Seasonal variations in the nutrient transformation and the effect of treatments on these transformations

1.1 Experiment on Tall indica

1.1.1 Organic carbon

The data on organic carbon content of soil at different periods from harvest of second crop of 1991 to harvest of second crop of 1992 are given in Table 1.

During the first crop season the organic carbon content showed a trend to decrease gradually with crop growth upto harvesting. Then it increased slightly at transplanting of the second crop. This increase was noticed for all treatments including those receiving inorganic fertilisers alone. This may be due to the decomposition of stubbles and roots left after the harvest of the first crop.

In the second crop season, the organic carbon content showed no definite trend upto the 50 per cent flowering stage and thereafter it increased at harvest for all the treatments. Almost all the treatments showed the same trend in both the seasons. This indicates that irrespective of the treatment, whether it included organic matter alone or inorganic fertilizer alone or a combination of both, the pattern of organic carbon content at different stages of growth of the crop is the same.

Table 1. Organic carbon content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, per cent (Tall indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	1.57	1.66	1.31	1.14	1.10	0.87	0.85	0.94	0.93	0.93	1.18
GL alone	1.35	1.37	1.22	0.98	0.94	0.74	0.86	0.79	0.74	0.76	1.11
CM + GL	1.48	1.47	1.23	1.08	1.14	0.82	0.88	1.03	0.93	0.88	1.10
AS alone	1.35	1.35	1.15	0.88	1.07	0.70	0.76	0.75	0.68	0.86	1.12
CM + NPK	1.30	1.33	1.25	1.01	1.06	0.72	0.88	0.76	0.92	0.92	1.06
GL + NPK	1.20	1.31	1.24	0.93	1.17	0.73	0.85	0.79	0.82	0.81	1.00
CM+GL+NPK	1.30	1.34	1.13	0.98	0.98	0.86	0.81	0.84	0.82	0.79	1.08
NPK alone	1.33	1.25	1.00	0.99	1.03	0.76	0.71	0.80	0.84	0.73	1.04
SEm	0.105	0.074	0.071	0.067	0.063	0.671	0.074	0.063	0.081	0.063	0.067
CD	NS	0.154	0.147	0.144	0.132	NS	0.154	0.132	0.168	0.132	NS

Significant differences existed between treatments at all stages of crop growth in both seasons except at harvest, where all the treatments were statistically on par. The treatment CM alone, recorded the highest content at most of the growth stages in both crop seasons. Similar results have been reported earlier by Kurumthottical (1982), in the same experimental fields. The results indicate the favourable role of cattle manure in increasing the organic carbon status of soil. The treatment involving application of green leaves alone has recorded low organic matter content compared to treatment CM alone at all the periods of analysis. The lower contents recorded by the treatment GL alone may be attributed to the rapid decomposition of the fresh glyricedia leaves. Similar results of decrease in organic carbon content due to continuous application of green leaves were reported by Padmam (1992). At harvest, in both seasons, no significant difference in the organic carbon content was noticed between the treatments which have received a large quantity of manures at the rate of 8000 kg ha^{-1} and those receiving no manure application at all. The inability of organic manures to enhance the organic matter content of soil considerably at harvest may be due to their higher rate of decomposition in the tropical condition.

The values recorded at the time of harvest of the second crop of 1991 were higher for all the treatments compared to the values recorded at the time of harvest of second crop of 1992. Even after application of manures, the organic carbon content showed a trend to decrease at the time of transplanting of first crop of 1992 compared to that at the time of harvest of second crop of 1991.

Comparison of data in the two seasons by two tail 't' test showed that at transplanting, tillering and 50 per cent flowering stages, significantly higher values were maintained in the first crop season compared to the second crop season (Table 2). But at harvest, just the reverse of this trend was observed.

1.1.2 Available nitrogen

The data on available N content are given in Table 3. During the first crop season the values decreased from transplanting to tillering and then increased gradually at 50 per cent flowering and again decreased at harvest. The nitrogen fertilizer namely ammonium sulphate was applied at the time of tillering and that may be one of the reasons for the increase in the available N content in the treatments receiving fertilizer application. At all stages, all the treatments maintained the available N level in the medium range. At the time of transplanting of the second crop, it again increased, for all treatments except the treatment CM + NPK, then decreased at tillering and again increased towards harvest. During the second crop season also ammonium sulphate was applied at the tillering stage and that may be one of the reasons for the increase noticed from the tillering stage in the ammonium sulphate applied plots.

Significant differences between treatments occurred at transplanting and harvesting stages of the first crop, but the difference was significant only at the transplanting stage of the second crop. Among the treatments, the treatment CM alone has recorded comparatively high values at most of the stages of observation. At the time of transplanting of the first crop it was significantly superior to all other treatments, but no such difference was noticed during the other stages. There was no significant reduction in the available N content of soil due to application of inorganic fertilizers alone in both the seasons at the time of harvest. Contrary to this, Padmam

Table 2. Seasonal variation in organic carbon content of soil (Tall indica)

Stage of crop growth	Average organic carbon in soil, per cent		t value
	First crop	Second crop	
Transplanting	1.19	0.84	12.58*
Tillering	0.99	0.83	7.5*
50% flowering	1.06	0.83	8.96*
Harvest	0.78	1.09	-12.00*

* Significant at 5 per cent level

Table 3. Available nitrogen content of soil at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, kg ha^{-1} (Tall indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	540.75	550.38	470.70	360.63	384.13	370.05	360.65	421.80	319.88	407.67	420.25
GL alone	563.30	555.05	407.67	349.67	377.88	370.05	355.92	388.85	343.38	406.13	410.83
CM + GL	531.50	533.10	423.38	363.77	393.58	346.55	354.35	407.65	348.10	402.98	418.67
AS alone	534.50	495.48	387.15	341.83	376.30	351.50	327.70	371.63	330.85	385.75	401.40
CM + NPK	511.25	533.13	360.55	354.38	407.70	384.17	330.83	338.67	349.67	395.15	399.85
GL + NPK	552.00	547.22	373.20	362.23	387.70	330.00	352.77	343.38	334.00	417.08	415.52
CM+GL+NPK	547.25	495.48	401.42	355.92	354.38	349.67	379.45	379.45	376.33	412.40	424.92
NPK alone	494.00	498.63	354.38	352.80	349.67	344.95	376.33	382.60	337.15	379.48	446.82
SEm	27.745	40.912	14.471	22.183	18.174	14.804	21.907	18.312	16.534	19.210	20.392
CD	NS	NS	30.092	NS	NS	30.794	NS	38.090	NS	NS	NS

(1992) reported that the treatments receiving NPK alone and GL alone have recorded low available N contents.

The values recorded at the time of harvest of the second crop in 1991 were much higher than that in 1992, for all the treatments.

Comparing between seasons, higher contents were recorded in the first season than the second during the first two stages, though no statistical difference existed as shown by two tail 't' test (Table 4). But during the last two stages significant variation was observed between seasons with higher values being recorded in the second season. This trend is almost the same as that shown by organic carbon. The difference noticed between the seasons may be due to the differences in the duration of submergence and temperature as they influence strongly the concentration of water soluble NO_3^- and water soluble NH_4^+ (Ponnamperuma, 1977).

1.1.3 Available phosphorus

Available P content of soil in general was medium to high at all stages of crop growth in both seasons (Table 5). During the first crop season, it decreased from transplanting stage to harvest in all the treatments. It again decreased at transplanting of the second crop, for all treatments, indicating that addition of manures and fertilizers has failed to increase its availability in soil. At tillering also this trend continued for most of the treatments. But at 50 per cent flowering, it showed an increase for all treatments and it further increased at harvest. The values at harvest were comparable with those recorded at the time of transplanting of the first crop.

Significant difference between treatments was observed at all stages of crop growth in both seasons. Treatments which involve cattle manures addition

Table 4. Seasonal variation in available nitrogen content of soil (Tall indica)

Stage of crop growth	Average available N content in soil, kg ha^{-1}		t value
	First crop	Second crop	
Transplanting	389.07	379.25	1.45
Tillering	355.15	342.42	1.70
50% flowering	378.86	400.83	-3.11*
Harvest	357.12	417.29	-7.93*

* Significant at 5 per cent level

Table 5. Available phosphorus content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, kg ha^{-1} (Tall indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	57.50	44.70	64.07	54.07	57.19	49.45	37.52	25.80	21.72	39.99	66.33
GL alone	40.97	44.29	26.98	23.11	16.99	15.91	21.82	10.97	11.29	15.27	22.79
CM + GL	54.28	54.61	44.40	33.65	34.62	18.27	24.30	18.18	18.06	20.00	42.78
AS alone	50.20	36.20	24.30	21.28	22.15	16.13	19.89	12.47	6.99	11.29	40.74
CM + NPK	78.38	77.18	64.29	54.07	44.83	28.17	21.93	18.06	26.44	33.79	50.53
GL + NPK	47.18	60.65	44.94	34.40	33.76	22.15	20.32	15.27	14.51	14.40	31.60
CM+GL+NPK	69.38	70.41	52.46	44.08	40.31	23.65	31.28	20.32	18.36	21.72	58.59
NPK alone	55.67	57.83	50.76	53.32	31.93	22.79	22.04	12.04	15.00	15.80	37.84
SEm	10.248	8.267	4.314	8.932	5.743	4.950	6.553	3.915	4.403	6.641	10.710
CD	21.376	17.196	8.973	18.574	11.939	10.306	NS	8.134	9.158	13.811	22.277

showed higher values compared to those involving green leaves addition and inorganics alone. Addition of organic matter has been reported to increase the availability of P. The beneficial effects of organic matter in increasing the availability of P is reported to be due to the formation of insoluble organic complexes with Fe and Al thereby preventing their reaction with P in acid soils (Tisdale and Nelson, 1975). But in the present study, beneficial effect of organic matter was shown only by cattle manure, whereas application of green leaves reduced the availability of P. Similar results have been reported by Padmam (1992) for dwarf indica variety. The cumulative effect of cattle manure addition, which has higher P content compared to green leaves, for 60 seasons may be one of the reasons for increased availability of P in treatment CM alone. During decomposition of green manure under anaerobic conditions, the pH of the soil decreases due to the formation of various organic acids and at low pH the conversion of available P into Fe-P and Al-P may be more. This may be another reason for the low available P content recorded in the green leaves applied plots.

As in the case of organic carbon and available N, higher values were recorded at the time of harvest of second crop of 1991 compared to that of 1992.

Compared to the second crop season, higher contents were recorded during the first crop season upto the 50 per cent flowering stage. But at harvest, the trend reversed. Variation at all stages were statistically significant, as shown by two tail t test (Table 6). The increased availability of P in the initial stages of the first crop season can be attributed to the differences in soil reduction as the availability of P is reported to be increased proportionately with decrease in Eh (Chang, 1963).

Table 6. Seasonal variation in available phosphorus content of soil (Tall indica)

Stage of crop growth	Avervage available P content in soil, kg ha^{-1}		t value
	First crop	Second crop	
Transplanting	46.52	16.66	12.27*
Tillering	39.75	16.65	8.20*
50% flowering	35.22	21.41	6.89*
Harvest	24.56	43.90	-6.20*

* Significant at 5 per cent level

1.1.4 Available potassium

Data on available K content are presented in Table 7. The values gradually declined from transplanting to harvest during the first crop season. All the values were in the medium range at the time of transplanting of the crop. But at 50 per cent flowering stage, most of the values were in the low range and by harvest, all the treatments recorded low values. The K content in the second crop season followed a similar pattern as in the first crop season except that, at harvest the contents increased in most of the treatments. This increase was not shown by the treatment AS alone.

Significant differences between treatments were observed at all stages of first crop season and at transplanting and harvesting stages in the second crop. In the first season, treatment CM alone, which involved application of cattle manure at the rate of 8 t ha^{-1} recorded the highest value at all the stages. The treatments AS alone and NPK alone which included no organic matter recorded low values. During the second season also similar trends were observed.

As in the case of organic carbon. available N and available P, the values recorded at the time of harvest of second crop of 1991 were higher than that at the time of harvest of 1992. The differences noticed in the trend of available K and that of available N and P is that, available K content increased further after harvest of second crop of 1991 and much higher values were recorded at the time of transplanting of first crop of 1992. In the case of available N and P, their values have not increased even after addition of manures.

Table 7. Available potassium content of soils at different periods from harvest of second crop in 1991 to havest of second crop in 1992, kg ha^{-1} (Tall indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	127.50	133.00	204.40	151.20	140.00	92.40	156.80	96.60	100.50	89.60	112.00
GL alone	120.00	119.00	186.20	145.60	98.00	85.40	88.20	107.80	100.80	82.60	89.60
CM + GL	125.00	124.60	201.60	149.60	100.80	79.80	84.00	152.00	98.00	74.20	78.40
AS alone	111.25	105.00	135.80	100.80	89.60	61.60	67.20	65.80	74.20	82.60	67.20
CM + NPK	115.00	127.40	170.00	128.80	96.60	67.20	65.80	84.00	95.20	67.20	113.40
GL + NPK	128.25	147.00	182.00	133.60	113.40	72.80	93.80	86.80	98.00	82.60	84.00
CM+GL+NPK	117.50	128 80	180.60	138.60	98.00	88.20	79.80	88.20	98.00	72.80	96.60
NPK alone	91.00	105.00	142.80	117.60	71.00	64.40	65.80	85.40	75.60	67.20	72.80
SEm	14.36	14.41	19.45	14.19	9.44	7.35	9.22	13.97	13.09	6.68	10.99
CD	NS	NS	40.47	29.51	19.54	15.29	19.18	29.06	NS	NS	22.87

Like in the case of organic carbon, available N and P, during the initial stages higher values were recorded in the first crop season, compared to the second (Table 8). At harvest, significantly higher values were recorded in the second season, compared to the first. The differences in the availability of K at different periods in the two seasons may be due to the differences in the duration of submergence and temperature, as in the case of N and P (Ponnamperuma, 1977).

1.1.5 Exchangeable calcium

In general, the exchangeable Ca content of soil decreased from transplanting to harvest during the first crop season (Table 9). On the other hand during the second crop season exchangeable calcium decreased first from transplanting to tillering and then increased gradually towards harvest.

Significant differences between treatments occurred at all stages of first crop, except at harvest. The treatment AS alone, recorded the lowest values throughout the first season. In the second season, significant difference was noticed only at harvest and at this stage also, treatment AS alone recorded low value. The low exchangeable Ca content in the ammonium sulphate applied plot indicates the decalcifying power of ammonium sulphate under conditions of waterlogging and leaching. Green leaves have been found to be inferior to cattle manure in increasing the exchangeable Ca content of soil, at all stages except at harvesting of the first crop. With regard to other treatments, no definite trend was shown at different growth stages.

No regular trend was noticed in the values obtained at the time of harvest of the second crop in 1991 and 1992 by the different treatments.

Table 8. Seasonal variation in available potassium content of soil (Tall indica)

Stage of crop growth	Average available K content of soil, kg ha^{-1}		t value
	First crop	Second crop	
Transplanting	175.33	94.67	11.88*
Tillering	133.17	93.10	9.98*
50% flowering	100.98	77.35	6.63*
Harvest	70.48	89.25	-3.20*

* Significant at 5 per cent level

Table 9. Exchangeable calcium content of soil at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, cmol(+) kg^{-1} (Tall indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	1.68	2.05	2.07	1.99	1.66	1.34	1.59	1.42	1.01	1.39	1.75
GL alone	1.83	2.13	1.75	1.68	1.40	1.48	1.28	1.20	0.94	1.16	1.30
CM + GL	2.06	1.84	2.03	1.83	1.54	1.30	1.38	1.45	1.27	1.51	1.43
AS alone	1.12	1.53	1.46	1.65	1.33	1.11	1.31	1.25	1.18	1.27	1.27
CM + NPK	2.07	1.93	1.82	2.09	1.65	1.25	1.38	1.40	1.29	1.18	2.13
GL + NPK	1.58	2.07	1.97	1.80	1.76	1.43	1.33	1.28	1.23	1.53	1.73
CM+GL+NPK	1.46	1.64	1.75	2.00	1.60	1.63	1.25	1.21	1.23	1.37	1.25
NPK alone	1.38	1.78	2.11	2.03	1.89	1.49	1.44	1.28	1.12	1.11	1.59
SEm	0.169	0.187	0.172	0.148	0.148	0.183	0.116	1.220	0.138	0.145	0.136
CD	0.351	0.389	0.357	0.309	0.309	NS	0.242	NS	NS	NS	0.283

Compared to the first season, lower values were recorded during the second season at all stages except at harvest (Table 10). Similar trend was noticed in the case of all other nutrients studied. Variation between seasons was statistically significant at all stages.

4.1.1.6 Exchangeable magnesium

No definite pattern was followed by the treatments in the exchangeable Mg content of soil in both seasons (Table 11). But at 50 per cent flowering stage of the first crop, an increase was noted for most treatments and these values decreased at harvest. No such trend was observed in the second crop season.

Except at 50 per cent flowering stage of the first crop, and tillering stage of the second crop, treatment differences were significant. Treatment CM alone recorded higher values compared to GL alone at most of the stages. Padmam (1992) also reported that application of cattle manure has a favourable effect on the exchangeable Mg content of soil, compared to green leaves, in dwarf indica variety of rice.

In general the magnesium content at the time of harvest of second crop of 1992 were lower for most of the treatments compared to the corresponding values obtained in 1991.

Significant seasonal variation occurred only at 50 per cent flowering stage at which higher contents were recorded in the first season compared to the second (Table 12).

Table 10. Seasonal variation in exchangeable calcium content of soil (Tall indica)

Stage of crop growth	Average exchangeable Ca content in soil, cmol(+) kg^{-1}		t value
	First crop	Second crop	
Transplanting	1.87	1.31	9.30*
Tillering	1.88	1.16	13.73*
50% flowering	1.61	1.32	5.25*
Harvest	1.38	1.56	-2.42*

* Significant at 5 per cent level

Table 11. Exchangeable magnesium content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, cmol(+) kg^{-1} (Tall indica)

Treatment	Harvest of second crop 1991	Before application of manure 1st crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	1.68	2.05	0.31	0.32	0.71	0.36	1.59	0.33	0.65	0.41	0.28
GL alone	1.83	2.13	0.30	0.29	0.48	0.39	1.28	0.24	0.34	0.18	0.40
CM + GL	2.06	1.84	0.30	0.24	0.63	0.34	1.38	0.49	0.61	0.28	0.32
AS alone	1.12	1.53	0.21	0.24	0.52	0.21	1.31	0.19	0.21	0.13	0.22
CM + NPK	2.07	1.93	0.20	0.40	0.96	0.44	1.38	0.30	0.31	0.36	0.31
GL + NPK	1.58	2.07	0.37	0.32	0.38	0.36	1.33	0.22	0.26	0.15	0.21
CM+GL+NPK	1.46	1.64	0.31	0.29	0.29	0.31	1.25	0.27	0.29	0.12	0.44
NPK alone	1.38	1.78	0.22	0.28	0.43	0.22	1.44	0.36	0.33	0.31	0.27
SEm	0.169	0.187	0.065	0.042	0.124	0.055	0.116	0.055	0.163	0.074	0.039
CD	0.351	0.389	0.136	0.087	NS	0.115	0.242	0.114	NS	0.154	0.081

Table 12. Seasonal variation in exchangeable magnesium content of soil (Tall indica)

Stage of crop growth	Average exchangeable Mg content in soil, cmol(+) kg^{-1}		t value
	First crop	Second crop	
Transplanting	0.28	0.30	-0.74
Tillering	0.30	0.37	-1.74
50% flowering	0.51	0.24	9.38*
Harvest	0.32	0.31	0.59

* Significant at 5 per cent level

Seasonal variations in the organic carbon content and available N, P and K and exchangeable Ca and Mg are presented in Fig. 3 and 4.

1.2 Experiment on Dwarf indica

1.2.1 Organic carbon

The data on organic carbon content of soil at various growth stages of crop during first and second seasons are presented in Table 13. During the first season, the organic carbon content first decreased from transplanting to tillering and then increased slightly at 50 per cent flowering and again decreased at harvest. But in the second season, it increased at tillering, then decreased at 50 per cent flowering stage and again increased at harvest.

The influence of treatments was significant at all stages in both the seasons except at harvesting of the first crop and at 50 per cent flowering in the second season. Comparatively higher values were recorded by treatments CM alone and CM + GL, during both seasons. Lower values were recorded by treatments AS alone and NPK alone. The results obtained in this study are in accordance with the results reported by Padmam (1992) based on the studies conducted on the same experimental plots. In the experiment with tall indica varieties also cattle manure application has recorded higher values of organic matter content at all stages of crop growth.

The organic carbon content recorded at the time of harvest of second crop was lower than those at transplanting of first crop and the values recorded at the time of harvest of the second crop of 1991 were higher than those for the corresponding period in 1992. Similar results were obtained for tall indica also. In this

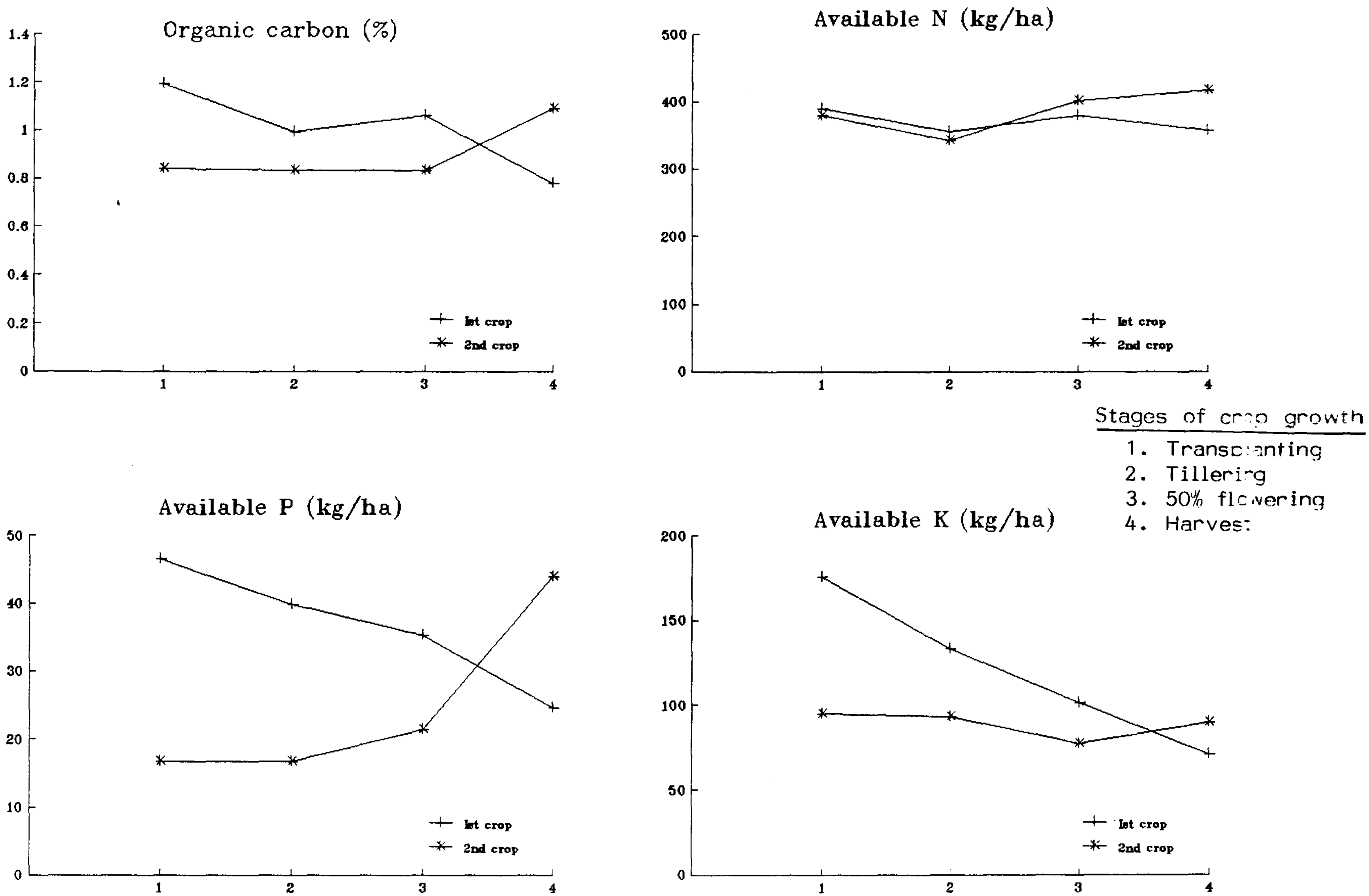


Fig.3. Seasonal changes in the organic carbon and available N, P and K in soil (Tall indica)

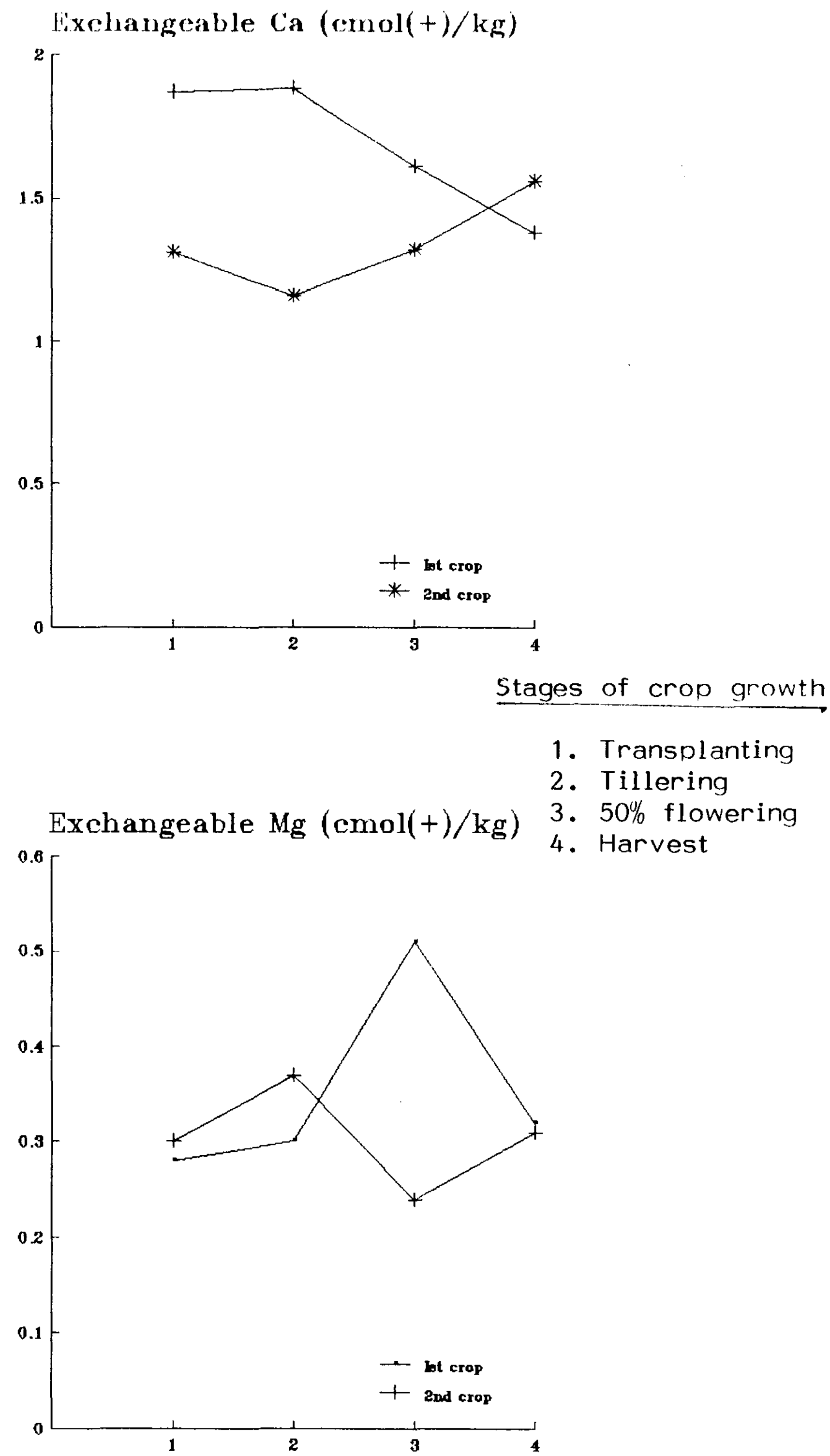


Fig.4. Seasonal variations in the exchangeable Ca and Mg content in soil (Tall indica)

Table 13. Organic carbon content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, per cent (Dwarf indica)

Treatment	Harvest of second crop 1991	Before application of manure 1st crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trnas-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	0.42	0.69	1.46	1.23	1.23	0.83	0.32	1.05	1.15	0.85	1.13
GL alone	0.37	0.47	1.25	0.96	1.19	0.73	0.25	0.82	0.95	0.80	1.11
CM + GL	0.30	0.41	1.46	1.15	1.33	0.87	0.34	1.03	1.06	0.94	1.15
As alone	0.31	0.20	1.04	0.99	1.03	0.70	0.21	0.71	0.94	0.67	0.81
CM + NPK	0.40	0.29	1.22	0.99	1.02	0.76	0.21	0.74	0.90	0.80	1.05
GL + NPK	0.49	0.78	1.30	0.97	1.07	0.75	0.21	0.76	0.94	0.89	0.98
CM+GL+NPK	0.70	0.54	1.31	0.95	1.14	0.82	0.40	0.77	0.99	0.85	0.93
NPK alone	0.37	0.25	1.00	0.91	0.93	0.68	0.24	0.65	0.81	0.76	0.88
SEm	0.066	0.116	0.077	0.067	0.055	0.063	0.067	0.097	0.084	0.102	0.089
CD	0.157	0.242	0.161	0.140	0.114	NS	0.139	0.203	0.174	NS	0.186

experiment for dwarf indica varieties the quantity of manures and fertilizers applied were about twice that for tall indica varieties. But there was not much difference in the organic carbon content of soil of the two experiments and that may be due to the high rate of decomposition of organic matter under tropical conditions.

Paired 't' test has shown that seasonal variations were significant at transplanting, 50 per cent flowering and harvesting stages (Table 14). Significantly higher contents were maintained in the first season at transplanting and at 50 per cent flowering. But at harvest, the reverse trend was observed. The same trend was observed for tall indica also.

1.2.2 Available nitrogen

Available N content of soil in the first crop season decreased at tillering from the transplanting stage and then increased at 50 per cent flowering, then it decreased at harvest (Table 15). Similar trend was observed for tall indica rice also during the first season. During the second season, most treatments showed a gradual increase towards harvest though a slight decrease was showed at tillering by the treatments CM + NPK, CM + GL + NPK and NPK alone. This trend slightly differs from the observation on tall indica for the same season, where a decrease was noticed at tillering stage for all treatments except the treatment CM + NPK. In the case of tall indica varieties, ammonium sulphate was applied as a single dose i.e., at tillering only. In the dwarf indica nitrogenous fertilizer was applied in two splits i.e., at transplanting and at panicle initiation stages and that may be one of the reasons for the variation in the trend noticed in the available N content of soil, between the two experiments.

Table 14. Seasonal variation in organic carbon content of soil (Dwarf indica)

Stage of crop growth	Average organic carbon content of soil, per cent		t value
	First crop	Second crop	
Transplanting	1.25	0.82	14.12*
Tillering	1.02	0.97	1.90
50% flowering	1.12	0.82	10.28*
Harvest	0.76	1.00	-7.00*

* Significant at 5 per cent level

Table 15. Available nitrogen content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, kg ha^{-1} (Dwarf indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	537.82	545.67	471.97	390.43	409.25	355.94	417.09	357.50	432.77	387.30	407.68
GL alone	500.19	506.46	420.23	387.30	393.57	335.55	395.14	349.67	392.00	362.21	396.70
CM + GL	534.69	551.93	431.23	404.55	407.68	346.53	423.36	359.07	363.78	417.09	442.17
AS alone	476.67	475.11	379.45	349.66	399.84	357.51	390.43	343.39	363.71	399.84	398.27
CM + NPK	471.97	523.71	395.14	368.48	376.32	363.77	402.98	366.91	327.71	388.86	370.05
GL + NPK	589.89	512.74	402.98	354.37	409.25	379.46	393.57	330.85	371.61	423.39	442.17
CM+GL+NPK	504.90	490.79	379.45	376.32	404.55	368.48	354.37	340.26	321.44	387.30	412.39
NPK alone	453.15	468.83	370.05	319.87	363.77	338.69	396.70	362.21	344.96	354.37	388.86
SEm	33.932	29.371	42.614	18.151	14.635	22.686	26.792	19.212	24.457	22.464	22.882
CD	NS	NS	NS	NS	NS	NS	NS	50.856	NS	NS	NS

No significant difference between treatments was observed at different stages during the first crop. In the second season, significant variation between treatments was seen only at transplanting. In tall indica also no significant variation in the available N content of soil was noticed due to application of organic manures alone, inorganic fertilizers alone and in combinations, at the time of harvest of second crop in 1991 and 1992.

The available N content of soil at the time of harvest of second crop of 1991 was much higher than that at the time of harvest of second crop of 1992. Similar trend was noticed for tall indica varieties also. Organic carbon content showed a similar trend for both tall and dwarf varieties.

The variation between the two seasons in available N content was significant at transplanting and at harvest (Table 16). At transplanting significantly higher values were recorded during the first season as compared to the second. But at harvest higher values were recorded in the second season. Similar were the trends observed for tall indica. These variations were observed for all treatments irrespective of the type of manures/fertilizers added.

1.2.3 Available phosphorus

High values were recorded by all treatments during both seasons (Table 17). The contents showed a declining trend during the first season from transplanting to harvest with a slight increase being shown by some treatments at 50 per cent flowering. The initial values, recorded at transplanting were reduced to almost half at harvesting stage for most of the treatments. For tall indica also the trend was same, but the difference is that, the values were low. During the second

Table 16. Seasonal variation in available nitrogen content of soil (Dwarf indica)

Stage of crop growth	Average available N content in soil, kg ha^{-1}		t value
	First crop	Second crop	
Transplanting	406.31	351.23	4.83*
Tillering	368.87	367.76	0.45
50% flowering	395.53	390.04	0.89
Harvest	355.74	407.29	-6.66*

* Significant at 5 per cent level

Table 17. Available phosphorus content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, kg ha^{-1} (Dwarf indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	233.80	258.00	160.73	169.85	146.75	98.38	190.40	143.64	101.80	96.21	158.75
GL alone	80.53	54.83	43.65	42.57	42.68	34.62	49.88	13.44	29.89	36.10	28.13
CM + GL	187.05	183.93	126.10	111.81	93.22	55.04	122.01	51.26	67.82	66.54	123.85
AS alone	50.20	62.35	51.60	33.33	31.07	26.34	42.68	17.20	35.90	25.37	40.42
CM + NPK	219.85	285.95	194.02	139.75	151.99	42.68	146.63	21.07	75.68	89.24	155.45
GL + NPK	183.93	154.80	116.42	103.30	83.74	56.87	147.68	28.38	74.18	65.58	113.42
CM+GL+NPK	149.88	178.66	138.55	93.51	115.99	71.71	181.60	49.88	54.18	61.26	132.45
NPK alone	185.65	182.20	98.57	74.94	79.75	53.00	43.93	33.22	47.94	46.44	108.89
SEm	33.172	32.713	14.404	29.141	19.262	19.267	30.0046	17.535	25.613	17.872	22.891
CD	68.991	68.053	29.954	60.612	40.067	40.066	62.412	36.441	NS	37.177	46.462

season, the contents at transplanting stage were even lower than those recorded at harvest of the first crop, except for treatment CM alone. For this treatment, P content declined upto 50 per cent flowering after which it increased sharply. In general for all treatments, available P content increased from transplanting to harvest. Almost similar trend was observed for tall indica variety also. Values recorded at the time of harvest of second crop were comparable with those recorded at transplanting of the first crop. The values recorded were much higher than those recorded for tall indica variety. This may be due to the high rate of phosphorus application for dwarf indica varieties. Only a small fraction of the applied phosphorus is used by plants. Since the soils are high in sesquoxides and kaolinitic clays having high P adsorption capacities, they rapidly adsorb added soluble phosphates since the soil is acidic in nature, and they slowly become available during the course of time.

Significant difference between treatments existed at all stages of crop growth in both the seasons except at tillering of the second crop. Treatments involving cattle manure addition recorded higher values and those involving green leaves alone and ammonium sulphate alone recorded lower values at all stages. Similar results were obtained for the experiment on tall indica rice also. Padmam (1992) reported similar results based on studies conducted in the same experimental fields.

The values recorded at the time of harvest of second crop of 1991 were much higher than the corresponding values recorded for 1992. Similar results were obtained for tall indica variety also.

Medium to high values were recorded by treatments during both seasons, seasonal variations occurred at all stages of crop growth (Table 18). Higher contents were recorded in the first season compared to the second upto 50 per cent flowering

Table 18. Seasonal variation in available phosphorus content of soil (Dwarf indica)

Stage of crop growth	Average available P content in soil, kg ha^{-1}		t value
	First crop	Second crop	
Transplanting	116.21	44.76	7.29*
Tillering	96.13	60.92	5.62*
50% flowering	93.54	60.09	6.16*
Harvest	54.83	107.89	-5.72*

* Significant at 5 per cent level

stage. But at harvest like in the case of other nutrients, the trend changed. Identical results were obtained for tall indica also.

1.2.4 Available potassium

The available K content in the soil also showed a declining trend from transplanting to harvest of the first crop, just as in the case of tall indica variety (Table 19). The medium to high status maintained by the treatments initially was reduced to medium and low status at harvest. For tall indica also similar results were obtained.

Available K content of the soil at the time of transplanting of second crop slightly increased from the values at harvesting of the first crop, except for the treatment AS alone which involves no addition of manures or potassium fertilizers.

Significant difference between treatments was observed at all stages of crop growth during the first season. Almost same trend existed in the second season with the difference that at harvest, no significant variation existed between treatments. Treatments which include inorganics alone, viz., AS alone and NPK alone recorded the lower contents at most of the stages in both seasons. Observations on tall indica were also similar. Such a trend was not noticed in the case of available N and P. This indicates that the influence of manures in increasing the availability of nutrients is more in the case of K compared to N and P.

The values at the time of harvest of the second crop was much lower than those at the time of planting of the first crop and also those recorded at the time of harvest of second crop in 1991. Similar trends were shown for tall indica also.

Table 19. Available potassium content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, kg ha^{-1} (Drawf indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	173.75	200.20	289.80	285.60	151.20	119.00	176.40	101.50	155.40	133.00	130.20
GL alone	183.50	187.60	294.00	198.80	128.00	110.60	126.00	121.80	159.60	170.80	158.20
CM + GL	183.50	175.00	379.40	305.20	170.80	127.40	196.00	186.20	142.80	149.80	103.60
AS alone	88.50	142.80	162.40	148.40	95.20	70.00	116.20	68.60	100.80	95.20	116.20
CM + NPK	151.00	187.60	294.00	194.60	120.40	105.00	207.20	116.20	169.40	162.40	147.00
GL + NPK	145.75	211.40	277.20	193.60	100.80	103.60	182.00	117.60	151.20	133.00	133.00
CM+GL+NPK	143.00	138.60	277.20	158.20	133.00	100.80	193.20	134.00	78.40	119.00	102.20
NPK alone	130.25	127.40	219.20	120.40	86.40	63.00	126.00	103.60	107.80	114.80	89.60
SEm	17.805	26.632	36.092	41.561	18.132	18.101	25.795	18.821	25.482	22.612	89.604
CD	37.159	55.395	75.067	86.445	37.722	37.642	53.653	39.151	53.066	47.024	NS

Comparison between seasons showed that significant variation occurred at transplanting, tillering and harvesting stages (Table 20). While the first season dominated in available K content at transplanting and tillering, just the reverse was observed at harvest. The results are almost similar to those obtained for tall indica. Available K content of soil is much higher in the experiment for dwarf indica varieties compared to the experiment for tall indica varieties and the reason for this can be attributed to the higher doses of K application for dwarf indica varieties.

1.2.5 Exchangeable calcium

In general the treatments showed a declining trend from transplanting to harvest in the first season, with some showing a slight increase at tillering (Table 21). In spite of the application of manures and fertilizers the values recorded at the transplanting stage of second crop were lower compared to those recorded at the time of first crop harvest, for most of the treatments. The trend obtained for tall indica series was also the same. During the second season, no definite trend was shown by treatments from transplanting to 50 per cent flowering. But at harvest, the contents increased drastically for all the treatments. This increase was noticed in the case of tall indica varieties also. But the values recorded at the time of harvest of second crop were lower than those recorded at transplanting of the first crop. For most of the treatments the values increased from the harvest of second crop of 1991 to the transplanting of first crop of 1992. Similar results have been obtained for tall indica also.

During the first season, significant difference between treatments occurred at transplanting, 50 per cent flowering and harvesting stages, while in the second season, the variations were significant at all the stages. Padmam (1992) has

Table 20. Seasonal variation in available potassium content of soil (Dwarf indica)

Stage of crop growth	Average available K content in soil, kg ha^{-1}		t value
	First crop	Second crop	
Transplanting	274.23	131.25	11.85*
Tillering	200.55	133.17	4.55*
50% flowering	123.37	134.75	-1.51
Harvest	99.92	122.50	-2.59*

* Significant at 5 per cent level

Table 21. Exchangeable calcium content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, cmol(+) kg^{-1} (Dwarf indica)

Treatment	Harvest of second crop 1991	Before application of manure 1st crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	2.58	2.60	2.30	2.37	1.71	1.52	1.63	1.34	1.26	1.26	1.57
GL alone	1.27	1.88	1.95	1.96	1.38	1.38	1.38	1.22	0.92	1.11	1.41
CM + GL	2.07	1.59	2.21	1.94	1.24	1.24	1.54	1.11	1.61	1.41	1.65
AS alone	1.26	2.07	1.47	2.02	1.22	1.20	1.44	1.08	1.23	0.82	1.07
CM + NPK	1.57	2.25	1.99	1.85	1.60	1.24	1.63	1.63	1.48	1.23	1.57
GL + NPK	1.38	2.05	2.05	1.77	1.92	1.48	1.55	1.41	1.39	1.03	1.63
CM+GL+NPK	1.89	2.09	2.12	1.89	1.56	1.41	1.32	1.48	1.40	1.45	1.54
NPK alone	1.32	1.49	1.79	1.93	1.19	1.62	1.33	1.30	1.28	1.44	1.19
SEm	0.138	0.186	0.157	0.206	0.163	0.116	0.114	0.164	0.176	0.109	0.120
CD	0.287	0.386	0.326	NS	0.339	0.242	0.237	0.342	0.363	0.338	0.249

reported similar results. Treatment CM alone has recorded higher values compared to GL alone. Similar results were noted for tall indica rice also.

No definite trend was shown by the different treatments in the content of exchangeable Ca at the time of harvest of the second crop in 1991 and 1992. The treatment AS alone has recorded the lowest value at the time of harvest of second crop in 1991 and 1992.

Compared to the second season, significantly higher exchangeable Ca status was maintained in the first season at transplanting, tillering and 50 per cent flowering (Table 22). But at harvest, no significant variation between seasons occurred, though slightly higher values were shown in the second season. These results are almost the same as those obtained for tall indica.

1.2.6 Exchangeable magnesium

Like in the case of tall indica rice, the exchangeable Mg content showed no regular pattern due to treatments at different growth stages during the first season (Table 23). But during the second crop, the values at 50 per cent flowering were lower than that at transplanting for all the treatments. The Mg content of soil then increased at harvesting for all treatments except in the treatment CM + NPK.

Significant differences between treatments were observed during transplanting and harvest of the first crop and during all the stages of the second crop. The treatment CM alone recorded higher values compared to GL alone during most stages. Similar results were obtained for tall indica also.

Table 22. Seasonal variation in exchangeable calcium content of soil (Dwarf indica)

Stage of crop growth	Average exchangeable Ca content of soil, cmol(+) kg^{-1}		t value
	First crop	Second crop	
Transplanting	1.98	1.32	9.38*
Tillering	1.98	1.32	9.54*
50% flowering	1.48	1.22	3.66*
Harvest	1.40	1.45	-1.05

*Significant at 5 per cent level

Table 23. Exchangeable magnesium content of soils at different periods from harvest of second crop in 1991 to harvest of second crop in 1992, cmol(+) kg^{-1} (Dwarf indica)

Treatment	Harvest of second crop 1991	Before application of manure Ist crop 1992	First crop				Before application of manure 2nd crop 1992	Second crop			
			Trans-planting	Tillering	50% flowering	Harvest		Trans-planting	Tillering	50% flowering	Harvest
CM alone	0.66	0.30	0.65	0.34	0.48	0.50	0.31	0.70	0.55	0.30	0.78
GL alone	0.56	0.50	0.29	0.32	0.49	0.28	0.28	0.22	0.45	0.14	0.28
CM + GL	0.45	0.40	0.41	0.31	0.40	0.44	0.24	0.31	0.22	0.22	0.27
AS alone	0.21	0.20	0.22	0.20	0.42	0.25	0.21	0.20	0.40	0.10	0.16
CM + NPK	0.35	0.41	0.26	0.28	0.43	0.24	0.36	0.40	0.33	0.40	0.35
GL + NPK	0.50	0.54	0.52	0.57	0.43	0.27	0.44	0.43	0.26	0.21	0.27
CM+GL+NPK	0.45	0.37	0.44	0.22	0.32	0.22	0.39	0.44	0.28	0.25	0.28
NPK alone	0.22	0.20	0.30	0.26	0.22	0.29	0.34	0.37	0.23	0.26	0.28
SEm	0.087	0.097	0.084	0.059	0.097	0.592	0.05	0.05	0.055	0.054	0.053
CD	0.18	0.203	0.174	NS	NS	0.123	0.104	0.104	0.114	0.113	0.110

Magnesium content at the time of harvest of second crop of 1992 was lower than that at the time of harvest of second crop of 1991 for all treatments except for the treatment CM alone.

Significantly higher values were maintained in the second season at tillering, but at 50 per cent flowering stage, the first season showed significantly higher contents, as shown by the two tail t test (Table 24). At harvest, the variation among seasons was not significant. In the experiment with tall indica also, at 50 per cent flowering, significantly higher exchangeable Mg content was recorded in the first crop season and no significant difference was noticed between the two seasons at the time of harvest.

Seasonal changes in the organic carbon content, available N, P and K and exchangeable Ca and Mg are diagramatically presented in Fig. 5 and 6.

2 Seasonal variations in dry matter yield, content and uptake of nutrients

2.1 Experiment on Tall indica

2.1.1 Dry matter yield

Data on dry matter yield at different stages of crop growth are presented in Table 25.

The results indicate that at the initial stage of growth, i.e., at tillering there was not much difference in the dry matter yield between the seasons but from 50 per cent flowering onwards higher dry matter yield was recorded in the second crop season. The variation due to treatments was significant at all the growth stages except at tillering in the first crop season whereas in the second crop season the

Table 24. Seasonal variation in exchangeable magnesium content in soil (Dwarf indica)

Stage of crop growth	Average exchangeable Mg content in soil, cmol(+) kg^{-1}		t value
	First crop	Second crop	
Transplanting	0.36	0.38	-0.69
Tillering	0.29	0.36	-3.11*
50% flowering	0.40	0.23	4.85*
Harvest	0.31	0.33	-0.73

* Significant at 5 per cent level

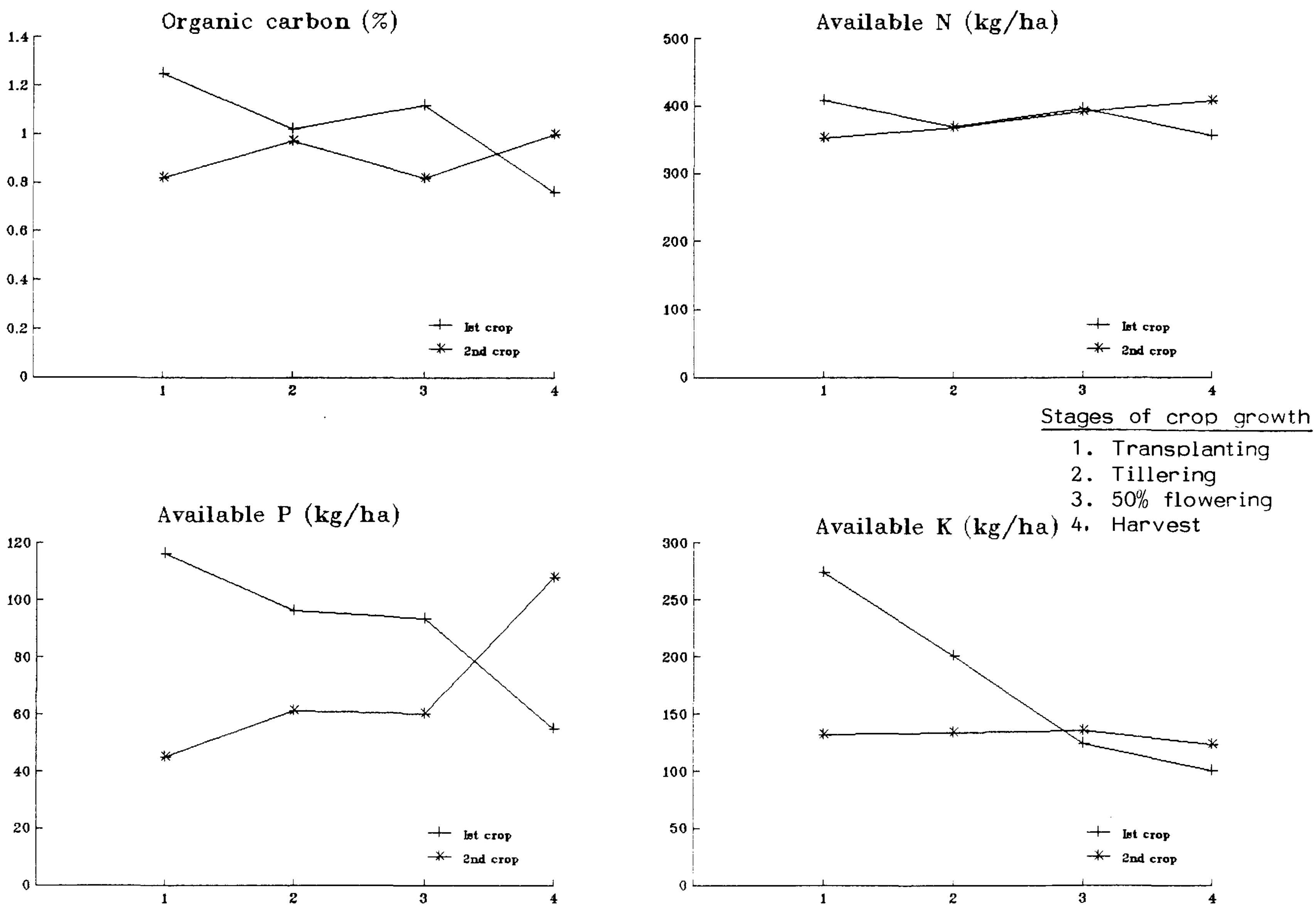


Fig.5. Seasonal variationsin the organic carbon and available N, P and K in soil (Drawf indica)

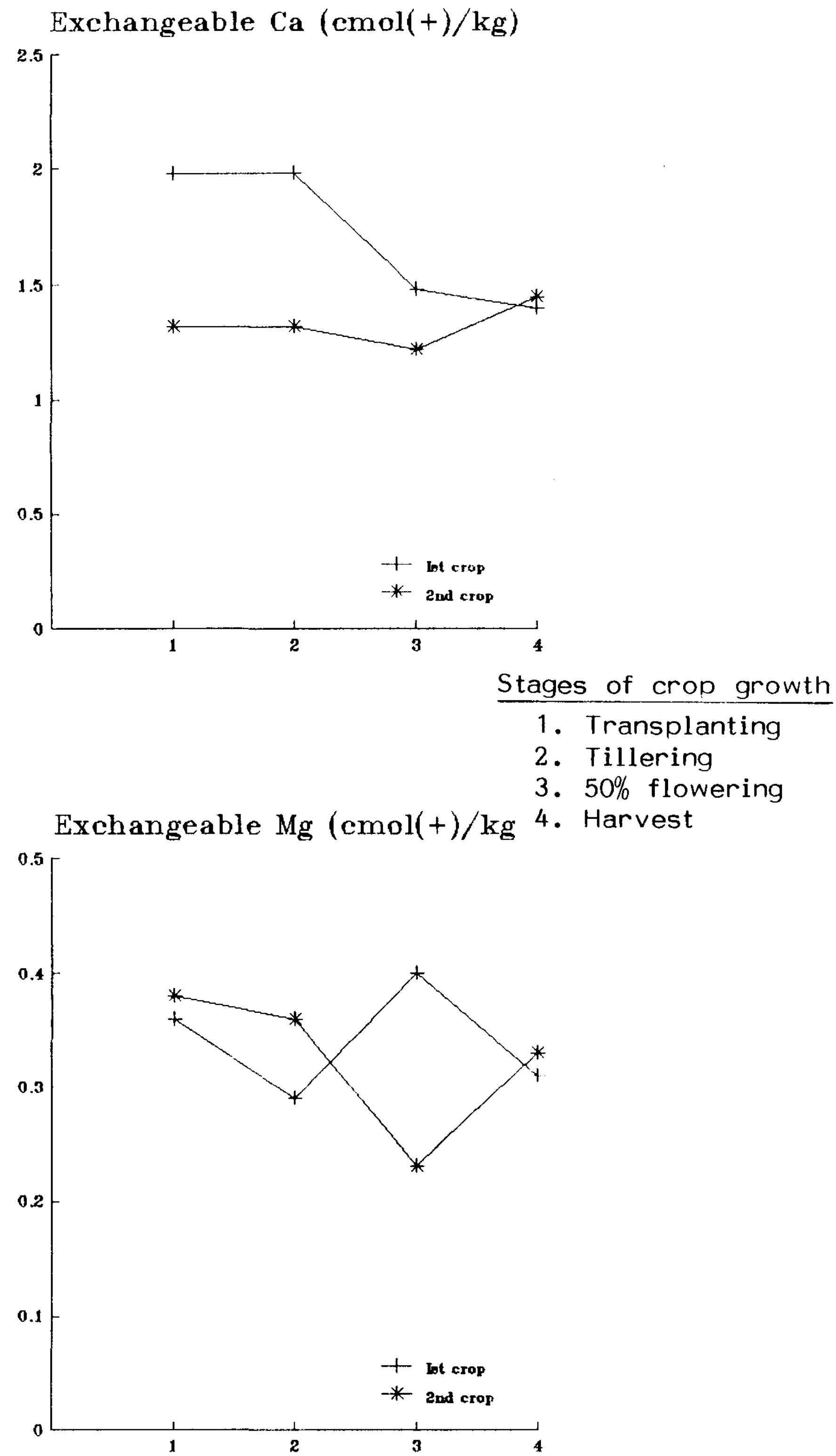


Fig.6. Seasonal variationsin the exchangeable Ca and Mg in soil (Dwarf indica)

Table 25. Dry matter yield at different stages of crop growth, kg ha^{-1} (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% lower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	970	3416	2959	2073	5032	1167	5250	4815	4735	9550
GL alone	908	2583	2149	1434	3583	958	4795	4859	4491	9350
CM + GL	975	3999	2949	1997	4946	1158	5521	5394	4724	10118
AS alone	945	2791	1761	1364	3125	1091	4583	5636	4453	10089
CM + NPK	1233	3458	2496	1889	4375	1183	5166	5768	4795	10563
GL + NPK	966	3875	2589	1715	4304	1391	4875	5808	4778	10586
CM + GL + NPK	1250	3958	2585	2002	4587	1275	4958	5521	4805	10326
NPK alone	999	3166	1896	1497	3393	1085	4916	5696	4632	10328
SEm	185	665	294	116	378	163	597	604	494	680
CD	NS	321	752	352	1043	NS	NS	NS	NS	NS

treatments have not shown significant difference in the yield of the crop. In general the treatments which have included cattle manure application have given higher yields in both the seasons compared to green leaves application. Treatments receiving only inorganic fertilizers alone have also recorded low yields in the first crop season.

The seasonal variations in the dry matter yield presented in Table 26 showed that the difference between the seasons was significant at 50 per cent flowering, and at harvest. Significantly higher dry matter yield was recorded in the second crop season at these stages. Available nutrient contents namely N, P, K and Ca were higher in the first crop season compared to second crop at transplanting, tillering and 50 per cent flowering but at harvest the trend reversed. Even at tillering and 50 per cent flowering when available nutrient contents were higher in the first crop season, higher dry matter yield was recorded in the second crop.

2.1.2 Nitrogen content and uptake

During the first season, the N content of plants increased slightly at 50 per cent flowering stage, from that at tillering for treatments CM alone, GL alone, CM + GL + NPK and NPK alone (Table 27). For others, it showed a decrease. The nitrogen content in the straw is much less than that of grain. This is because a significant portion of the nitrogen is translocated from the vegetative organs to the grain after flowering.

During the second crop season, the content decreased from tillering to 50 per cent flowering for all the treatments. Root recorded lower content compared to straw in the first season, whereas in the second season root recorded higher content

Table 26. Seasonal variation in dry matter yield (Tall indica)

Stages of crop growth	Average dry matter yield, kg ha^{-1}		
	First crop	Second crop	t value
Tillering	1031	1028	12
50% flowering	3017	5008	-414*
Harvest			
Straw	2423	5437	-916*
Grain	1746	4676	-814*
Total	4169	10113	-2018*

*Significant at 5 per cent level

Table 27. Nitrogen content in plant at different stages of crop growth, per cent (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	1.80	1.90	1.51	2.64	0.85	2.44	1.61	0.47	2.71	1.07
GL alone	1.67	1.92	1.15	2.71	0.91	2.66	1.57	0.47	3.21	0.91
CM + GL	1.74	1.64	1.26	2.79	0.57	2.90	1.20	0.45	2.90	0.94
AS alone	2.09	1.84	1.57	2.56	1.09	2.42	2.06	0.65	3.74	1.25
CM + NPK	1.76	1.65	0.91	2.78	0.90	2.98	2.62	0.70	3.27	1.34
GL + NPK	1.62	1.63	0.88	2.85	0.95	2.09	2.59	0.52	2.88	1.53
CM + GL + NPK	1.34	1.53	1.04	2.79	0.64	2.90	1.71	0.59	3.01	1.27
NPK alone	1.99	2.23	1.16	2.65	0.50	2.24	1.72	0.95	3.02	1.26
SEm	0.210	0.125	0.098	0.045	0.084	0.150	0.071	0.05	0.197	0.092
CD	NS	0.260	0.203	NS	0.174	0.311	0.147	0.104	0.411	0.192

compared to straw. This may be due to varietal difference as different varieties namely PTB-2 and PTB-20 were used in the first and second crop seasons respectively.

Significant difference in the N content between treatments occurred at 50 per cent flowering and in straw at harvest, during first crop season. Maximum content in straw was recorded by the treatment AS alone. The content in root also showed significant difference. In the second crop season, differences between treatments were significant at all the stages. Maximum content of nitrogen in the grain in the second crop season was recorded by the treatment AS alone.

The nitrogen content was higher at tillering, 50 per cent flowering and in grain in the second crop season (Table 28). But the content of N in the straw was higher in the first season. Seasonal differences were significant at tillering and at harvest. At 50 per cent flowering and at harvest available N content of soil was higher in the second crop season and that may be the reason for the significantly high values of N content recorded in the second crop season at 50 per cent flowering and in grain. The nitrogen content in the straw during the second crop season was very low compared to that in the first crop. This may be due to the difference in the varieties cultivated.

The uptake of N varied significantly only at harvest in the first season, but in the second crop season significant variation was noticed at all the stages (Table 29). No regular trend due to application of manures alone, fertilizers alone or combinations of both could be observed in both the seasons. This may be due to the medium to high level of available N maintained in soil by all treatments.

Table 28. Seasonal variation in nitrogen content of plant (Tall indica)

Stage of crop growth	Average nitrogen content in plant, per cent		t value
	First crop	Second crop	
Tillering	1.75	2.58	-8.72*
50% flowering	1.79	1.90	-1.22
Harvest			
Straw	1.19	0.60	9.92*
Grain	2.72	3.09	-4.75*
Root	0.80	1.20	-7.59*

*Significant at 5 per cent level

Table 29. uptake of nitrogen by plant at different stages of crop, kg ha^{-1} (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	17.47	64.92	44.70	54.71	99.40	28.47	84.53	22.65	128.24	150.89
GL alone	15.17	49.60	24.08	38.90	62.98	25.49	73.36	22.84	144.17	167.01
CM + GL	16.97	65.60	37.16	55.67	92.83	35.04	106.40	24.27	137.04	161.31
AS alone	19.68	51.37	31.48	34.84	66.32	23.39	94.87	36.65	166.51	203.16
CM + NPK	19.51	57.06	22.65	52.42	75.07	35.26	135.37	40.38	156.82	197.20
GL + NPK	15.66	63.16	22.78	48.93	71.71	29.09	126.26	29.86	137.57	167.43
CM+GL + NPK	17.09	60.56	26.90	55.80	82.70	36.98	84.79	32.58	144.63	177.21
NPK alone	19.90	70.62	21.06	39.21	60.27	24.26	84.57	53.24	139.92	193.16
SEm	3.041	11.361	4.450	4.614	7.461	4.161	11.281	3.480	5.014	6.790
CD	NS	NS	9.256	9.589	15.568	8.653	23.462	7.238	10.421	14.120

The difference in the uptake of nitrogen between seasons was significant and higher uptake was noticed in the second crop season at all the growth stages (Table 30). In general, for any varietal type, nitrogen response is higher during the sunny dry season than in the wet season. Under reduced light intensity rate of photosynthesis is reduced, starch accumulation decreases, root development is retarded, nitrogen uptake slows down and yield is reduced (Tanaka et al., 1969). The higher uptake noticed in the second crop season may be due to the favourable influence of climatic conditions in the second crop season.

2.1.3 Phosphorus content and uptake

Phosphorus content in plant remained more or less constant throughout the first season (Table 31). The content in straw was a bit lesser compared to that in plant at 50 per cent flowering. Grain recorded higher and root lower contents compared to straw. In the second season, P content in straw was much lower compared to that at 50 per cent flowering. Phosphorus which is a component of protein is translocated from the vegetative organs to the grain after flowering. So the phosphorus content of straw is less than that in the grain.

Comparatively higher P contents were recorded during the second season, at all stages (Table 32). The seasonal differences were significant at tillering, 50 per cent flowering and at harvest in straw and root. Available P content of soil was significantly higher in the first season in the initial stages of crop growth namely at transplanting, tillering and 50 per cent flowering. But significantly higher values in the content of P was recorded at all stages in the second crop. As in the case of N, the low P content in the plant in the first crop may be due to the low light intensity which retards root development and uptake of P.

Table 30. Seasonal variation in N uptake of plant (Tall indica)

Stage of crop growth	Average N uptake by plant, $kg\ ha^{-1}$		t value
	First crop	Second crop	
Tillering	17.38	29.75	-7.70*
50% flowering	60.36	99.02	-7.86*
Harvest			
Straw	28.85	32.81	-1.27
Grain	47.56	144.36	-27.03*
Total	76.31	177.17	-31.43*

* Significant at 5 per cent level

Table 31. Phosphorus content in plant at different stages of crop growth, per cent (Tall indica)

Treatment	First crop					Second crop				
	Tillering	50% flowering	Harvest			Tillering	50% flowering	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	0.27	0.27	0.30	0.34	0.19	0.40	0.34	0.15	0.30	0.28
GL alone	0.17	0.19	0.13	0.22	0.16	0.17	0.20	0.07	0.27	0.28
CM + GL	0.22	0.27	0.22	0.34	0.20	0.28	0.35	0.11	0.32	0.23
AS alone	0.17	0.14	0.13	0.25	0.22	0.14	0.23	0.09	0.24	0.23
CM + NPK	0.25	0.24	0.21	0.32	0.22	0.34	0.23	0.12	0.34	0.28
GL + NPK	0.18	0.23	0.15	0.29	0.10	0.23	0.27	0.07	0.30	0.21
CM + GL + NPK	0.20	0.25	0.20	0.33	0.21	0.29	0.35	0.12	0.36	0.28
NPK alone	0.22	0.16	0.14	0.27	0.23	0.24	0.22	0.13	0.30	0.24
SEm	0.029	0.041	0.026	0.019	0.015	0.026	0.033	0.02	0.018	0.015
CD	0.061	0.086	0.054	0.032	0.032	0.054	0.069	0.042	0.038	0.032

Table 32. Seasonal variation in phosphorus content of plant (Tall indica)

Stage of crop growth	Average P content in plant, per cent		t value
	First crop	Second crop	
Tillering	0.21	0.30	-5.00*
50% flowering	0.22	0.27	-5.02*
Harvest			
Straw	0.18	0.30	-10.99*
Grain	0.29	0.30	-1.51
Root	0.19	0.25	-6.29*

* Significant at 5 per cent level

Variation between treatments in the P uptake of plants was significant at all the stages of both seasons. The treatment devoid of P application, viz., AS alone has recorded low uptake of P during both seasons (Table 33). Same was the case with treatment GL alone. These treatments maintained low available P contents in soil. The dry matter production and P content of plants under these treatments were also comparatively low. Similar results have been reported by Padmam (1992).

Uptake of P by plants was higher during the second crop season at all the stages (Table 34). The quantity of P removed in the second crop season was about double the quantity removed in the first crop. This is mainly due to the higher dry matter production and higher P content in plant in the second crop season.

2.1.4 Potassium content and uptake

During the first crop season, the K content in plants increased as the crop growth advanced from tillering to 50 per cent flowering. But in the second crop season a reverse trend was noticed (Table 35). Grain and root recorded lower contents compared to straw. In the case of N and P, the content in the grain was higher or almost equal to that in the straw, but in the case of K, the content in the grain is much lower compared to straw. This may be due to the reason that there is no marked translocation of this element from vegetative organs to the grains during ripening.

Treatment differences were significant at all the stages of first crop with an exception that K content in grain did not vary significantly among treatments. In the second season, significant variation among treatments was noticed at all stages except at tillering. But no regular trend could be observed due to various treatments.

Tale 33. Uptake of phosphorus by plant at different stages of crop growth, kg ha^{-1} (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	2.14	8.88	8.81	6.42	15.23	4.08	18.38	10.12	14.20	24.32
GL alone	8.18	5.68	2.93	2.58	5.51	2.40	9.60	7.70	11.20	19.00
CM + GL	2.83	9.20	8.26	5.99	14.25	4.47	16.63	10.79	16.54	27.33
AS alone	1.79	5.31	2.61	2.86	5.47	1.93	9.17	8.12	9.80	17.92
CM + NPK	3.21	9.34	5.23	6.41	11.64	4.38	17.05	14.77	16.31	31.08
GL + NPK	2.42	10.46	5.18	5.67	10.85	3.90	13.65	9.19	13.37	22.56
CM + GL + NPK	3.95	11.08	7.50	6.60	14.10	4.72	18.35	14.36	13.93	28.29
NPK alone	2.40	9.18	3.09	3.25	6.34	3.68	11.80	13.10	10.66	23.76
SEm	0.406	9.691	0.840	0.490	1.801	0.543	1.672	1.071	0.387	2.075
CD	0.845	3.518	1.746	1.019	3.746	1.130	3.477	2.226	0.806	4.315

Table 34. Seasonal variation in phosphorus uptake by plant (Tall indica)

Stage of crop growth	Average P uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	2.61	3.70	-5.65*
50% flowering	8.64	14.33	-7.75*
Harvest			
Straw	5.20	11.03	-9.81*
Grain	4.97	13.25	-29.47*
Total	10.17	24.28	-34.21*

* Significant at 5 per cent level

Table 35. Potassium content in plant at different stages of crop growth, per cent (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	1.26	1.64	1.08	0.28	0.61	2.57	1.79	1.79	0.35	0.46
GL alone	1.01	2.06	1.40	0.23	0.81	2.44	1.85	1.66	0.31	0.30
CM + GL	1.75	1.97	1.06	0.25	0.85	2.35	2.13	2.21	0.32	0.51
AS alone	1.15	1.62	1.46	0.22	0.50	2.41	1.99	2.01	0.30	0.17
CM + NPK	1.77	1.52	1.33	0.24	0.95	2.39	2.01	1.45	0.26	0.45
GL + NPK	1.41	1.98	1.41	0.26	0.74	2.11	1.72	2.05	0.33	0.25
CM + GL + NPK	1.73	1.79	1.20	0.25	0.50	2.40	2.09	0.05	0.35	0.21
NPK alone	1.58	1.45	1.75	0.27	0.48	2.52	2.27	1.78	0.33	0.30
SEm	0.138	0.167	0.199	0.038	0.054	0.115	0.097	0.136	0.063	0.058
CD	0.267	0.348	0.413	NS	0.111	NS	0.202	2.283	0.132	0.120

Even treatment which included no K treatment (AS alone) has also recorded high K content. This can be attributed to the comparatively high content of potassium in the soil.

Variation between seasons in K content was significant all the stages of crop growth (Table 36). During all the stages, higher K contents were recorded in the second season compared to the first. But in the case of root, just the reverse trend was noticed. Available K content in the soil was significantly higher in the first crop season at the time of transplanting, tillering and 50 per cent flowering, but that has not been reflected in the K content of plants. The reason for this can be attributed to the better climatic conditions prevailing in the second crop season which resulted in better uptake of K as in the case of N and P.

Potassium uptake increased from tillering to 50 per cent flowering in both the seasons (Table 37). The uptake again increased at harvesting in the second crop season except for the treatment CM + NPK, whereas in the first crop the uptake at harvest is less than that at 50 per cent flowering for all the treatments. The uptake recorded at the time of harvest in the second crop season, though high compared to that at 50 per cent flowering, the rate of increase was very low compared to the corresponding increase in the case of N and P.

Potassium uptake varied among treatments significantly except at harvest (straw) of first crop and tillering and 50 per cent flowering of second crop. But there was no significant difference in the total uptake due to treatments. Treatments AS alone and GL alone recorded low uptake in the first season. Treatment GL alone recorded low uptake during the second season also. Low uptake for the above treatment is mainly due to low dry matter production.

Table 36. Seasonal variation in potassium content in plant (Tall indica)

Stage of crop growth	Average potassium content in plant, per cent		t value
	First crop	Second crop	
Tillering	1.48	2.40	-12.65*
50% flowering	1.75	1.98	-3.10*
Harvest			
Straw	1.34	1.87	-6.63*
Grain	0.25	0.32	-4.97*
Root	0.68	0.33	12.01*

* Significant at 5 per cent level

Table 37. Uptake of potassium by plant at different stages of crop growth, kg ha^{-1} (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	12.23	56.03	31.97	5.80	37.77	29.99	93.98	80.26	16.56	96.82
GL alone	9.17	53.22	29.32	3.30	32.62	23.38	88.80	80.67	13.92	94.50
CM + GL	17.06	78.80	31.26	4.99	36.25	28.39	118.04	119.20	15.12	134.32
AS alone	10.83	42.23	29.27	2.99	32.26	23.29	91.21	113.33	13.36	126.69
CM + NPK	19.62	52.57	33.11	4.53	37.64	28.28	103.85	83.64	12.47	96.11
GL + NPK	13.63	76.73	36.49	4.46	40.95	29.37	83.85	117.73	15.76	133.49
CM + GL + NPK	22.06	70.85	31.04	5.00	36.04	30.60	103.63	113.20	16.82	130.02
NPK alone	15.80	45.92	31.77	3.99	35.76	27.30	111.61	101.37	15.29	116.66
SEm	0.516	11.931	4.667	0.424	13.231	3.656	12.044	10.702	0.469	12.581
CD	1.074	24.814	NS	0.882	NS	NS	NS	22.260	0.975	NS

Potassium uptake during second season was significantly higher than that in the first season, at all the stages (Table 38). Uptake at second crop harvest was almost three times than that at first crop harvest. The higher dry matter production as well as higher K content in plants during the second crop season have resulted in the higher uptake. Potassium uptake at harvest is less compared to that at 50 per cent flowering in first crop whereas in the second crop it increased with crop growth.

2.1.5 Calcium content and uptake

During the first crop season, the Ca content decreased from tillering to 50 per cent flowering stage (Table 39). Grain showed lower contents than straw while root recorded higher content comparable to straw. In the second season, Ca content showed an increasing trend for most treatments from tillering to 50 per cent flowering. Effect of treatments was significant at all stages of growth in the first crop season whereas in the second crop season significant difference was noticed only at tillering and in straw and root. Compared to straw Ca content is low in grain as there is no marked translocation of this element from vegetative organs to the grain during ripening. No regular trend due to treatments was noticed in both the seasons.

Seasonal variations in Ca content were significant at all stages of crop growth (Table 40). At tillering and in grain higher contents were recorded during the first crop season, while at 50 per cent flowering and in straw, higher contents were recorded in the second season. The seasonal changes in the Ca content of soil has not reflected in the Ca content of plants as the Ca content in the soil was higher at tillering and 50 per cent flowering in the first crop season. At harvest higher Ca content

Table 38. Seasonal variation in potassium uptake by plant (Tall indica)

Stage of crop growth	Average K uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	15.05	27.57	-10.96*
50% flowering	59.92	99.37	-9.33*
Harvest			
Straw	31.78	101.93	-17.64*
Grain	4.38	14.91	-38.70*
Total	36.16	116.84	-42.40*

* Significant at 5 per cent level

Table 39. Calcium content in plant at different stages of crop growth, per cent (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	0.55	0.26	0.36	0.25	0.40	0.30	0.34	0.46	0.15	0.48
GL alone	0.50	0.36	0.38	0.22	0.36	0.25	0.37	0.47	0.11	0.32
CM + GL	0.69	0.31	0.34	0.25	0.37	0.28	0.38	0.45	0.13	0.40
AS alone	0.71	0.24	0.40	0.26	0.48	0.20	0.34	0.44	0.12	0.30
CM + NPK	0.64	0.29	0.36	0.16	0.47	0.37	0.36	0.43	0.16	0.36
GL + NPK	0.78	0.26	0.48	0.25	0.41	0.28	0.28	0.36	0.14	0.28
CM + GL + NPK	0.61	0.32	0.48	0.26	0.49	0.31	0.33	0.40	0.14	0.52
NPK alone	0.61	0.22	0.35	0.22	0.36	0.37	0.30	0.55	0.14	0.47
SEm	0.447	0.030	0.029	0.018	0.309	0.316	0.032	0.023	0.019	0.022
CD	0.093	0.063	0.060	0.037	0.064	0.066	NS	0.048	NS	0.045

Table 40. Seasonal variation in calcium content in plant (Tall indica)

State of crop growth	Average calcium content in plant, per cent		t value
	First crop	Second crop	
Tillering	0.63	0.30	14.86*
50% flowering	0.28	0.34	-4.75*
Harvest			
Straw	0.30	0.45	-27.00*
Grain	0.23	0.13	10.32*
Root	0.42	0.39	1.30

*Significant at 5 per cent level

in soil was recorded in the second crop season. Ca content in root at harvest, did not vary significantly between seasons.

Calcium uptake was found to be higher in the second season at all stages except tillering (Table 41). Calcium uptake increased as the growth advanced in both the seasons as in the case of N and P. There was significant difference in Ca uptake due to treatments at all stages except at tillering of first crop but no definite trend was shown by different treatments in the uptake in both the seasons.

Seasonal differences at all growth stages were statistically significant (Table 42). Higher uptake was recorded at all stages except at tillering in the second crop season. The higher uptake in the second season at harvest may be mainly due to the higher dry matter production as well as the high calcium content of the straw.

2.1.6 Magnesium content and uptake

No regular pattern could be observed in the Mg content in plant at different growth stages due to treatments in both seasons (Table 43). Magnesium content in grain was higher than in straw in both the seasons as its translocation to grain occurs to some extent.

The difference between treatments in the Mg content was significant at all the stages in the first and second seasons except in straw of first crop. But no regular trend could be observed in both seasons due to various treatments.

Magnesium content in plant differed between seasons at all growth stages significantly except at harvest in straw (Table 44). In the initial stages of growth, viz., at tillering and at 50 per cent flowering, significantly higher content was

Table 41. Uptake of calcium by plant at different stages of crop growth, kg ha^{-1} (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	5.34	8.58	10.66	4.16	14.82	3.50	17.85	22.17	7.10	29.27
GL alone	4.54	9.30	7.96	3.16	11.12	2.40	17.76	22.84	4.94	27.78
CM + GL	6.72	12.40	10.03	4.99	15.02	3.38	21.06	24.27	6.14	30.14
AS alone	6.69	6.70	8.02	3.54	11.56	1.93	15.58	24.81	5.34	30.15
CM + NPK	7.09	10.03	8.96	3.02	11.98	4.38	18.60	24.81	7.67	32.48
GL + NPK	5.54	10.07	12.42	4.29	16.71	3.90	13.65	20.67	6.69	27.36
CM + GL + NPK	7.78	12.67	12.42	5.20	17.62	3.95	15.95	22.09	6.73	28.82
NPK alone	6.10	6.97	6.35	3.25	9.60	4.01	14.75	31.32	6.49	37.81
SEm	1.106	1.811	1.393	0.620	2.897	0.474	2.071	2.393	0.158	2.871
CD	NS	3.767	2.897	1.291	6.026	0.987	4.308	4.977	0.329	5.971

Table 42. Seasonal variation in calcium uptake by plant (Tall indica)

Stage of crop growth	Average Ca uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	6.48	3.43	9.93*
50% flowering	9.63	16.90	-9.80*
Harvest			
Straw	9.60	24.12	-11.80*
Grain	3.95	6.39	-9.84*
Total	13.65	30.51	-18.14*

*Significant at 5 per cent level

Table 43. Magnesium content in plant at different stages of crop growth, per cent (Tall indica)

Treatment	First crop					Second crop				
	Tillering	50% flowering	Harvest			Tillering	50% flowering	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	0.12	0.17	0.11	0.15	0.04	0.12	0.05	0.12	0.25	0.04
GL alone	0.22	0.11	0.12	0.15	0.03	0.10	0.06	0.10	0.31	0.03
CM + GL	0.09	0.12	0.06	0.11	0.02	0.09	0.08	0.05	0.30	0.06
AS alone	0.16	0.14	0.09	0.08	0.02	0.09	0.06	0.11	0.19	0.08
CM + NPK	0.14	0.12	0.10	0.20	0.03	0.06	0.10	0.15	0.16	0.05
GL + NPK	0.09	0.16	0.10	0.09	0.04	0.07	0.04	0.06	0.22	0.07
CM + GL + NPK	0.19	0.11	0.07	0.15	0.02	0.08	0.14	0.12	0.32	0.05
NPK alone	0.16	0.10	0.12	0.07	0.04	0.05	0.11	0.11	0.24	0.05
SEm	0.015	0.016	0.019	0.026	0.006	0.011	0.012	0.012	0.045	0.015
CD	0.030	0.034	NS	0.054	0.013	0.023	0.025	0.025	0.013	0.032

Table 44. Seasonal variation in magnesium content of plant (Tall indica)

Stage of crop growth	Average Mg content in plant, per cent		t value
	First crop	Second crop	
Tillering	0.15	0.13	6.77*
50% flowering	0.13	0.08	4.68*
Harvest			
Straw	0.09	0.10	-1.13
Grain	0.12	0.25	-7.08*
Root	0.03	0.05	-5.90*

*Significant at 5 per cent level

recorded in the first season, while at harvest, higher contents were recorded in both grain and straw in the second season. There was no difference in the exchangeable Mg content of soil between the seasons at harvest. So the higher content recorded in the second crop may be due to the favourable climatic conditions in the second crop season.

As in the case of other nutrients Mg uptake in the second season was found to be much higher than that in the first at harvest. This is due to higher dry matter production as well as higher Mg content in plant at this stage. No regular trend in the uptake due to treatments was noticed in both the seasons (Table 45). During the initial stages, i.e., at tillering and 50 per cent flowering, higher uptake was recorded in the first season (Table 46).

Seasonal variation in the uptake of nutrients are presented in Fig.7 and 8.

2.2 Experiment on Dwarf indica

2.2.1 Dry matter yield

Data on dry matter yield at different stages of crop growth are presented in Table 47.

As in the case of tall indica varieties higher dry matter yield was recorded in the second crop season at all the growth stages. The influence of treatments in the yield of grain and straw was significant in the first crop season whereas significant difference was noticed only in the case of grain in the second crop season. The beneficial influence of cattle manure compared to green leaves is seen in this experiment. Treatments which received inorganic fertilizers alone have recorded low yields in both the seasons. Similar results have been recorded in tall indica are also.

Table 45. Uptake of magnesium by plant at different stages of crop growth, kg ha^{-1} (Tall indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	1.16	5.81	3.26	3.11	6.37	1.40	2.63	6.38	11.83	18.21
GL alone	2.00	2.84	2.51	2.15	4.66	0.96	2.88	4.86	13.92	18.78
CM + GL	0.88	4.80	1.77	2.19	3.96	1.09	4.43	2.70	14.18	16.88
AS alone	1.51	3.91	1.81	1.09	2.90	0.87	2.75	6.28	8.27	14.55
CM + NPK	1.55	4.15	2.49	3.77	6.26	0.71	5.17	8.65	7.67	16.32
GL + NPK	0.87	6.20	2.54	1.50	4.04	0.97	1.95	3.45	10.51	13.96
CM + GL + NPK	2.42	4.35	1.81	3.00	4.81	1.02	6.94	6.74	15.03	21.77
NPK alone	1.60	3.17	2.18	1.03	3.21	0.54	5.41	6.28	11.12	17.40
SEm	0.264	0.825	0.301	0.234	0.440	0.224	0.538	0.640	0.402	0.793
CD	0.550	0.715	0.624	0.488	0.915	0.465	1.120	1.332	0.832	1.619

Table 46. Seasonal variation in magnesium uptake by plant (Tall indica)

Stage of crop growth	Average Mg uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	1.50	0.95	4.37*
50% flowering	4.40	4.02	0.84
Harvest			
Straw	2.30	5.65	-9.42*
Grain	2.24	11.56	-19.02*
Total	4.54	17.21	-21.16*

*Significant at 5 per cent level

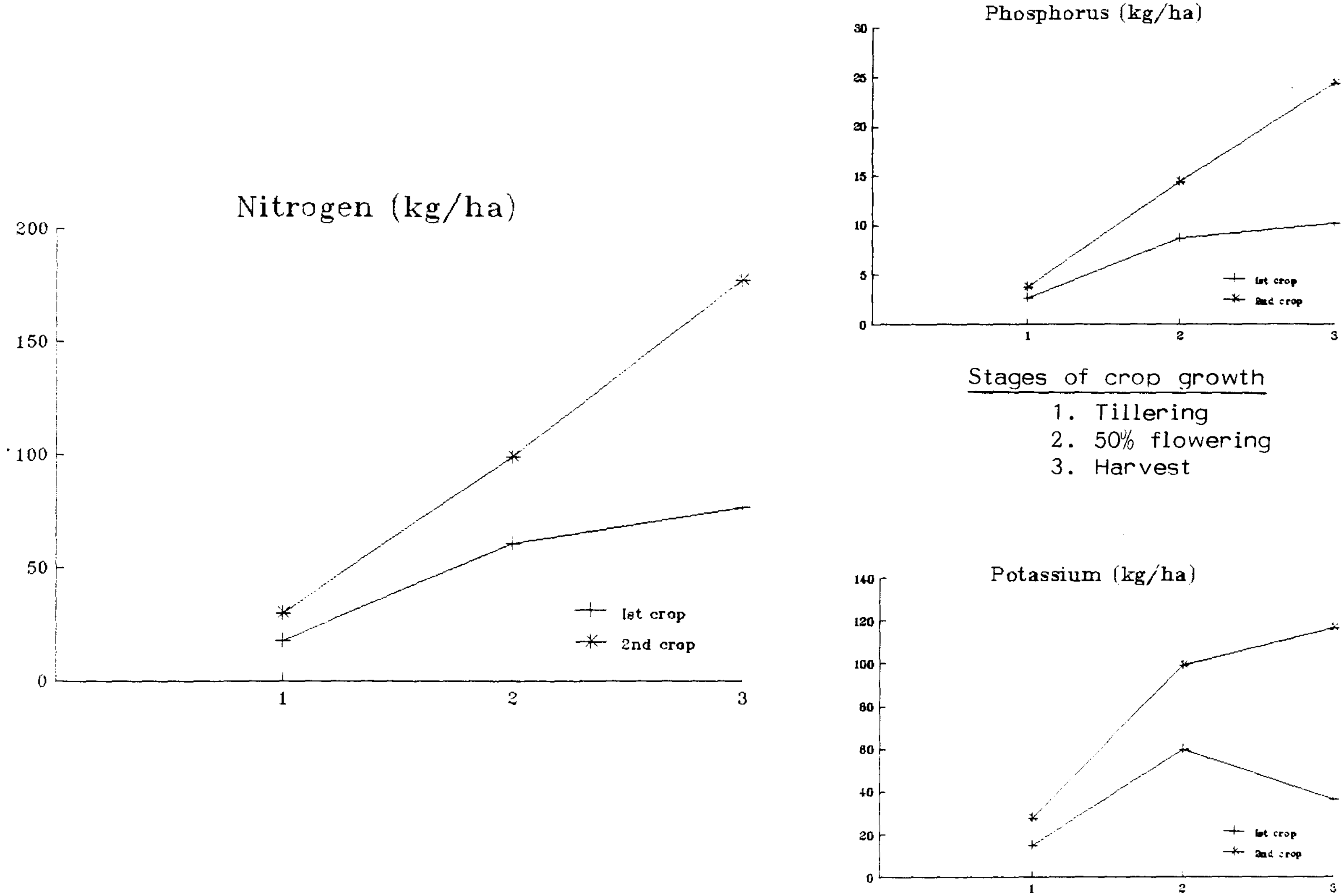
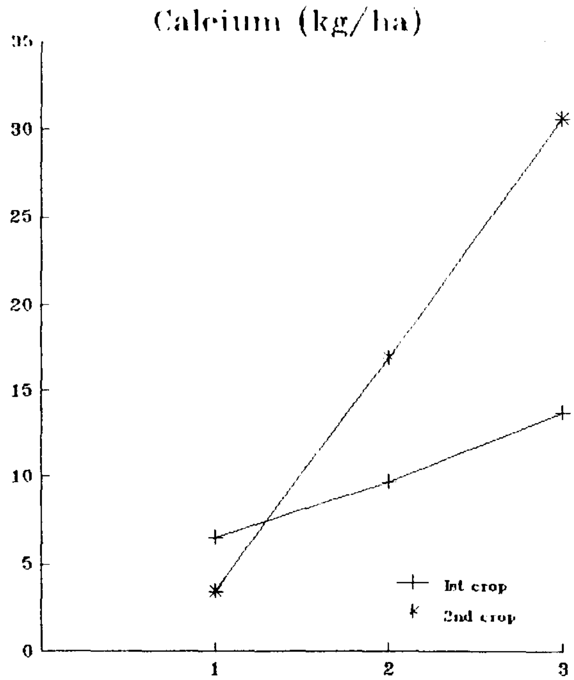


Fig.7. Seasonal variationsin the uptake of N, P and K (Tall indica)



Stages of crop growth

1. Tillering
2. 50% flowering
3. Harvest

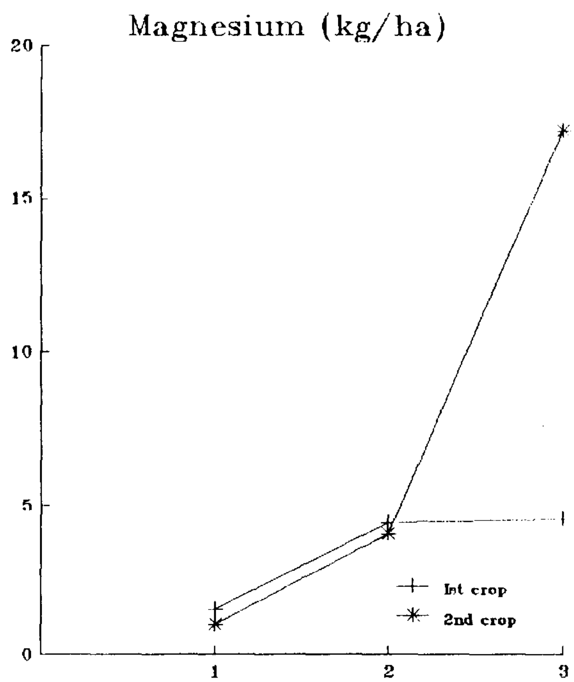


Fig.8. Seasonal variations in the uptake of Ca and Mg (Tall indica)

Table 47. Dry matter yield at different stages of crop growth, kg ha^{-1} (Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	1408	7083	3955	4566	8521	1916	6999	3997	4531	8528
GL alone	1208	5750	2869	4229	7098	1832	6083	3895	3591	7486
CM + GL	1399	6250	3488	4038	7526	1833	7083	4885	4361	9246
AS alone	1233	5417	2575	3935	6510	1499	5999	3706	3593	7299
CM + NPK	1499	5750	3879	4038	7917	2099	6916	4237	4471	8708
GL + NPK	1508	6500	3030	3537	6567	1899	6500	4073	3900	7973
CM + GL + NPK	1583	6166	3787	3960	7747	2333	6583	3984	4811	8795
NPK alone	1275	6000	3068	3642	6710	1916	5999	3855	3927	7782
SEm	199	591	212	115	304	330	490	368	245	252
CD	NS	1012	652	348	1110	NS	NS	NS	598	679

Though higher dry matter yield was recorded in the second crop season compared to the first crop at all the growth stages, the difference between the seasons was significant only in the case of straw (Table 48). In this experiment also as in the case of the experiment with tall indica varieties available nutrient contents were higher in the first crop season in the early growth stages while at harvest the trend reversed.

2.2.2 Nitrogen content and uptake

Nitrogen content in plant decreased gradually in the first crop season for most treatments from tillering to 50 per cent flowering (Table 49). In the second crop season all the treatments showed a decrease from tillering to 50 per cent flowering. The N content in root was found to be lesser compared to straw in the first crop while in the second season root recorded a higher content compared to straw. Similar trend was noticed for tall indica varieties also.

Generally the pattern of the content of nutrients at different stages was almost the same in both the seasons and that may be due to the reason that the same variety 'Jaya' was grown in both the seasons. Treatment effects were significant at all the stages in both the seasons except at tillering of the first crop. But no uniform trend due to treatments was noticed in both the seasons and this may be due to the medium level of available N in soil. Similar results were obtained for tall indica varieties also.

Higher nitrogen content was recorded at all the growth stages in second crop season except in straw (Table 50). Similar results have been noticed in tall indica varieties also where two different varieties namely PTB-2 and PTB-20 were

Table 48. Seasonal variation in dry matter yield (Dwarf indica)

Stage of crop growth	Average dry matter yield in kg ha^{-1}		
	First crop	Second crop	t value
Tillering	1389	1916	-215
50% flowering	6115	6520	-486
Harvest			
Straw	3331	4079	-341*
Grain	3994	4148	-213
Total	7325	8227	-414

*Significant at 5 per cent level

Table 49. Nitrogen content in plant at different stages of crop growth, per cent (Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	2.44	1.57	1.08	2.64	0.70	2.97	2.34	0.89	2.71	1.84
GL alone	2.42	1.93	1.06	2.71	0.77	2.98	2.18	0.88	2.21	1.85
CM + GL	2.51	2.58	1.08	2.79	0.75	3.03	1.64	0.87	2.90	1.26
AS alone	2.67	2.42	2.07	2.76	2.19	2.07	2.06	1.64	3.74	1.77
CM + NPK	2.36	2.48	1.99	2.78	0.81	2.55	2.05	1.12	3.27	1.47
GL + NPK	2.69	2.00	1.61	2.85	0.76	3.11	2.62	1.03	2.88	1.19
CM + GL + NPK	2.33	2.45	1.58	2.78	0.77	3.18	2.34	1.57	3.01	1.29
NPK alone	2.42	1.67	1.04	2.64	0.89	3.06	2.37	1.51	3.02	1.74
SEm	0.338	0.246	0.059	0.095	0.067	0.081	0.061	0.062	0.197	0.105
CD	NS	0.512	0.123	0.197	0.139	0.168	0.128	0.130	0.411	0.218

Table 50. Seasonal variation in nitrogen content of plant (Dwarf indica)

Stage of crop growth	Average N content in plant, per cent		t value
	First crop	Second crop	
Tillering	2.48	2.95	-5.16*
50% flowering	2.14	2.20	-0.68
Harvest			
Straw	1.44	1.19	3.57*
Grain	2.72	3.09	-4.75*
Root	0.95	1.55	-7.20*

*Significant at 5 per cent level

grown in first and second crop seasons,respectively. The variety 'Jaya' was grown in both the seasons in dwarf indica experiment, so the results obtained indicates that the higher content recorded in the second crop season is due to the seasonal differences in the soil and climatic conditions. Though there was no significant difference in the available N content of soil at tillering and 50 per cent flowering higher nitrogen content was recorded at second crop. This again confirms the favourable influence of climate in the second crop season in the uptake of N.

The uptake of nitrogen at the time of harvest was found to vary from 83.79 to 140.20 kg ha^{-1} in first crop and from 101.10 to 145.37 kg ha^{-1} in second crop (Table 51).

Influence of treatments in the uptake of N was significant at all the stages of both crops except at tillering of first season. Here also no definite trend could be observed, due to treatments as in the case of tall indica rice.

Seasonal differences in N uptake was noted at all stages, with higher uptake being shown in the second season (Table 52). The uptake by plant at tillering and that by grain varied between the seasons significantly. Higher uptake recorded in the second crop season may be due to the higher dry matter yield and higher N content in second season. Similar results were obtained for tall indica varieties also. But the difference noticed between the tall and dwarf indica varieties is that in the case of tall indica rice the uptake of N increased as the growth advanced upto harvesting. But in the case of dwarf indica, the total uptake of N by grain and straw were lower than that at 50 per cent flowering in both the seasons. This may be due to the natural loss of plant parts or due to loss of N from plants through exudation as reported by Datta (1981).

Table 51. Uptake of nitrogen by plant at different stages of crop growth, kg ha^{-1}
(Dwarf indica)

Treatment	First crop					Second crop				
	Tillering	50% flowering	Harvest			Tillering	50% flowering	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	34.24	111.21	42.49	66.79	109.28	56.54	163.80	35.57	68.50	104.07
GL alone	28.86	110.98	30.41	65.37	95.78	54.57	131.40	34.27	66.83	101.10
CM + GL	36.11	161.25	37.67	62.94	100.61	55.97	116.17	42.06	71.72	113.78
AS alone	32.00	131.08	53.28	55.50	108.78	40.29	123.60	60.76	80.20	140.96
CM + NPK	36.08	150.87	77.22	62.98	140.20	51.01	141.78	47.46	85.12	132.58
GL + NPK	39.91	135.00	46.75	56.91	103.66	62.33	170.00	41.94	63.59	105.53
CM + GL + NPK	53.38	151.08	59.75	62.73	122.48	83.76	154.05	62.55	82.82	145.37
NPK alone	30.78	100.20	31.91	52.08	83.99	60.80	142.20	60.46	67.33	127.79
SEm	6.55	12.952	4.806	3.834	16.961	10.330	11.272	4.403	5.351	11.580
CD	NS	26.936	9.987	7.967	35.30	21.611	23.442	9.152	11.128	24.084

Table 52. Seasonal variation in nitrogen uptake by plant (Dwarf indica)

Stage of crop growth	Average N uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	34.18	58.16	-6.32*
50% flowering	131.46	142.91	-1.59
Harvest			
Straw	47.45	48.14	-0.22
Grain	60.54	73.27	-5.88*
Total	107.99	121.41	-7.12*

*Significant at 5 per cent level

2.2.3 Phosphorus content and uptake

There was not much variation in the P content of plant at tillering and at 50 per cent flowering, during both seasons. But it declined in straw, for most treatments during both seasons (Table 53). Same trend was noticed for tall indica rice also.

Variations due to the treatments of manures and fertilizers were significant at all stages of crop growth for P content. Treatments AS alone, GL alone and NPK alone recorded lower P content of grains in both the seasons. Treatments CM alone recorded higher contents of P compared to GL alone at all the stages. Similar trends were noted for tall indica also.

Higher P contents were recorded during the second season, compared to the first at tillering, 50 per cent flowering and in straw (Table 54). Seasonal differences were significant at all stages except in the case of grain for P content.

Available P content of soil was higher at tillering and 50 per cent flowering in the first season but during that period also higher content in plant was recorded in the second season. Similar results have been noticed in tall indica rice also. This indicates that climatic conditions are more favourable for P absorption in the second crop season.

Low uptake for the treatment GL alone and AS alone is mainly due to the low P contents of the plants and due to the low dry matter production. Similar results have been recorded for tall indica rice also. Available P content of soil was also low for these treatments.

Table 53. Phosphorus cont[illegible] in plant at different stages of crop growth, per cent (Dwarf [illegible]ndica)

Treatment	First crop					Second crop				
	Tillering	50% flowering	Harvest			Tillering	50% flowering	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	0.22	0.26	0.23	0.31	0.14	0.35	0.38	0.21	0.30	0.19
GL alone	0.24	0.22	0.14	0.18	0.13	0.25	0.20	0.16	0.25	0.26
CM + GL	0.29	0.23	0.28	0.30	0.12	0.37	0.30	0.20	0.35	0.13
AS alone	0.18	0.19	0.13	0.21	0.13	0.20	0.20	0.14	0.22	0.18
CM + NPK	0.29	0.27	0.21	0.34	0.19	0.37	0.32	0.26	0.34	0.19
GL + NPK	0.25	0.27	0.20	0.33	0.28	0.28	0.28	0.16	0.28	0.27
CM + GL + NPK	0.31	0.28	0.29	0.33	0.14	0.37	0.37	0.26	0.29	0.19
NPK alone	0.24	0.29	0.17	0.22	0.17	0.34	0.24	0.23	0.23	0.17
SEm	0.024	0.022	0.021	0.039	0.015	0.025	0.026	0.023	0.013	0.015
CD	0.050	0.045	0.044	0.081	0.032	0.052	0.054	0.047	0.027	0.032

Table 54. Seasonal variation in phosphorus content of plant (Dwarf indica)

Stage of crop growth	Average phosphorus content in plant, per cent		t value
	First crop	Second crop	
Tillering	0.25	0.32	-6.66*
50% flowering	0.25	0.28	-3.04*
Harvest			
Straw	0.21	0.28	-8.76*
Grain	0.28	0.28	-0.55
Root	0.16	0.20	-4.52*

* Significant at 5 per cent level

Uptake of P was found to be higher in the second season compared to the first at all the stages (Table 55) and the difference between seasons was significant at tillering and at harvest (Table 56). Higher uptake of P in the second season is due to the higher P content and increased dry matter production. Uptake of P increased with increase in the growth stage of the crop.

2.2.4 Potassium content and uptake

For most treatments, the K content in plant decreased from tillering to 50 per cent flowering in the second crop season but in the first crop no such trend was noticed. Root recorded lower and grain still lower contents compared to straw (Table 57). The influence of treatments in the K content of grain was not significant in the first crop season whereas significant difference was noticed in the second crop season. In the case of straw there was significant difference in both the seasons. But no regular trend was noticed in the K content of straw and grain due to treatments in both the seasons. Similar results were obtained for tall indica rice also.

Significant seasonal variation in the K content was found at all stages except at 50 per cent flowering stage of the crop (Table 58). Significantly higher contents were recorded in the second season at tillering and in straw and grain. But in the case of root, the reverse trend was seen. Available K content in soil was higher in the first season at tillering and at 50 per cent flowering compared to the second. But this was not reflected in the K content in plants.

Higher uptake of K was noted during the second season compared to the first at all stages (Table 59). The treatment AS alone has recorded lowest K uptake

Table 55. Uptake of phosphorus by plant at different stages of crop growth, kg ha^{-1}
(Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	3.10	18.42	9.05	14.15	23.20	6.71	24.50	8.39	13.59	21.98
GL alone	2.80	12.65	4.02	7.61	11.63	4.58	12.17	6.23	8.97	15.20
CM + GL	4.08	14.37	9.47	12.11	21.58	6.78	21.25	9.67	15.26	24.93
AS alone	2.34	10.28	3.35	8.27	11.62	3.00	12.00	5.18	7.90	13.09
CM + NPK	4.35	16.43	8.15	13.73	21.88	7.40	22.81	11.02	15.20	26.22
GL + NPK	3.81	18.43	5.81	11.66	17.47	5.60	18.20	6.52	10.92	17.44
CM + GL + NPK	4.91	14.18	10.98	13.28	24.26	8.63	24.36	10.36	13.95	24.31
NPK alone	3.06	17.18	5.21	7.79	13.00	6.52	14.40	9.21	8.96	18.17
SEm	0.520	1.515	0.787	0.515	1.242	1.129	1.418	0.704	0.809	1.763
CD	1.081	3.151	1.638	1.071	2.580	2.349	2.949	1.456	1.683	3.663

Table 56. Seasonal variation in phosphorus uptake by plant (Dwarf indica)

Stage of crop growth	Average P uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	3.57	6.15	-7.39*
50% flowering	15.25	18.71	-1.11
Harvest			
Straw	7.04	8.32	-3.79*
Grain	11.07	11.84	-2.34*
Total	18.11	20.16	-1.84*

*Significant at 5 per cent level

Table 57. Potassium content in plant at different stages of crop growth, per cent (Dwarf indica)

Treatment	First crop					Second crop				
	Tillering	50% flowering	Harvest			Tillering	50% flowering	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	1.64	1.89	1.71	0.27	1.65	2.55	2.38	1.76	0.39	0.54
GL alone	1.59	2.04	1.83	0.25	1.35	2.38	1.53	1.40	0.34	0.40
CM + GL	2.29	1.89	1.40	0.23	1.49	2.63	1.94	2.05	0.33	0.51
AS alone	1.86	1.97	0.98	0.22	0.65	2.33	1.81	1.81	0.33	0.40
CM + NPK	2.53	1.97	1.38	0.26	1.35	2.51	1.93	2.10	0.47	0.69
GL + NPK	1.91	1.63	1.87	0.26	1.31	2.38	2.08	1.72	0.31	0.48
CM + GL + NPK	2.54	2.19	1.92	0.29	1.44	2.64	2.37	2.25	0.36	0.65
NPK alone	1.71	2.20	1.32	0.32	0.55	2.71	1.30	1.77	0.31	0.38
SEm	0.243	0.190	0.222	0.034	0.083	0.152	0.206	0.143	0.037	0.067
CD	0.505	NS	0.463	NS	0.429	0.297	0.076	0.139	0.077	0.139

Table 58. Seasonal variation in potassium content of plant (Dwarf indica)

Stage of crop growth	Average K content in plant, per cent		t value
	First crop	Second crop	
Tillering	2.01	2.51	-5.29*
50% flowering	1.97	1.93	0.42
Harvest			
Straw	1.56	1.86	-3.15*
Grain	0.26	0.36	-6.93*
Root	1.22	0.51	1.74

*Significant at 5 per cent level

Table 59. Uptake of potassium by plant at different stages of crop growth, kg ha^{-1}
(Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grains	Total
CM alone	23.10	133.88	67.28	12.33	79.61	48.88	166.61	70.34	17.67	88.01
GL alone	19.21	117.30	52.51	10.57	63.08	43.64	93.07	54.53	12.20	66.73
CM + GL	32.07	118.13	48.84	9.28	58.12	48.21	137.41	99.12	14.39	113.51
AS alone	22.94	106.71	25.22	8.63	33.85	34.95	108.60	67.07	11.85	78.92
CM + NPK	37.95	119.84	53.55	10.52	64.07	50.20	133.49	88.99	21.01	110.00
GL + NPK	28.81	110.03	54.31	9.19	63.50	47.61	135.20	70.04	12.09	82.13
CM + GL + NPK	40.22	134.87	72.73	11.60	84.73	61.60	156.03	89.64	17.31	106.95
NPK alone	21.81	132.00	40.50	11.34	51.84	51.94	78.06	70.87	12.67	83.54
SEm	4.074	12.843	5.297	0.453	7.236	8.311	10.050	6.374	1.054	9.124
CD	8.466	NS	11.003	0.942	15.052	NS	20.904	13.258	2.191	18.254

during the first season. During the second season also, it recorded comparatively low values.

Seasonal differences were significant at tillering and harvesting stages and higher uptake was recorded in the second crop (Table 60). This again is due to the higher dry matter production as well as higher K content during the second season. The uptake at the time of harvest is much less than the uptake at the time of 50 per cent flowering in both the crops. But in tall indica varieties this was noticed only in the first crop season.

2.2.5 Calcium content and uptake

During the first crop season Ca content increased from tillering to 50 per cent flowering in most of the treatments and then decreased in the straw. As in the first crop season, in the second crop season also most of the treatments showed an increase from tillering to 50 per cent flowering. The Ca content in the straw is much higher than that at 50 per cent flowering in the second crop. Calcium content in the grain is much lower than in the straw in both the seasons because there is no marked translocation of this element from vegetative organs to the grain during ripening. Calcium content in grain, was the lowest and that in root was comparable with that in straw (Table 61).

Differences among treatments in Ca content were significant at all stages of both seasons. But no regular trend due to the application of different types of manures and fertilizers could be noticed.

Calcium content in plants during tillering, 50 per cent flowering and in grain and root at harvest were significantly higher in the first season than in the

Table 60. Seasonal variation in potassium uptake by plant (Dwarf indica)

Stage of crop growth	Average K uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	28.26	48.38	-7.94*
50% flowering	121.59	126.05	-0.67
Harvest			
Straw	51.87	76.32	-6.97*
Grain	10.43	14.82	-7.54*
Total	62.30	71.14	-6.34*

*Significant at 5 per cent level

Table 61. Calcium content in plant at different stages of crop growth, per cent (Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	0.40	0.62	0.40	0.25	0.40	0.30	0.34	0.46	0.14	0.33
GL alone	0.50	0.61	0.47	0.22	0.36	0.25	0.37	0.47	0.14	0.29
CM + GL	0.41	0.34	0.54	0.25	0.37	0.28	0.38	0.45	0.15	0.30
AS alone	0.45	0.54	0.34	0.26	0.48	0.20	0.34	0.44	0.15	0.40
CM + NPK	0.50	0.65	0.38	0.16	0.47	0.37	0.36	0.43	0.10	0.41
GL + NPK	0.43	0.40	0.46	0.25	0.41	0.28	0.28	0.36	0.13	0.31
CM + GL + NPK	0.56	0.56	0.39	0.26	0.49	0.31	0.33	0.40	0.15	0.49
NPK alone	0.48	0.66	0.40	0.22	0.36	0.37	0.30	0.55	0.15	0.30
SEm	0.032	0.049	0.043	0.018	0.031	0.037	0.029	0.023	0.011	0.027
CD	0.066	0.103	0.089	0.037	0.064	0.076	0.061	0.048	0.034	0.055

second. But just the reverse was found in the case of straw (Table 62). Calcium content in plants showed the trend similar to that of the exchangeable Ca content in soil as the Ca content was significantly higher at tillering and 50 per cent flowering in the first crop season whereas at harvest the difference between the two seasons were not significant. In the tall indica varieties also almost similar trend was noticed.

Calcium uptake was higher in the second crop season compared to the first season at tillering and at harvesting for all the treatments (Table 63). There was significant difference in the uptake of calcium in both the seasons at harvest and maximum uptake was recorded by the treatment GL + NPK in both the seasons. Uptake for the treatment AS alone was found to be the lowest during both seasons. Exchangeable Ca content in the soil was also the lowest for this treatment in both the seasons.

Uptake by straw in second season was significantly higher than that in first season (Table 64). Though the uptake by plant at 50 per cent flowering and grain during the first season was significantly higher compared to the second season total uptake at the time of harvest was more in the second season. This was observed in the case of tall indica also. Calcium uptake at the time of harvest was much lower than that at the time of 50 per cent flowering in the first crop season whereas in the second crop season it increased with crop growth. For tall indica varieties the uptake increased with crop growth in both seasons.

2.2.6 Magnesium content and uptake

Just like in the case of calcium, no definite trend existed in the Mg content of plants at various stages during both seasons. Magnesium content in grain

Table 62. Seasonal variation in calcium content of plant (Dwarf indica)

Stage of crop growth	Average Ca content in plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	0.47	0.39	4.17*
50% flowering	0.55	0.37	0.30
Harvest			
Straw	0.40	0.45	0.60
Grain	0.19	0.13	6.78*
Root	0.45	0.36	7.97*

*Significant at 5 per cent level

Table 63. Calcium uptake by plant at different stages of crop growth, kg ha^{-1} (Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	5.64	43.92	15.74	6.85	22.59	6.52	23.10	21.58	6.34	27.92
GL alone	6.05	35.07	13.48	8.30	21.51	7.59	18.25	19.08	5.03	24.12
CM + GL	5.74	21.25	11.66	6.05	17.91	6.67	29.04	24.66	6.54	31.20
AS alone	5.55	29.25	8.75	7.48	16.23	6.15	22.80	21.49	5.39	26.88
CM + NPK	7.51	39.54	14.75	6.46	21.21	5.80	27.07	26.27	4.47	30.74
GL + NPK	6.49	27.00	16.09	8.13	24.22	8.00	27.30	30.54	5.07	35.61
CM + GL + NPK	8.87	34.54	14.77	9.20	23.97	9.10	26.34	27.09	7.21	34.28
NPK alone	6.12	41.10	12.27	8.50	20.77	9.39	19.27	24.83	6.23	31.06
SEm	0.997	1.515	1.444	0.406	1.840	1.116	1.817	2.012	0.424	1.916
CD	2.075	3.151	2.996	0.845	3.834	NS	3.782	4.185	0.882	3.991

Table 64. Seasonal variation in calcium uptake by plant (Dwarf indica)

Stage of crop growth	Average Ca uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	6.49	7.44	-1.98
50% flowering	33.77	24.21	4.71*
Harvest			
Straw	13.46	24.44	-13.56*
Grain	7.59	5.79	7.15*
Total	21.05	30.23	-11.97*

*Significant at 5 per cent level

was slightly higher and that in root lower than that in straw in both the seasons (Table 65). Treatment differences were significant at all stages of first crop. During the second season, this was not observed at harvest both in straw and grains. But no regular trend due to influence of treatments could be observed in both the seasons.

Seasonal variation in Mg content was significant at tillering, 50 per cent flowering and at harvest in grain (Table 66). Higher Mg content at the time of tillering and 50 per cent flowering was noted in the first crop season, whereas the content in grain was significantly higher in the second season. Similar results were obtained for tall indica rice also. The exchangeable magnesium content in soil showed a different trend from that of the magnesium content of plants.

Uptake of Mg also varied among treatments at all stages of both crops, but no regular trend due to influence of treatments could be observed (Table 67).

Significant seasonal differences occurred at 50 per cent flowering and harvest (Table 68). Higher uptake was noticed in the first season at 50 per cent flowering while just the opposite of this was observed at harvest. This may be due to the higher Mg content and dry matter production during the second season. Same trend was obtained for tall indica varieties also.

Seasonal variations in the uptake of nutrients N, P, K, Ca and Mg are presented in Fig. 9 and 10.

Table 65. Magnesium content in plant at different stages of crop growth, per cent (Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Root			Straw	Grain	Root
CM alone	0.11	0.22	0.12	0.19	0.04	0.09	0.09	0.11	0.23	0.05
GL alone	0.15	0.22	0.08	0.13	0.09	0.11	0.07	0.11	0.26	0.05
CM + GL	0.12	0.11	0.13	0.20	0.07	0.09	0.04	0.13	0.28	0.03
AS alone	0.20	0.10	0.06	0.07	0.03	0.08	0.15	0.09	0.16	0.08
CM + NPK	0.19	0.06	0.06	0.19	0.08	0.14	0.12	0.20	0.28	0.08
GL + NPK	0.19	0.08	0.09	0.18	0.09	0.14	0.11	0.14	0.19	0.06
CM + GL + NPK	0.14	0.14	0.16	0.15	0.04	0.10	0.06	0.12	0.23	0.07
NPK alone	0.17	0.22	0.14	0.14	0.03	0.08	0.14	0.19	0.18	0.05
SEm	0.014	0.021	0.025	0.033	0.012	0.022	0.018	0.017	0.048	0.009
CD	0.029	0.043	0.052	0.068	0.024	0.047	0.038	NS	NS	0.019

Table 66. Seasonal variation in magnesium content of plant (Dwarf indica)

Stage of crop growth	Average Mg content in plant, per cent		t value
	First crop	Second crop	
Tillering	0.15	0.08	6.77*
50% flowering	0.13	0.08	4.68*
Harvest			
Straw	0.10	0.10	-1.13
Grain	0.16	0.23	-4.88*
Root	0.06	0.06	0.09

*Significant at 5 per cent level

Table 67. Magnesium uptake by plant at different stages of crop growth, kg ha^{-1}
(Dwarf indica)

Treatment	First crop					Second crop				
	Tiller-ing	50% flower-ing	Harvest			Tiller-ing	50% flower-ing	Harvest		
			Straw	Grain	Total			Straw	Grain	Total
CM alone	1.55	18.58	4.71	8.67	13.38	1.73	6.30	4.40	10.42	14.82
Gl alone	1.81	12.65	2.30	5.50	7.88	2.02	4.26	3.88	9.33	13.22
CM + GL	1.68	6.88	4.54	8.07	12.61	1.65	2.83	6.28	12.21	18.49
AS alone	2.47	5.42	1.54	2.76	4.30	1.20	9.00	7.04	5.75	12.79
CM + NPK	2.85	3.65	2.33	7.67	10.00	2.80	9.68	8.47	12.52	20.99
GL + NPK	2.87	5.40	2.61	6.36	8.97	2.80	7.15	5.70	7.41	13.11
CM + GL + NPK	2.22	8.63	6.00	6.06	12.06	2.32	3.95	4.78	11.07	15.85
NPK alone	2.17	13.20	4.29	4.96	9.24	1.53	8.40	7.61	7.01	14.62
SEm	0.321	0.873	0.402	0.302	1.321	0.374	0.520	0.458	0.624	1.120
CD	0.674	1.813	0.858	0.624	2.751	0.778	1.081	0.953	1.299	2.334

Table 68. Seasonal variation in Mg uptake by plant (Dwarf indica)

Stage of crop growth	Average Mg uptake by plant, kg ha^{-1}		t value
	First crop	Second crop	
Tillering	2.20	2.01	1.67
50% flowering	8.93	6.45	2.38*
Harvest			
Straw	3.55	6.02	-5.34*
Grain	6.25	9.46	-10.67*
Total	9.80	15.48	-12.51*

*Significant at 5 per cent level

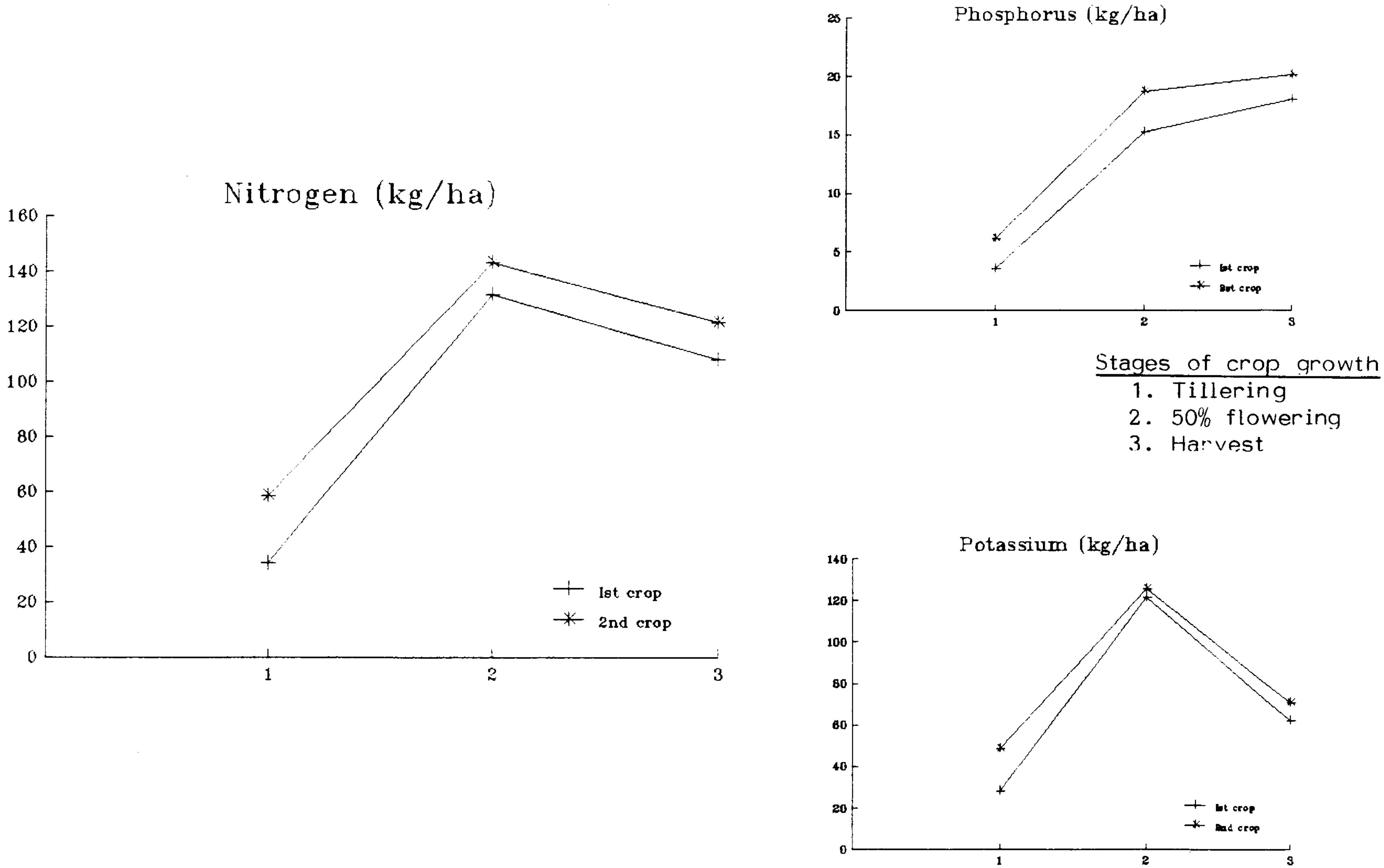
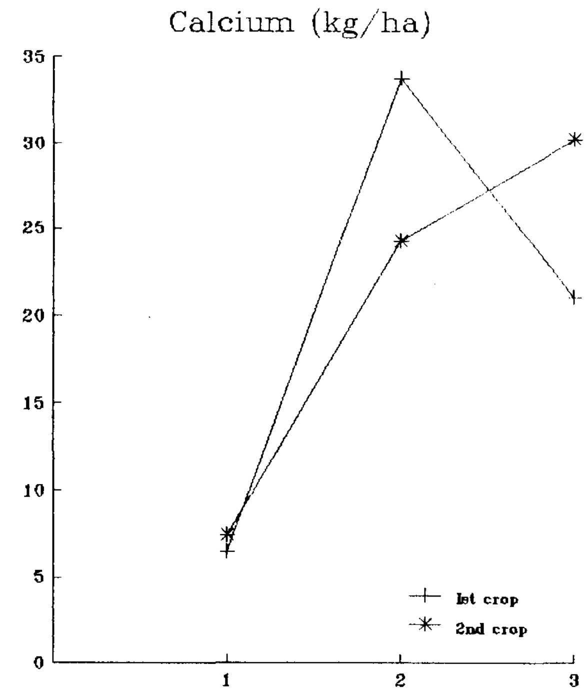


Fig.9. Seasonal variations in the uptake of N, P and K (Dwarf indica)



Stages of crop growth

1. Tillering
2. 50% flowering
3. Harvest

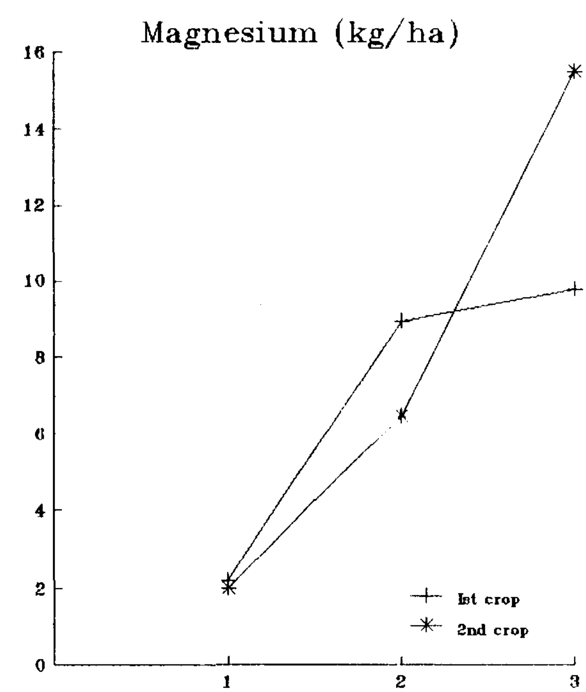


Fig.10. Seasonal variations in the uptake of Ca and Mg (Dwarf indica)

Summary

SUMMARY

A study was conducted to find out the seasonal variations in nutrient transformations in the two permanent manurial trials of rice at the Regional Agricultural Research Station, Pattambi. It was also aimed at finding out the influence of various treatments on the nutrient availability in soil in both the seasons. Along with these, seasonal variations in nutrient content and uptake by the crop was also included in the objectives.

The study was conducted making use of the soil and plant samples from the existing two permanent manurial trials on rice (tall indica and dwarf indica) at the Regional Agricultural Research Station, Pattambi. The results obtained and the salient conclusions drawn are given below. Yield data obtained from the station records were also statistically analysed and conclusion drawn.

1. In the experiment for tall indica variety organic carbon content was higher in the first crop season compared to second crop season at transplanting, tillering and 50 per cent flowering. But at harvesting the trend reversed.

2. There was no significant difference in the available N content of soil between the seasons at the transplanting and tillering but at 50 per cent flowering and at harvest higher values were recorded in the second crop season compared to that at the first crop.

3. Regarding available P, significantly higher values were recorded in the first crop season in the initial stages upto 50 per cent flowering but at harvest the reverse trend was observed.

4. As in the case of available P, in the initial periods of plant growth namely at transplanting, tillering and 50 per cent flowering significantly higher values of available K were recorded in the first crop whereas the values increased significantly at harvest in the second crop season. For exchangeable calcium content also similar results were obtained.

5. In the case of exchangeable Mg, there was no significant difference in the magnesium content between the first and second crop seasons at transplanting, tillering and at harvest while at 50 per cent flowering significantly higher values were recorded in the first crop season.

6. In the experiment with dwarf indica rice also significantly higher values of organic carbon were recorded in the first crop season at transplanting and at 50 per cent flowering whereas at harvest significantly higher values were recorded in the second crop season.

7. Though the available N content in the soil was significantly higher in the first crop season at transplanting, significantly higher values were recorded at harvest in the second crop season.

8. For available P content also significantly higher values were recorded in the first crop season in the initial growth periods upto 50 per cent flowering but at harvest reverse trend was observed.

9. In the case of available K significantly higher values were recorded in the first crop season whereas the trend reversed at harvest.

10. In the case of exchangeable Ca significantly higher values were recorded in the initial stages of crop growth in first crop season namely at transplanting, tillering and 50 per cent flowering. But there was no significant difference in the values recorded at harvest.

11. In the case of exchangeable magnesium no significant difference was noticed at the time of transplanting and at harvest between the two seasons. At tillering significantly higher values were recorded in the second crop season whereas at 50 per cent flowering higher values were recorded in the first crop season.

12. In the experiment with tall indica varieties nitrogen content in the plant was higher at tillering, 50 per cent flowering and in grain during the second crop season while in straw higher content was recorded in the first crop season. Nitrogen uptake was higher in the second crop season at all the periods. Uptake increased with crop growth in both the seasons.

13. Phosphorus content and uptake was significantly higher in the second crop season at all the stages. Uptake increased with crop growth in both the seasons.

14. Potassium content in the plants and uptake were higher at all the stages in the second crop season. The uptake showed a decrease at the time of harvest compared to that at 50 per cent flowering in the first season whereas in the second season it showed an increase with growth stage.

15. Calcium content in the grain was significantly higher in the first crop season whereas in the straw it was higher in the second crop season. Calcium uptake at the time of harvest was higher in the second crop season.

16. Magnesium content in grain was significantly higher in the second crop season compared to that in the first crop whereas there was no difference in the straw between the seasons. Significantly higher uptake was recorded in the second crop season at harvest.

17. In the experiment with dwarf indica series significantly higher N content was recorded in the second crop season at tillering and in grain whereas in straw the reverse trend was noticed. Total uptake by grain and straw was significantly higher in the second crop season as in the case of tall indica series. The uptake at the time of harvest was low compared to that at 50 per cent flowering in both the seasons.

18. At tillering, 50 per cent flowering and in straw significantly higher P content in plant was recorded during the second crop season whereas there was no difference in the P content of grain between seasons. Significantly higher uptake values were recorded in the second crop season at harvest. Uptake increased with advance in crop growth.

19. Significantly higher K content was recorded in the second crop season in grain and straw. Total uptake at harvest was also significantly higher in the second crop season compared to that in the first crop. The uptake at the time of harvest was much low compared to that at 50 per cent flowering in both seasons.

20. Significantly higher Ca content was recorded in the first crop season in grains whereas total uptake at harvest was higher in the second crop season. Calcium uptake at the time of harvest was low in the first crop season compared to that

at 50 per cent flowering, but in the second crop season uptake increased as the growth stage advanced.

21. Higher Mg content at the time of tillering and 50 per cent flowering was noted in the first crop season, whereas the content in grain was significantly higher in the second season. Total uptake was higher in the second crop season at harvest.

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SEASONAL VARIATIONS IN THE NUTRIENT TRANSFORMATION IN THE LATERITIC ALLUVIAL RICE SOILS OF PERMANENT MANURIAL TRIALS

BY

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ABSTRACT OF A THESIS

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ABSTRACT

A study was conducted during the first and second crop seasons of 1992 to find out the seasonal variations in nutrient transformations in the existing two permanent manurial trials (one with tall indica varieties and the other with dwarf indica varieties) at the Regional Agricultural Research Station, Pattambi. The experiment with tall indica variety was started in 1961 and the experiment with dwarf indica variety was started in 1973. The experiments were laid out in randomised block design with four replications and eight treatments.

The treatments consisted of application of entire quantity of N as organic manure (cattle manure alone, green leaves alone and cattle manure + green leaves), inorganic fertilizers alone (ammonium sulphate alone and NPK fertilizers) and a combination of organics with inorganics (cattle manure + NPK fertilizers, green manure + NPK fertilizers and cattle manure + green leaves + NPK fertilizers). In both the experiments, the treatments are the same, but the dose of manures and fertilizers varied based on the nutrient requirements of tall indica and dwarf indica varieties. For tall indica the dose of NPK applied is 40:20:20 kg/ha whereas in the dwarf indica varieties the dose applied is 90:45:45 kg/ha.

Soil samples were collected from all the replications of the various treatments at 11 stages from harvesting of second crop of 1991 to harvest of second crop of 1992. Plant samples were also collected at different stages of crop growth viz., tillering, 50 per cent flowering and harvest. Data on yield of grain and straw were collected from the Regional Agricultural Research Station, Pattambi. Soil and plant samples were analysed in the laboratory to find out the seasonal variations in

the availability of nutrients in the soil and in the content and uptake of nutrients by the crop.

Results of analysis of soil samples showed that significantly higher values of organic carbon, available N, P, K and Ca were recorded in the initial stages of crop growth namely transplanting, tillering and 50 per cent flowering in the first crop season but at harvest the trend reversed in both the experiments. In the case of magnesium significant difference between the seasons was noticed only at 50 per cent flowering and at this stage higher values were recorded in the first crop season in both the experiments.

At the initial stages of crop growth, namely at tillering and 50 per cent flowering higher content of available nutrients namely N, P, K and Ca were recorded in the soil in the first crop season but higher contents of N, P and K in the plant were recorded in the second crop season for both tall and dwarf indica varieties. For magnesium content in plant comparatively higher values were recorded in the first crop season compared to second crop season for both tall and dwarf indica varieties at tillering and 50 per cent flowering. With regard to calcium higher contents were recorded in the first crop season at tillering but at 50 per cent flowering the trend reversed in the case of tall indica varieties. At both the stages higher contents were recorded in the first crop season in the dwarf indica varieties.

In the grain significantly higher content of N, K and Mg were recorded in the second season. There was not much difference in the P content between the seasons. Similar trend was noticed in the nutrient content for both tall and dwarf indica varieties except for Ca. In the case of calcium no uniform trend was shown in both the experiments.

Higher contents of P, K and Ca were noticed in the second crop season in the straw. Significantly higher values were recorded in the first crop season for nitrogen. No significant difference in magnesium content was noticed between the seasons. Similar trend was noticed in both the experiments for all the elements.

Significantly higher uptake of N, P and K was noticed at all the growth stages in the second crop season in both the experiments. In the case of Ca and Mg though higher uptake was recorded in the initial growth periods, at the time of harvest the trend reversed and for these elements also higher values were recorded in the second crop season.