EFFECT OF LONG TERM APPLICATION OF MANURES AND FERTILISERS ON SOIL PROPERTIES, UTILISATION EFFICIENCY OF NUTRIENTS AND QUALITY OF RICE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Effect of long term application of manures and fertilisers on soil properties, utilization efficiency of nutrients and quality of rice**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled "Effect of long term application of manures and fertilisers on soil properties, utilization efficiency of nutrients and quality of rice" is a record of research work done by **Miss.M.K. Padmam** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of Miss.M.K. Padmam, a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled "Effect of long term application of manures and fertilizers on soil properties, utilization efficiency of nutrients and quality of rice" may be submitted by Miss.M.K. Padmam in partial fulfilment of the requirement for the degree.

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CONTENTS

	Page No.
INTRODUCTION	1
REVIEW OF LITERATURE	4
MATERIALS AND METHODS	29
RESULTS AND DISCUSSION	36
SUMMARY	111
REFERENCES	i-xi
APPENDIX	
ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
1	Physical properties of soil	37
2	Soil reaction, cation exchange capacity and organic carbon content of soil	41
3	Nitrogen status of soil	46
4	Phosphorus status of soil	51
5	Potassium status of soil	58
6	Calcium and magnesium status of soil	62
7	Micronutrient status of soil	65
8	Soil reaction at various stages of crop growth	68
9	Cation exchange capacity of soil at different stages of crop growth, cmol (p^+) kg^{-1}	70
10	Organic carbon content of soil at various stages of crop growth, per cent	71
11	Available nitrogen content of soil at various stages of crop growth, kg ha^{-1}	74
12	Available phosphorus content of soil at various stages of crop growth, kg ha^{-1}	75
13	Available potassium content of soil at various stages of crop growth, kg ha^{-1}	77
14	Exchangeable calcium content of soil at various stages of crop growth, cmol (p^+) kg^{-1}	79
15	Exchangeable magnesium content of soil at various stages of crop growth, cmol (p^+) kg^{-1}	80
16	Yield of dry matter at different growth stages, grain and straw, kg ha^{-1}	82

Table No.	Title	Page No.
17	Nitrogen content in plant at different growth stages, per cent	86
18	Phosphorus content in plant at different growth stages, per cent	88
19	Potassium content in plant at different growth stages, per cent	90
20	Calcium content in plant at different growth stages, per cent	91
21	Magnesium content in plant at different growth stages, per cent	93
22	Micronutrient content in grain and straw, ppm	94
23	Uptake of nitrogen by plant at different growth stages and by grain and straw, kg ha^{-1}	96
24	Uptake of phosphorus by plant at different growth stages and by grain and straw, kg ha^{-1}	98
25	Uptake of potassium by plant at different growth stages and by grain and straw, kg ha^{-1}	99
26	Uptake of calcium by plant at different growth stages and by grain and straw, kg ha^{-1}	102
27	Uptake of magnesium by plant at different growth stages and by grain and straw, kg ha^{-1}	103
28	Uptake of micronutrients by grain and straw, kg ha-1	105
29	Utilisation efficiency of nitrogen, per cent	108
30	Quality of grain and straw	109

LIST OF ILLUSTRATION

Fig. No.	Title
1	Lay out of field experiment
2	Relationship between organic carbon and bulk density of soil
3	Relationship between organic carbon and water holding capacity of soil
4	Relationship between organic carbon and available phosphorus in soil
5	Relationship between organic carbon in soil and grain yield
6	Relationship between available P in soil and grain yield

LIST OF APPENDIX

Meteorological parameters of the experimental site at the Regional Agricultural Research Station, Pattambi, Kerala.

Introduction

INTRODUCTION

Since the introduction of inorganic fertilizers, the cultivators have become aware of the adverse effects of the continuous use of heavy doses of chemical fertilizers on physical and chemical properties of the soil. Application of organic manures is known to improve the physical and chemical properties of soil in addition to their contribution of nutrients. Another aspect which has been under investigation for several years is the residual effect of the continuous application of inorganic fertilizers particularly those containing P and K. Exhaustion of nutrient elements by continuous cropping and antagonistic interaction of the nutrients in the soil system are some of the problems noticed. In order to get answers to some of these questions, permanent manurial experiments have been laid out in the middle of the last century in several locations.

In 1973, a permanent manurial experiment on rice with dwarf indica variety was started at the Regional Agricultural Research Station, Pattambi. There are eight treatments in the experiment and the treatments consisted of application of cattle manure, green leaves and ammonium sulphate alone and in combination with and without P and K. The major objectives of this trial at the time of formulation were to find out the deleterious effect, if any due to continuous use of inorganic fertilizers alone, whether high yields can be maintained by the use of organic manures alone and thirdly to work out the most judicious and economic combination of organic and inorganic fertilizers for formulating feasible recommendations that can be practised by cultivators.

Permanent manurial experiments become more useful when periodical soil analysis and a critical examination of the soil data in relation to both the treatments and yield are made to bring about the residual effects of nutrients and imbalances created due to continuous application of manures and fertilizers either alone or in combination with various treatments. Moreover, analysis of the yield data obtained from the permanent manurial experiment for the first ten years from 1973 to 1985 indicated the superiority of cattle manure application in increasing the yield. Application of green leaves showed a tendency to decrease the yield (KAU 1991). Though the general effects of organic matter in improving the physical and chemical properties of soil are well known, the comparative efficiency due to prolonged application of cattle manure and green manure upon the physical and chemical properties of soil which in turn affect the growth of rice have not been studied in detail under the soil and climatic conditions of Kerala. It is also not known how these organic manures differ in their ability to counteract the deleterious effects caused by the continued use of inorganic fertilizers. So the present study is formulated to find out the changes in the physico-chemical properties of soil due to prolonged application of cattle manure, green leaves and inorganic fertilizers either alone or in combination and to examine how these properties influence the yield of the crop and uptake of nutrients at various growth stages. Influence of these treatments on the quality of rice grain and straw also will be evaluated based on chemical analysis.

Review of Literature

REVIEW OF LITERATURE

The literature pertaining to the present investigation on the effect of long term application of manures and fertilizers on soil properties, utilization efficiency of nutrients and quality of rice are reviewed below.

1. Manures as source of plant nutrients

Organic manures from plants and animals are valuable byproducts of farming and allied industries. Farmyard manures, rural and urban composts, green manures and crop residues supply low quantities of major plant nutrients. These organic manures work like slow-release fertilizers, N is slow acting and less than 30 per cent P and 75 per cent K become available to the immediate crop. The rest of the plant nutrients becomes available to subsequent crops as residual effect (Gaur, 1984).

Green manures are good sources of N for rice. They are comparatively high in N, low in C:N ratio and contain considerable amount of plant nutrients such as K, Ca and other mineral elements. Green manures contain considerable amount of sugars, cellulose etc. and they decompose rapidly and various substances toxic to rice roots accumulate in submerged soils during early stages of decomposition (Tanaka, 1978). Bouldin (1988) showed that green manures contain two fractions, one which decomposes during the first rice crop and the other which decomposes slowly over the years. He further observed that with most green manure crops, the first fraction is 50-80 per cent of the total N, so the residual effect is relatively small when green manure is applied only once, but cumulative effects of several applications are appreciable.

Ponnamperuma (1964) reported that the low yield of rice consequent to green manuring of flooded acid soils is mainly due to higher concentration of CO_2 and thereby lowering the uptake of nutrients.

2. Effect of long term application of manures and fertilizers on soil properties

2.1. Physical properties

2.1.1. Bulk density and porosity

Bulk density of soil was found to be decreased by continuous application of farmyard manure and green manure under dry farming situation (Havanangi and Mann, 1970). When the dose of organic manures applied was high, improvement in bulk density was found to be better (Biswas et al., 1971).

Results of a study by Manickam and Venkitaramanan (1972) to find out the effects of prolonged application of various inorganic fertilizers alone and in combination with farmyard manure on physical properties of soil revealed that combined use of organics and inorganics had registered high values for bulk density.

Long term application of farmyard manure in conjunction with chemical fertilizers (over a period of 20 years) resulted in improving the bulk density of soil (Prasad and Singh, 1980). A decrease in bulk density was noticed by the application of lime and farmyard manure in combination with chemical fertilizers; whereas continuous use of chemical fertilizers alone caused an increase in bulk density (Sinha et al., 1980).

Porosity was improved by combined application of farmyard manure and chemical fertilizers (Mahimairaja et al., 1986).

A six year field study on the use of organics in rice-wheat crop sequence showed that application of farmyard manure and crop residues significantly lowered the bulk density of soil (Sharma et al., 1987).

2.1.2. Water retention

Application of farmyard manure, groundnut cake and green manure in a rice-fallow rotation for 10 years improved the water retention characteristics of an alluvial sandy loam soil (Biswas et al., 1969). A study by Biswas et al. (1971) to know the cumulative effect of different levels of manures and fertilizers on the physical properties of soil in the permanent manurial trial at

Sabour revealed that water retention characteristics of soil was significantly improved by application of organic manures and when the dose of manure was high, improvement was better.

Continuous application of farmyard manure in combination with chemical fertilizers was proved to be beneficial in increasing the water holding capacity of soil (Manickam and Venkitaramanan, 1972; Prasad and Singh, 1980). Available water content was increased by application of NPK fertilizers together with compost or farmyard manure (Patnaik et al., 1989).

2.1.3. Soil aggregation

A study by Bandyopadhya et al. (1969) to know the effect of continuous application of compost, ammonium sulphate and lime on some physical and chemical properties of rice soils at Central Rice Research Institute, Cuttack revealed that there was no change in the percentage of aggregates greater than 0.5, 0.25 and 0.1 mm. However, several other workers observed an improvement in water stable aggregates by combined application of organics and inorganics (Biswas et al., 1969; Havanangi and Mann, 1970; Mahimairaja et al., 1986; Patnaik et al., 1989).

2.2. Chemical properties

2.2.1. Soil reaction

The effect of continuous application of organic manure and ammonium sulphate for 15 years in mulberry fields indicated that use of ammonium sulphate and cowdung decreased soil pH (Mandal and Pain, 1965). A slight increase in pH of 0.2 to 0.4 unit was noticed by prolonged application of farmyard manure in rice soils at Kyushu Agricultural Experiment Station, Japan (Yamashita, 1967). In a trial conducted at Shiga Agricultural Experiment Station, Japan, it was found that application of ammonium sulphate caused a decrease in soil pH by about 0.5 to 1 unit (Nakada, 1980).

Results of a long term experiment with bajra-wheat rotation revealed that pH of the soil remained more or less unaffected by application of chemical fertilizers as well as by farmyard manure (Chaudhary et al., 1981). In the permanent manurial experiments with dwarf indica at Pattambi, the pH was uninfluenced by continuous application of organic manures or inorganic fertilizers. The values ranged from 5.1 to 5.5 (Kurumthottical, 1982).

On the other hand, long term application of fertilizers for 19 years brought about considerable decrease in soil pH in the permanent manurial trial conducted at Chotanagpur (Sharma et al., 1988). Soil pH was not influenced significantly due to long term application of cattle manure and pig slurry in an experiment conducted on acid silty loam soil cultivated with maize (Ndayegamiye and Cote, 1989).

2.2.2. Cation exchange capacity

Prolonged application of farmyard manure increased the CEC of rice soil from 1 to 7 milli equivalents in an experiment conducted in Japan (Yamashita, 1967). Enhancement in CEC of soil by application of compost was reported by several other workers also (Bandyopadhya *et al.*, 1969; Nakada, 1980; Udayasoorian *et al.*, 1988).

Results from the permanent manurial experiment at Pusa showed that CEC of soil was increased with green manuring, but the effects of farmyard manure and fertilizers were rather small (Maurya and Ghosh, 1972). Organic matter application had raised the CEC of soils in the permanent manurial experiments on paddy conducted at Pattambi (Kurumthottical, 1982).

Results of a long term field study with farmyard manure and pig slurry showed that CEC of soil was significantly higher with farmyard manure than with pig slurry (Ndayegamiye and Cote, 1989). Increase in CEC by application of farmyard manure alone or in combination with fertilizers or lime and a reduction in CEC by application of fertilizers alone was noticed in the permanent manurial experiment conducted at Chotanagpur (Sharma *et al.*, 1988).

2.2.3. Organic carbon

Long term application of fårmyard manure in doses varying from 4000 to 8000 lbs acre^{-1} year^{-1} increased the carbon content of soil by 20 to 40 per cent over unmanured check plot (Acharya and Rajagopalan, 1956). Combined application of organic manures and inorganic fertilizers also had resulted in higher organic carbon content of soil (Kanwar and Prihar, 1962; Mathan et al., 1978; Chaudhary et al., 1981; Rabindra and Gowda, 1986; Sharma et al., 1988; Udayasoorian et al., 1988). In the permanent manurial experiment conducted at Pusa, application of green manures with phosphate fertilizers resulted in higher content of organic matter in the soil (Ghosh and Kanzaria, 1964). Application of farmyard manure and phosphate fertilizers improved the organic matter status of soil in the permanent manurial experiment at Ranchi (Biswas et al., 1969).

A study by Shinde and Ghosh (1971) revealed that organic carbon content in the surface layer of a medium black soil was significantly increased by application of farmyard manure at the rate of 5.6 t ha^{-1}.

In the permanent manurial experiment conducted at Pattambi with tall indica rice varieties, continuous application of organic matter as cattle manure alone and as equal amounts of cattle manure and green manure resulted in significant improvement in organic carbon content of soil compared to inorganic fertilizers. Similar results were obtained for experiments conducted at Pattambi with dwarf indica varieties also and the values varied from 1.19 to 1.43 per cent. Contrary to this, continuous application of organic matter for 31 seasons in different forms failed to give any significant increase in organic carbon level in the permanent manurial experiment conducted in sandy soils at Kayamkulam (Kurumthottical, 1982).

Irrespective of the levels of farmyard manure used, carbon content was increased upto 52 days after application and thereafter it decreased (Gupta et al., 1988). Carbon content of soil increased from 0.911 to 1.584 per cent by the continuous application of organic manures and among the organic manures, farmyard manure had a significant influence (Udayasoorian et al., 1988).

2.2.4. Nitrogen

2.2.4.1. Total nitrogen

The results from a permanent manurial experiment at Punjab revealed that there was increase in the total N content of soil due to continuous addition of farmyard manure (Kanwar and Prihar, 1962). Addition of compost and cowdung continuously increased the total N content of soil in a long term experiment at Berhampur in West Bengal (Mandal and Pain, 1965). Continuous growing of paddy by the use of high dose of chemical fertilizers resulted in exhaustion of soil N (Prasad and Jha, 1973). Significant increase in total N content of soil was noticed in the permanent manurial experiment on paddy at Kayamkulam by long term application of cattle manure whereas no significant variation was noticed in the N content of soil in the permanent manurial experiments on paddy at Pattambi. The highest value of 0.056 per cent was recorded in the new permanent manurial trial for the treatment which received a combination of cattle manure, green leaves and NPK fertilizers and lowest content of 0.047 per cent was noticed in treatment which received only cattle manure. The C:N ratio of these soils varied from 22.75 to 30.43 (Kurumthottical, 1982).

Application of balanced NPK fertilizers at 100 per cent of the recommended dose and above had resulted in soil build up of N whereas considerable decrease has been noticed in soils which had not been fertilized with N for more than 12 years in the long term fertilizer experiments conducted at various locations in India (Nambiar, 1985). On the other hand, results from a long term manurial experiment from Canada revealed that the effect due to solid cattle manure and pig slurry on the N content of soil was not significant (Ndayegamiye and Cote, 1989).

2.2.4.2. Available nitrogen

Two fold increase in the available N content of soil in the cattle manured plot compared to control plot in a period of 40 years has been reported from the permanent manurial experiment at Coimbatore (Raju, 1952). Long term use of compost and cowdung caused an increase in available N content of soil in an experiment conducted with Jute at Berhampur in West Bengal (Mandal and Pain, 1965). 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 and chemical fertilizers had no effect on the available N content of soil under irrigated condition (Muthuvel et al., 1977). In the permanent manurial experiment on dwarf indica at Pattambi, significant variation was noticed in available N content of soil. Highest value of 106.2 kg ha^{-1} was observed in treatment where 90 kg N ha^{-1} was supplemented through organic and inorganic sources together with P_2O_5 and K_2O. Lowest amount of available nitrogen was noticed in treatment which received only NPK fertilizers (Kurumthottical, 1982). An increase in available N content of soil upto 20 days after farmyard manure application and a decrease thereafter was noticed in a long term field experiment with wheat (Gupta et al., 1988).

Review of research information from long term fertilizer experiments specific to wet land rice in India has revealed that 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 +

FYM and 150 per cent NPK treatments and least in unfertilized control (Patnaik *et al*., 1989).

2.2.4.3. Nitrogen fractions

Continuous application of manures and fertilizers for more than 8 years to rice resulted in maintaining only a very small portion of total N in mineralised form, while organic N fractions predominated in all the treatments. Among the N fractions, insoluble humus and amino acid N dominated. Addition of farmyard manure had a pronounced influence in increasing total and organic N contents and green manuring yielded greater amounts of nitrate N (Puranik *et al*., 1978).

The results obtained from the permanent manurial experiment at Nagpur indicated that organic N accounts for 73 - 95 per cent of total N in soil and is fractionated into various forms like hydrolysable NH_4 - N + amino sugar -N constituting 9 - 23 per cent of total N, acid soluble humin -N constituting 11 - 23 per cent of total N and insoluble humin -N which constituted 20 - 36 per cent of total N. Application of high doses of farmyard manure increased the level of all these fractions considerably (Kamat *et al*., 1982).

In an intensive rice-rice cropping system in Alfisol at Coimbatore, continuous application of farmyard manure over a period of 7 years significantly increased the total, ammoniacal, nitrate and organic N contents of both surface and subsurface soils. Continuous addition of green manure had no influence on the different fractions of N (Udayasoorian et al., 1989).

2.2.5. Phosphorus

2.2.5.1. Total phosphorus

Application of phosphate fertilizers in combination with organic manures had resulted in higher P content of soil when compared to inorganic fertilization alone in the permanent manurial experiment on paddy at Pattambi (Kurumthottical, 1982).

2.2.5.2. Available phosphorus

Long term effects of four rotations and application of farmyard manure and fertilizers indicated that farmyard manure increases the available P_2O_5 content of soil (Havanangi and Mann, 1970). A significant increase in available P in the surface layer of soil was obtained by application of farmyard manure at 5.6 t ha^{-1} to a field crop rotation of rice-gram at Bagwai in Madhya Pradesh (Shinde and Ghosh, 1971).

Results from the permanent manurial experiments on paddy at Pattambi revealed that application of phosphate fertilizers in combination with organics had resulted in higher content of available P as compared to inorganic fertilization 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 with NPK fertilizers (Kurumthottical, 1982).

Continuous application of N alone had resulted in a decline of available P after 8 years of cropping (Chhillar and Swarup, 1984). In a long term fertilizer cum manurial experiment on paddy - wheat cropping sequence, addition of higher doses of N showed more depletion of available P both in the absence and presence of farmyard manure (Kaushik et al., 1984).

Phosphorus enrichment in soils with application of balanced or high doses of NPK and combined use of NPK and farmyard manure and P depletion in the absence of P fertilization was quite evident in the long term fertilizer experiments with wet land rice conducted at various locations in India (Nambiar, 1985; Patnaik et al., 1989).

Available P content of soil increased upto 52 days after application of farmyard manure, irrespective of the levels in a long term field experiment conducted with wheat at Hissar and a decrease was noticed after 52 days (Gupta et al., 1988).

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

2.2.5.3. Phosphorus fractions

Intensive and continuous cropping in an alluvial soil resulted in less depletion of inorganic P (13 per cent) and more of organic P (45 per cent). Nitrogen applied alone had showed similar effects in these forms. Regular addition of inorganic P increased both inorganic and organic forms. Application of farmyard manure in combination with NPK fertilizers further enhanced organic P (Rao and Ghose, 1981).

The fractionation studies on P in the permanent manurial experiment on paddy at Kayamkulam revealed that application of cattle manure in combination with ammonium sulphate enhanced Fe-P fraction and lowered Al-P fraction. An increase in Fe-P fraction and decrease in Al-P fraction by continuous use of organic manures were noticed in the permanent manurial experiment on paddy at Pattambi (Kurumthottical, 1982).

A study on the P fractions in soil after 13 years of continuous application of fertilizers, manures and intensive cropping with rice-wheat-cowpea rotations indicated that graded doses of NPK fertilizers increased saloid-P, Al-P, reductant soluble-P and available P status of soil. However, Ca-P remained in the original level. Among

Al-P, Fe-P and Ca-P fractions, Fe-P showed the highest increase over control. Aluminium-P was found to be the more important fraction contributing towards available P followed by reductant soluble-P and saloid-P (Agarwal et al., 1987).

2.2.6. Potassium

2.2.6.1. Total potassium

Application of organic matter increased the potassium content of soil in the old permanent manurial experiment conducted at Coimbatore (Raju, 1952). The treatment which received K directly through inorganic sources or indirectly through organic matter had registered higher values for total K in the permanent manurial experiment conducted at Kayamkulam also. In the permanent manurial experiment with dwarf indica at Pattambi, neither the organic matter treatments, nor a combination of organic matter with inorganic fertilizers especially potassium increased the total potassium status of soil. The values varied from 1.52 to 1.83 cmol (p^+) kg^{-1} (Kurumthottical, 1982).

2.2.6.2. Available potassium

Increase in the available K status of soil by application of farmyard manure was reported by several workers (Kanwar and Prihar, 1962; Singh et al., 1983; Kaushik et al., 1984). Available K content of soil was increased by the application of K fertilizers both in the new and old permanent manurial experiments at Coimbatore (Muthuvel *et al.*, 1977).

2.2.6.3. Non-exchangeable potassium

In the permanent manurial experiment on paddy at Kayamkulam, treatments which received some amount of K either from inorganic sources or through organic matter had recorded higher values of difficultly exchangeable K. But, in the new permanent manurial experiment at Pattambi, application of organic manures and inorganic fertilizers failed to produce any significant variation in the difficultly exchangeable K content of soil (Kurumthottical, 1982).

Studies on the effect of long term application of farmyard manure, fertilizers and lime for 28 years on the status of total (6N HCl K), non-exchangeable (1N HNO_3 K), exchangeable (1N ammonium acetate K) and water soluble K in surface soil revealed that non-exchangeable K was found to increase in the fertilized and manured plots (Lal *et al.*, 1990).

2.2.7. Calcium and Magnesium

2.2.7.1. Total calcium and magnesium

Effect of continuous cropping and manuring in a fixed crop rotation of rice-gram at Bagwai in Madhya Pradesh was studied by Shinde and Ghosh (1971) and they concluded that there was an increase in the percentage of total CaO in the soil. The increase in CaO was reported to be due to phosphate treatment but Mg content of soil was unaffected by it.

In the permanent manurial experiments with dwarf indica at Pattambi, it was found that Mg content of soil was influenced significantly by application of manures and fertilizers while Ca content was unaffected by the different treatments. The values of total Ca and Mg varied from 0.013 to 0.019 per cent and from 0.056 to 0.073 per cent respectively (Kurumthottical, 1982).

2.2.7.2. Exchangeable calcium and magnesium

Application of N alone as ammonium sulphate markedly reduced the exchangeable Ca content of soil by about one half, but exchangeable Mg content was unaffected by the treatment. The initial status of exchangeable Ca was increased or retained in the plots which received application of FYM and NPK fertilizers (Prasad and Singh, 1980).

Exchangeable Ca and Mg contents were higher in the treatments which received organic manure either alone or in combination with phosphate fertilizers in the permanent manurial experiments on paddy at Pattambi and Kayamkulam. The values of exchangeable Ca and Mg in the new permanent manurial experiment at Pattambi varied from 0.277 to 0.592 and from 0.118 to 0.293 cmol (p^{+}) 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).

Continuous application of compost improved the status of exchangeable Ca, but lowered the exchangeable Mg content which showed a decreasing trend in the permanent manurial experiment conducted at Coimbatore (Udayasoorian et al., 1988).

2.2.8. Micronutrients

2.2.8.1. Micronutrient content in soils

Application of farmyard manure had resulted in an increase in exchangeable Mn status of soil in the permanent manurial experiment at Pusa. The content of reducible Mn was high under green manuring and NPK fertilization (Maurya and Ghosh, 1972). In a long term manurial trial, it was found that available Zn was significantly increased with farmyard manure application and decreased with P application. Application of K did not affect available Zn content of soil. Similar effects of farmyard manure and P and K fertilizers were noticed on total Zn content also (Sharma and Meelu, 1975).

In the permanent manurial experiments at Pattambi, treatments which have included some form or other of organic matter have recorded higher content of available Zn and Mn than treatments which have received inorganic fertilizers alone (Kurumthottical, 1982).

In a long term field experiment on a fixed rotation of soya-bean-potato-wheat at Ranchi Agricultural College, eight years of fertilizer application with lime has resulted in reduction of available micronutrients whereas farmyard manure application with balanced dose of chemical fertilizers increased the micronutrient status of soil (Prasad and Sinha, 1982). However, micronutrient status was more or less unaffected after eight years of intensive cropping and manuring in an annual rotation of jute-rice-wheat (Mandal et al., 1983).

Results of a long term manurial experiment with farmyard manure and NPK fertilizers showed that increasing rates of farmyard manure application caused a decrease in Fe and an increase in Al contents of soil. Chemical fertilizers had little effect on Zn, Mn and Cu concentration (Kepka and Chojnicki, 1987).

2.2.8.2. Critical levels of micronutrients in soil

One ppm Mn soluble in DTPA + $CaCl_2$ (pH 7.3) and 0.2 ppm Cu soluble in DTPA + $CaCl_2$ (pH 7.3) have been found to be useful as critical levels in rice soils (Randhawa et al., 1978). A critical limit of 1.5 ppm was reported for Zn soluble in 0.01 M EDTA + M $(NH_4)_2CO_3$ (Sims and Patrick, 1978). Rice in soil with 2.0 ppm iron or less developed visible symptoms of Fe deficiency (Agarwala and Sharma, 1979).

3. Response of rice to long term application of manures and fertilizers

3.1. Dry matter production in the early growth stages

A study on the effect of long term application of compost to rice field in Japan indicated that dry matter production in the early growth stages was nearly the same in compost treated and control plots. After heading, the dry matter production in the compost treated plots increased more rapidly (Kamata and Okada, 1976).

3.2. Yield

Bulky organic manures and ammonium sulphate applied at equal levels of N was found to give exactly similar response on yield of rice and their combination gave the same magnitude of response as individual components (Basak et al., 1957). A combination of organics + inorganics gave the highest yield of spring paddy followed by organic manure alone (Ghosh, 1964).

The trends of permanent manurial experiments on paddy under Palur conditions of Madras State showed superiority of ammonium sulphate over oil cake and green leaf. Compost was found to be as good as farmyard manure in increasing yield of paddy in a permanent manurial experiment at Aduthurai (Narayanaswami, 1968).

Results obtained from old permanent manurial experiment on wet land rice at Bhubaneswar during the period from 1956 to 1965 revealed that the best combination for highest yield of indica rice was 45 kg N ha^{-1} as chemical fertilizer with basal dressing of farmyard manure to supply 45 kg N ha^{-1}. Application of organic manure at 45 kg N ha^{-1} gave an yield equal to that obtained with 67.5 Kg N ha^{-1} as ammonium sulphate (Sahu and Nayak, 1971).

Application of farmyard manure at 5.6 t ha^{-1} significantly increased the yield of paddy in a fixed crop rotation of rice-gram from 1955 to 1967 at Bagwai in Madhya Pradesh (Shinde and Ghosh, 1971). In the absence of urea-N, cattle, pig and poultry manures increased the grain yield by 37, 40 and 98 per cent respectively (Maskina et al., 1988).

Permanent manurial experiments on paddy at Pattambi and Kayamkulam also showed the superiority of organic matter in increasing the grain yield of rice (Kurumthottical, 1982). Continuous application of N significantly enhanced the yield of both rice and wheat grown in sequence (Chhillar and Swarup, 1984). A combination of N and farmyard manure increased the yield of rice (Kaushik et al., 1984; Sharma et al., 1987). Incorporation of farmyard manure at 10 - 15 t ha^{-1} (along with 100 per cent NPK) produced an additional grain yield of 0.3 - 0.6 t ha^{-1} over 150 per cent NPK in submontaine and foot hill soils (Nambiar, 1985).

A study on long term field experiment on rice-rice cropping system revealed that grain yield could be significantly increased by application of organic manures (Udayasoorian, 1988).

The average increase in grain yield due to integrated use of organic manures and chemical fertilizers in a three year period (84 - 87) was 0.7 t ha^{-1} over a super optimum NPK dose (150 per cent) for Kharif rice in laterite soil at Bhubaneswar (Nambiar and Abrol, 1989).

Pooled analysis of the yield data from the permanent manurial experiments with dwarf indica at Pattambi from 1973 to 1985 for the Virippu crop season showed the superiority of cattle manure application in increasing the yield and the failure of green leaf application to produce higher yield (KAU, 1991).

3.3. Nutrient composition and critical levels of nutrients in rice

3.3.1. Nurient composition of rice

In the permanent manurial experiment with dwarf indica at Pattambi, the N content in grain and straw varied from 0.919 to 1.238 and 0.555 to 0.824 per cent respectively. In both cases, maximum and minimum values were recorded by treatments which received a combination of cattle manure and NPK fertilizers and cattle manure alone respectively (KAU, 1986).

In a long term field experiment involving rice-wheat cropping sequence and NPK fertilization at Karnal, fertilizer N reduced the P content in rice (Swarup and Chhillar, 1986). A pot culture experiment with 7 successive rice crops revealed that in the absence of K manuring, K content in rice plants growing in different soils declined from the range of 0.7 - 1.3 per cent to 0.4 - 0.5 per cent at the third or fourth harvest, when fairly steady state of dry matter production was reached (Chakravorty et al., 1987).

3.3.2. Critical levels of nutrients in rice

For high yield, the optimum N concentration in the leaf blade is 2.3 to 4.0 per cent at early panicle formation and 2.2 to 3.3 per cent at heading stage. The straw of high yielding cultivars generally have 0.7 to 0.8 per cent N, and often more than 1 per cent (Jones, 1987).

Rice plants whose P concentration in the leaf blade at tillering stage is 0.1 per cent or lower are P deficient. If P concentration in straw at maturity is 1.0 per cent or higher, P becomes toxic (Tanaka and Yoshida, 1970).

When the K content of straw at harvest or that of the leaf blade at tillering stage is 1.0 per cent, a deficiency is likely to exist (Tanaka and Yoshida, 1970). Results from 20 sites, in an area of Latosols in Taiwan where the critical K value at which 98 per cent of the maximum grain yield was attained, was 1.7 to

1.8 per cent of the dry matter at full heading and at harvest (Su, 1976).

Values of less than 0.15 per cent are considered as deficiency levels for Ca in rice (Jones, 1987). For magnesium, concentrations less than 0.1 per cent in mature straw is considered as the critical deficiency level (Jones et al., 1972).

Regarding manganese, values less than 25 ppm are considered as deficiency levels for many crops including rice. About 20 ppm in the shoot is considered the lower limit for rice, although the stage of growth, the cultivar and the environmental conditions may modify this limit (Tanaka and Yoshida, 1970).

The critical deificiency level for copper in mature rice straw is 6 ppm (Jones, 1987).

For zinc, the critical deficiency limit in mature rice straw is 25 ppm (Jones et al., 1980).

3.4. Uptake of nutrients

A study conducted at Aomori Prefactural Experiment Station, absorption of N, P and K was found to be increased with increasing amounts of farmyard manure. Increase in K was highest, followed by those in N and P (Yamashita, 1964).

The beneficial effect of green manures alone and in combination with fertilizer N on NPK uptake was noticed in a permanent manurial experiment on upland rice (Tiwari et al., 1980).

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

3.5. Utilization efficiency of nutrients

De Datta and Gomez (1975) have concluded that efficiency of N was highest in the first rice crop which declined progressively with successive rice crops. For P, the trend was opposite. The efficiency of K increased sharply over the years.

Response of high yielding varieties of rice to application of NPK was declined in a long term fertilizer experiment at Phillipines. Though the crop showed highest response to N, its efficiency decreased over the years in the plots where no P and K were given (Uexkull and Von, 1978).

The cumulative nutrient use efficiency in rice-rice cropping system in India for the period 1971-1985 clearly indicated the beneficial effect of organic manure in laterite soils (Panda and Sahoo, 1989).

Materials and Methods

MATERIALS AND METHODS

The present study involves the collection and analysis of soil and plant samples from the existing permanent manurial trial on rice (dwarf indica), at the Regional Agricultural Research Station, Pattambi started in 1973. The station is situated at 10° 48" N latitude and 76° 12" E longitude and at an altitude of 25 m above mean sea level. The study was conducted during the first crop season of 1990.

1. Details of the field experiment

The soil type of the experimental site is laterite. The meteorological parameters of location of the experimental site are given in Appendix I and the layout of the experiment in Fig. 1. The details of the experiment are as follows:

Design	: RBD
Replication	: 4
Variety	: Jaya
Spacing	: 15 x 15 cm
Plot size	: 7.8 x 5.25 cm (gross) 7.5 x 4.95 m (net)

Treatment

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)

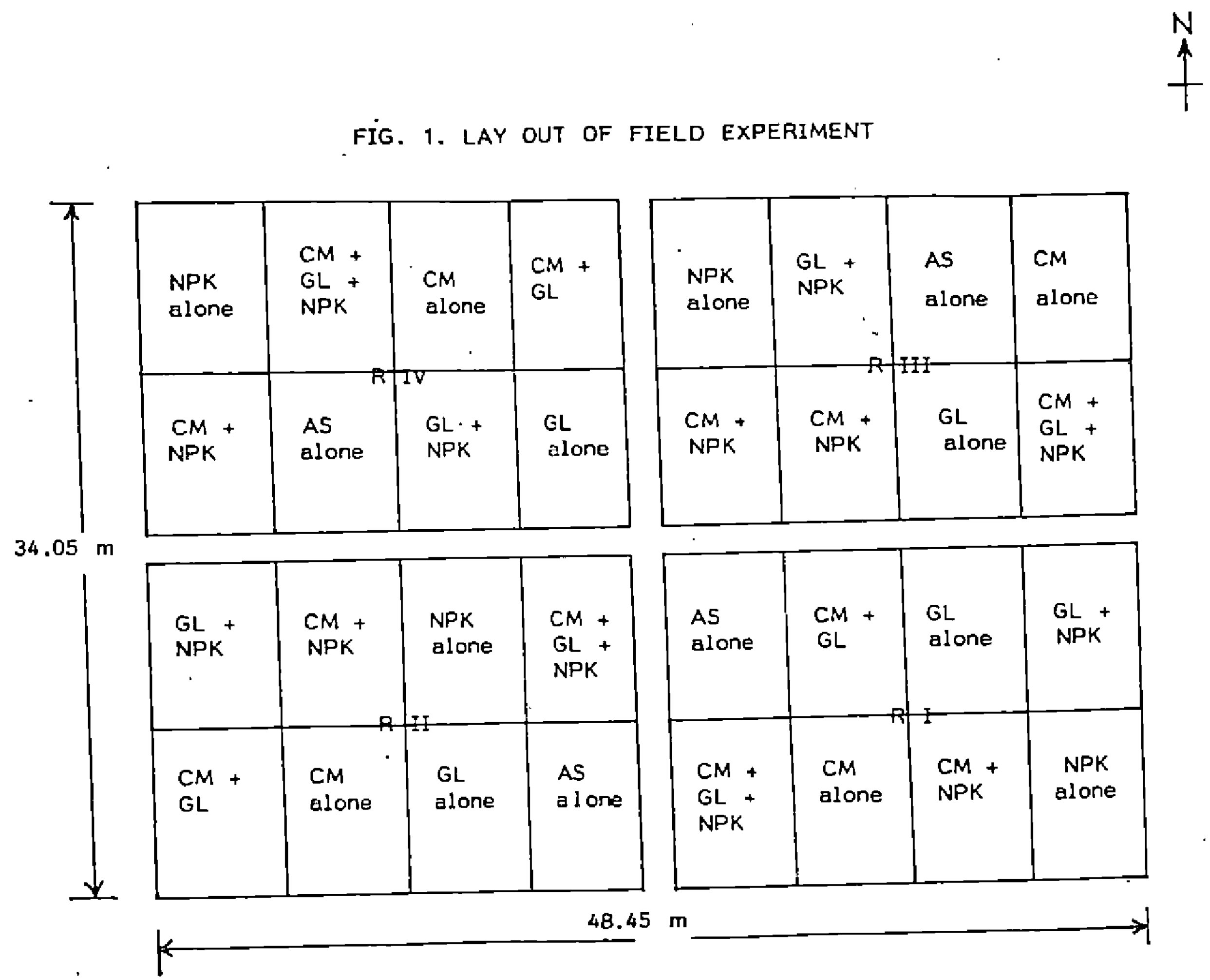


FIG. 1. LAY OUT OF FIELD EXPERIMENT

3\. Cattle manure   9 t ha^{-1} (45 kg N ha^{-1}) + Green manure 9 t ha^{-1} (45 kg N ha^{-1}) (CM + GL)

4\. Ammonium sulphate to supply 90 kg N ha^{-1} (AS alone)

5\. Cattle manure   9 t ha^{-1} (45 kg N ha^{-1}) + NPK 45:45:45 kg ha^{-1} (CM + NPK)

6\. Green leaves   9 t ha^{-1} (45 kg N ha^{-1}) + NPK 45:45:45 kg ha^{-1} (GL + NPK)

7\. Cattle manure   4.5 t ha^{-1} (22.5 kg N ha^{-1}) + Green manure 4.5 t ha^{-1} (22.5 kg N ha^{-1}) + NPK (45:45: 45 kg N ha^{-1}) (CM + GL + NPK)

8\. NPK   90:45:45 kg ha^{-1} (NPK alone)

N, P and K are supplied as ammonium sulphate, super phosphate and muriate of potash.

Nitrogen level is kept constant by taking the percentage of N in cattle manure and green leaves as 0.5. Treatments 1, 2 and 3 are organics alone, treatments 5, 6 and 7 are organics + inorganics and treatments 4 and 8 are inorganics alone.

2. Collection of samples

Soil samples were taken from all the replications of various treatments before planting, at different stages of crop growth viz., tillering, panicle initiation, 50 per cent flowering and after harvest of crop. Plant samples were collected at different stages of crop growth as above.

Before planting, soil samples were collected with the help of spade. Soil samples at different stages of crop growth and at harvest were drawn using a wet soil sampler.

Plant samples were collected from the pre-designated sample rows. Three hills were pulled out, roots were removed and washed with water and dilute HCl at pre-determined intervals.

3. Laboratory studies

3.1. Soil samples

3.1.1. Preparation of the sample

A part of each of the soil sample was kept in its natural undisturbed condition for aggregate analysis. The rest of the soil sample was air dried, powdered gently and passed through a 2 mm sieve. The samples were kept in labelled plastic containers for further analysis.

3.1.2. Analysis of the sample

3.1.2.1. Physical properties

Aggregate stability of undisturbed soil was determined based on the technique developed by Tiulin (1928) and Yoder (1936). Particle size distribution of soil was found out by Hydrometer method (Piper, 1942). Determination of bulk density, particle density and water holding capacity of soil was carried out based on the method of Keen and Raczkowski (1921) using Keen - Raczkowski boxes.

3.1.2.2. Chemical properties

The pH of the soil water suspension was determined using a soil water ratio of 1:2.5 by a pH meter (Jackson, 1967). For the determination of organic carbon content of soil Walkley and Black's method (Piper, 1942) was followed. Cation exchange capacity of soil was determined by normal ammonium acetate method (Piper, 1942).

For the determination of total N, kjeldahl's digestion and distillation method (Jackson, 1967) was followed. Available N was determined by alkaline permanganate method (Subbiah and Asija, 1956). Fractions of soil nitrogen viz., ammoniacal nitrogen, nitrate nitrogen, hydrolysable nitrogen and nonhydrolysable nitrogen were determined based on the procedure described by Bremner (1965).

Total P_2O_5 in the soil was determined in the diacid extract of soil by vanado-molybdo phosphoric yellow colour method in HNO_3 (Jackson, 1967). Available P in the soil was extracted by Bray No.1 extractant and the P content was determined colorimetrically by the chlorostannous reduced molybdo - phosphoric blue colour method in HCl system (Jackson, 1967). Various fractions of P in soil viz., saloid-P, Fe-P, Al-P and Ca-P were determined based on the procedure described by Chang and Jackson (1957).

Total K_2O in the soil was determined using standard procedure as outlined by Jackson (1967). Available K in the soil was determined in the ammonium acetate leachate collected during the determination of cation exchange capacity. An aliquot of this leachate was diluted and read in EEl flame photometer. For the determination of non-exchangeable K, 1 g of soil was boiled with 50 ml IN HNO_3 for 10 min. After filtration an aliquot of the above was diluted and read in EEl flame photometer.

Total Ca and Mg in the soil were determined in the diacid extract of soil by EDTA titration method (Hesse, 1971). Determination of exchangeable Ca and Mg was made in the ammonium acetate leachate obtained at the time of cation exchange capacity and EDTA titration method was followed for the estimation of Ca and Mg in this leachate.

For the determination of available micronutrients, the soil samples were extracted with DTPA extractant in the ratio of 1:2, shaken for 2 h. and estimated in an atomic absorption spectrophotometer (Lindsay and Norwell, 1978).

3.2. Plant samples

3.2.1. Preparation of the sample

Plant samples were dried in a hot air oven at 70°C and the dry weights were recorded. The samples were powdered and composite samples were kept in brown paper covers for further analysis.

3.2.2. Analysis of the sample

The total N content of the samples was determined by micro-kjeldahl digestion and distillation method (Jackson, 1967). For the determination of P, K, Ca, Mg and micronutrient elements, triacid extract (HNO_3, H_2SO_4, $HClO_4$) of the plant material was made use of. Phosphorus was determined by vanado-molybdo phosphoric yellow colour method (Jackson, 1967). Potassium was determined by using EEl flame photometer. Calcium and magnesium were estimated in the extract by EDTA titration method (Cheng and Bray, 1951). Micronutrient elements in the plant material viz., Fe, Mn, Cu and Zn were determined in the extract using an atomic absorption spectrophotometer.

Protein contents of grain and straw were computed from the nitrogen contents of the samples. For the determination of starch content of grain, content of total reducing sugars present in the acid hydrolysate was estimated by titration with Fehlings solution (AOAC, 1960). From this, starch content was calculated. Fibre content of straw was determined based on the procedure described by Kanwar and Chopra (1976).

Uptake of nutrients by crop at different growth stages and by grain and straw was computed from the respective nutrient contents and yields of dry matter, grain and straw. Utilization efficiency of nitrogen was computed as percentage of applied N (90 kg N ha^{-1}) taken up by the crop at harvest.

4. Statistical analysis

The results obtained were subjected to analysis of variance technique for RBD (Panse and Sukhatme, 1985). Correlation and regression between various factors were worked out, as described by Snecdor and Cochran (1967).

Results and Discussion

RESULTS AND DISCUSSION

The results obtained in the present study are presented and discussed in this chapter. The data on yield of grain and straw obtained from the station records were also statistically analysed, presented and discussed.

1. Effect of long term application of manures and fertilizers on physical properties of soil samples collected before planting of the crop

Data presented in Table 1 represent the values of soil physical constants viz., bulk density, particle density, water holding capacity, particle size distribution and percentage aggregate stability as influenced by long term application of manures and fertilizers.

1.1. Bulk density

The influence of long term application of manures and fertilizers on the bulk density of soil was significant. The treatment CM alone recorded the minimum value of 1.190 Mg m^{-3}. The treatments GL alone, CM + GL and CM + NPK have also recorded comparatively lower values and they were statistically on par with treatment CM alone. The maximum value of 1.270 Mg m^{-3} was recorded by treatments AS alone and NPK alone. The results thus clearly

Table 1. Physical properties of soil

Treatment	Bulk density, Mg m^{-3}	Particle density, Mg m^{-3}	Water holding capacity, (%)	Particle size distribution (%)			Percentage aggregate stability
				Sand	Silt	Clay	
CM alone	1.190	2.274	47.45	61.03	9.99	28.98	63.2
GL alone	1.199	2.288	48.89	59.03	9.99	30.98	63.9
CM + GL	1.207	2.261	48.91	61.03	9.99	28.98	62.5
AS alone	1.270	2.319	42.18	60.03	10.99	28.98	59.9
CM + NPK	1.229	2.434	44.90	62.03	8.99	28.98	62.1
GL + NPK	1.243	2.299	45.60	61.03	9.99	28.98	62.2
CM + GL + NPK	1.269	2.312	44.14	62.03	8.99	28.98	62.8
NPK alone	1.270	2.334	41.81	62.03	9.99	27.98	60.1
SEm±	0.0212	0.0427	1.634	1.210	1.283	1.479	
CD (0.05)	0.0624	NS	4.805	NS	NS	NS	

revealed that application of appreciable quantities of organic manures either alone or in combination with chemical fertilizers continuously for the last 34 seasons has resulted in improving the bulk density of soil. The influence of organic matter in improving the bulk density of soil is well known and widely reported (Biswas *et al.*, 1971; Havanangi and Mann, 1970; Prasad and Singh, 1980; Sinha *et al.*, 1980; Sharma *et al.* 1988).

1.2. Particle density

There was no significant difference in the particle density of soil due to continuous application of manures and fertilizers. The values varied from 2.261 Mg m^{-3}, recorded by treatment CM + GL to 2.434 Mg m^{-3}, recorded by treatment CM + NPK. The influence of continuous addition of organic manures at a high dose of 18 t ha^{-1} was not reflected in the particle density of soil and this can be attributed to the comparatively low increase in the organic matter content of soil under the tropical climatic conditions.

1.3. Water holding capacity

Significant variation was noticed in the water holding capacity of soil due to different treatments. Maximum value of 48.91 per cent was recorded by treatment CM + NPK and treatments GL alone, CM alone, GL + NPK, CM + NPK and CM + GL + NPK were statistically on par with the above treatment. Treatment NPK alone which recorded the minimum value of 41.81 per cent was followed by treatment AS alone. There was not much variation between these two treatments. The results thus revealed that treatments which received addition of organic matter either alone or in combination with inorganic fertilizers had higher water holding capacity, while treatments in which inorganic fertilizers alone were applied recorded the lowest values. The improvement in moisture retention characteristics of soil by organic matter addition has been reported by several workers (Biswas et al., 1969; Manickam and Venkitaramanan, 1972; Prasad and Singh, 1980).

1.4. Particle size distribution

Particle size distribution of soil was not influenced significantly by the application of organic manures either alone or in combination. This is quite expected as the textural classes of soil are not subjected to easy modification in the field. The texture of the soil is sandy clay loam.

1.5. Soil aggregation

Stability of soil aggregate was determined in the pooled sample of the treatments collected from all the four replications. Percentage aggregate stability of soil varied from 59.9 to 63.9. In general, higher values were recorded by treatments which received application of organic manures either alone or in combination with inorganic fertilizers and lower values were recorded by treatments AS alone and NPK alone which were devoid of any kind of organic matter application for the last 34 seasons. The variation in the percentage aggregate stability may be attributed to the differences in the content of organic matter as cementing agents in the different treatments. Favourable influence of organic matter on soil aggregation has been observed by several other workers also (Biswas et al., 1969; Havanangi and Mann, 1970; Mahimairaja et al., 1986; Patnaik et al., 1989).

2. Effect of long term application of manures and fertilizers on chemical characteristics of soil samples collected before planting of crop

Data relating to soil reaction, cation exchange capacity and organic carbon content of soil are presented in Table 2.

2.1. Soil reaction

Statistical analysis of the data revealed that long term application of organic manures and inorganic fertilizers had not influenced soil pH significantly. The variation due to various treatments was only 0.4 pH units. The highest value of 6.3 was recorded by treatment GL alone and the lowest value of 5.9 was recorded by treatment AS alone which was followed by treatment NPK alone. It may be noted that eventhough ammonia containing

Table 2. Soil reaction, cation exchange capacity and organic carbon content of soil

Treatment	pH	Cation exchange capacity, cmol (p^+) kg^{-1}	Organic carbon (%)
CM alone	6.1	8.98	1.39
GL alone	6.3	8.06	1.18
CM + GL	6.2	7.47	1.43
AS alone	5.9	6.60	1.15
GM + NPK	6.0	8.37	1.40
GL + NPK	6.2	7.96	1.17
CM + GL + NPK	6.1	10.33	1.34
NPK alone	6.0	6.98	1.10
SEm±	0.14	1.451	0.082
CD (0.05)	NS	NS	0.241

fertilizers have a tendency to increase the acidity of soil, application of ammonium sulphate alone to supply 90 kg N ha^{-1} continuously for the last 17 years has not increased the acidity of soil significantly. Eventhough the treatment AS alone had low exchangeable Ca and Mg contents (Table 6), that was not reflected in the pH of the soil. Kurumthottical (1982) has also obtained similar results in the studies conducted in the same experimental plots at Pattambi. The values recorded in his study varied from 5.1 to 5.5. The result obtained in this study is in agreement with the result reported by several other workers also (Chaudhary et al., 1981; Ndayegamiye and Cote, 1989), but disagrees with reports of Nakada (1980) and Sharma et al. (1988).

2.2. Cation exchange capacity

In spite of the continuous addition of one form or other of organic matter, variation in the CEC of soil due to treatments remained non-significant. The significant difference obtained in the organic carbon content of soil due to various treatments was not reflected in the CEC of soil. The values varied from 6.6 cmol (p^+) kg^{-1}, recorded by treatment AS alone to 10.33 cmol (p^+) kg^{-1}, recorded by treatment CM + GL + NPK. The low values noticed in the CEC may be attributed to the dominance of kaolinite in the clay complex. The high porosity and water logged nature of the soil might have resulted in the leaching of the colloidal organic matter to a deeper zone and this may be another reason for the non-significant difference observed in the CEC values. Contrary to the results obtained in the present study increased CEC of rice soil due to prolonged application of FYM has been reported by Ndayegamiye and Cote (1989) and Sharma et al. (1988).

2.3. Organic carbon

The organic carbon content of soil was influenced significantly due to treatments. The maximum value of 1.43 per cent was recorded by treatment CM + GL which was found to be on par with treatments CM + NPK, CM alone and CM + GL + NPK. The results thus clearly revealed that all the treatments which received cattle manure at the rate of 4.5 t ha^{-1} or more have shown higher organic carbon content due to continuous application. Similar results of increase in organic carbon content due to continuous application of farmyard manure was reported by several workers (Biswas et al., 1969; Shinde and Ghosh, 1971; Udayasoorian et al., 1988). The lowest values of 1.07 and 1.15 per cent were recorded by treatments NPK alone and AS alone respectively which were devoid of any kind of organic matter application. The treatments GL + NPK and GL alone have also recorded comparatively lower organic carbon content. These treatments received application of Glyricidia leaves at the rate of 9 and 18 t ha^{-1} respectively. The lower organic carbon content noticed in these plots may be attributed to the rapid

FIG. 2. RELATIONSHIP BETWEEN ORGANIC CARBON AND BULK DENSITY OF SOIL

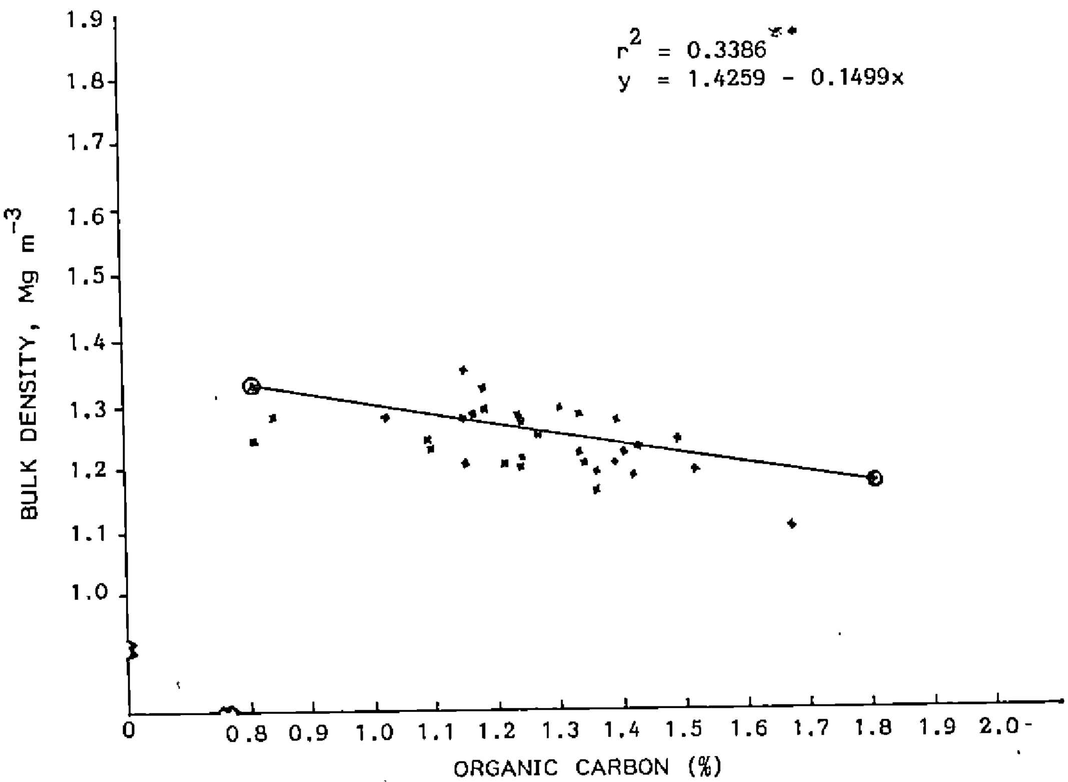
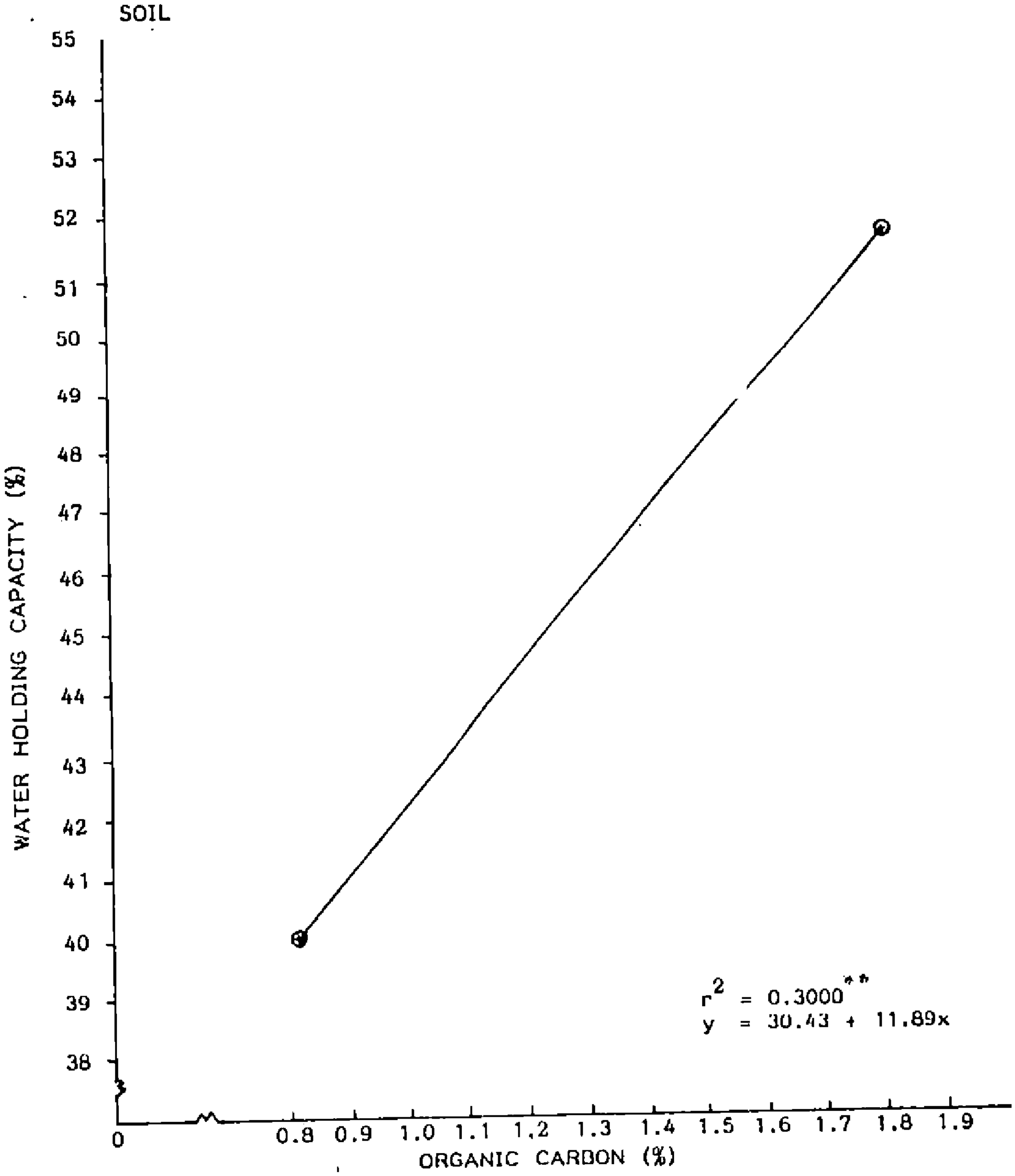


FIG. 3. RELATIONSHIP BETWEEN ORGANIC CARBON AND WATER HOLDING CAPACITY OF SOIL



decomposition of the fresh Glyricidia leaves. Significant correlation existed between organic carbon content and bulk density ($r = -0.5819^{**}$) and water holding capacity of soil ($r = 0.5476^{**}$), (Fig.2 and 3).

Kurumthottical (1982) obtained similar results on analysing the soil collected from the same experimental plots 10 years ago and the values he obtained ranged from 1.19 to 1.43 per cent. This indicate that organic carbon content of soil has not changed considerably due to continuous application of organic manures and inorganic fertilizers either alone or in combination during the last 10 years. Though continuous addition of organic matter at high doses for a successive period of 34 seasons has brought about statistically significant increase in organic carbon levels compared to inorganic fertilizers alone, it has to be realised that this higher level is only in the range between 1 to 3 per cent. The inability of organic manures to enhance the organic carbon content of soil considerably in spite of their appliation at high doses is mainly due to continuous cropping and tropical conditions of high rainfall and temperature which might have resulted in higher rate of decomposition of organic matter. Under water logged anaerobic situation prevailing in the experimental plots, the rate of degradation of organic matter is markedly low compared to upland aerobic situation. But it has to be noted that after every two cropping season in a year, the fields pass through a summer fallow when the soils are totally dry. During this period, it is possible that the accumulated humus gets oxidised.

2.4. Nitrogen status

Data on total N, available N and fractions of N are presented in Table 3.

2.4.1. Total nitrogen

There was no considerable variation in the total N content of soil due to continuous application of organic and inorganic sources of N, singly or in combination. The values ranged from 0.143 per cent, recorded by treatment GL + NPK to 0.184 per cent, recorded by treatment CM + GL. Treatment CM + GL has also recorded the highest level of organic carbon content (Table 2). Kurumthottical (1982) obtained similar results with values ranging from 0.0471 to 0.0561 per cent in his studies conducted 10 years ago in the same experimental fields. This indicates that total N content of soil has increased considerably due to continuous application of 90 kg N ha^{-1} either in the organic or inorganic form or by a combined application of both forms. Similar non-significant variation in the N content of soil due to prolonged application of FYM has been reported by Ndayegamiye and Cote (1989). But the results

Table 3. Nitrogen status of soil

Treatment	Total nitrogen (%)	Available nitrogen, kg ha^{-1}	Fraction of nitrogen, ppm			
			NH_4-N	NO_3-N	Hydro-lysable N	Non-hydro-lysable N
CM alone	0.169	332.1	10.04	3.46	940	749
GL alone	0.153	323.6	12.89	4.21	845	685
CM + GL	0.184	390.2	10.30	4.79	1047	793
AS alone	0.153	344.7	14.85	4.34	816	714
CM + NPK	0.152	329.1	14.04	2.42	892	628
GL + NPK	0.143	373.5	9.40	3.30	845	583
CM + GL + NPK	0.165	373.5	13.38	4.03	1025	652
NPK alone	0.164	323.1	12.51	3.72	901	505
SEm±	0.016	28.46	1.49	0.57	48	33
CD (0.05)	NS	NS	NS	NS	141.7	97.5

of the present study disagrees with the results reported by several other workers (Kanwar and Prihar, 1962; Mandal and Pain, 1965; Nambiar, 1985).

In the present study, the C:N ratio of soil varied from 6.52:1 to 9.21:1, while Kurumthottical (1982) has reported much wider values ranging from 22.75:1 to 30.43:1. It is generally stated that the C:N ratio of soil will be usually within the range of 10:1 to 12:1 whereas the result of present investigation gave mean values of less than 10:1. The lower C:N ratio obtained in the study may be due to the greater degree of oxidation of the organic matter thereby decreasing the ratio between carbon and nitrogen. The increase in the nitrogen content of the soil may be another reason for the lowering of the C:N ratio of soil.

2.4.2. Available nitrogen

Continuous application of N either in organic or inorganic form or by a combined application of both forms has not resulted in any significant variation in the available N content of soil. In general, the availability of N associated with different treatments was medium as the values ranged from 319.1 to 390.2 kg ha^{-1}. The maximum value was recorded by treatment CM + GL and the same treatment has recorded highest values for total N and organic carbon content also. The lowest content of available N was recorded by treatments NPK alone and GL alone. The results obtained in this study is in accordance with the results reported by Muthuvel et al. (1977). On the other hand, Kurumthottical (1982) observed significant difference in the available N content of soil due to treatments, but the lowest value was recorded by treatment NPK alone as in the present study. The value obtained by him ranged from 98.60 to 106.20 kg ha^{-1}. Increase in available N content of soil due to long term application of organic manures was reported by many other workers also (Mandal and Pain, 1965; Patnaik et al., 1989).

2.4.3. Fractions of nitrogen

2.4.3.1. Ammoniacal nitrogen

There was no significant variation in the ammoniacal nitrogen content of soil due to continuous application of organic and inorganic sources of N. The maximum value of 14.85 ppm was recorded by treatment AS alone and minimum value of 9.40 ppm was recorded by treatment GL + NPK. Ammoniacal N accounts for only less than 1 per cent of total N and the reasons for such low values can be attributed to the low CEC of the major type of clay mineral namely kaolinite present in the soil. Contrary to the results obtained in the present study Udayasoorian et al. (1989) reported increase in the ammoniacal N content of soil due to continuous application of FYM. He has also reported that green manures had no influence in the different fractions of N.

2.4.3.2. Nitrate nitrogen

Similar to ammoniacal nitrogen, nitrate nitrogen content of soil also failed to show significant difference due to treatments. The values varied from 2.42 to 4.79 ppm which were recorded by treatments CM + NPK and CM + GL respectively. Udayasoorian et al. (1989) has also obtained results similar to that obtained in the present study.

2.4.3.3. Hydrolysable nitrogen

Hydrolysable nitrogen which is known to contribute to the pool of available nitrogen during the cropping period was influenced significantly due to continuous application of manures and fertilizers. Among the treatments, continuous application of cattle manure and green leaves at equal doses (CM + GL) recorded the maximum value of 1047 ppm. This treatment was on par with treatments CM + GL + NPK and CM alone. The lowest content was noticed in the treatment AS alone which is on par with treatments GL + NPK, GL alone, CM + NPK and NPK alone. The results indicate that cattle manure has a tendency to increase the hydrolysable nitogen, while green leaves tend to reduce it. Hydrolysable nitrogen contributes to 55 to 65 per cent of total N. Hydrolysable nitrogen content of soil is significantly correlated with organic carbon content of soil (r = 0.4113*).

2.4.3.4. Non-hydrolysable nitrogen

Significant difference was also noticed in the non-hydrolysable nitrogen content of soil due to treatments. Non-hydrolysable nitrogen content of soil was also found to be higher in cattle manure applied plots compared to plots which received green leaves and NPK fertilizers alone. Maximum value (793 ppm) and minimum value (505 ppm) were recorded by treatments CM + GL and NPK alone respectively. Correlation studies indicate that non-hydrolysable nitrogen content of soil is significantly related to organic carbon content of soil (r = 0.4187*).

The results obtained in this study is in conformity with the results reported by Puranik _et al_. (1978) and Udayasoorian _et al_. (1989).

2.5. Phosphorus status

Data on total P, available P and fractions of inorganic P are presented in Table 4.

2.5.1. Total phosphorus

Not much difference was noticed in the total P content of soil due to continuous application of manures and fertilizers. The values ranged from 0.039 to 0.089 per cent and the lowest value of 0.039 per cent was recorded by the treatment which had been

Table 4. Phosphorus status of soil

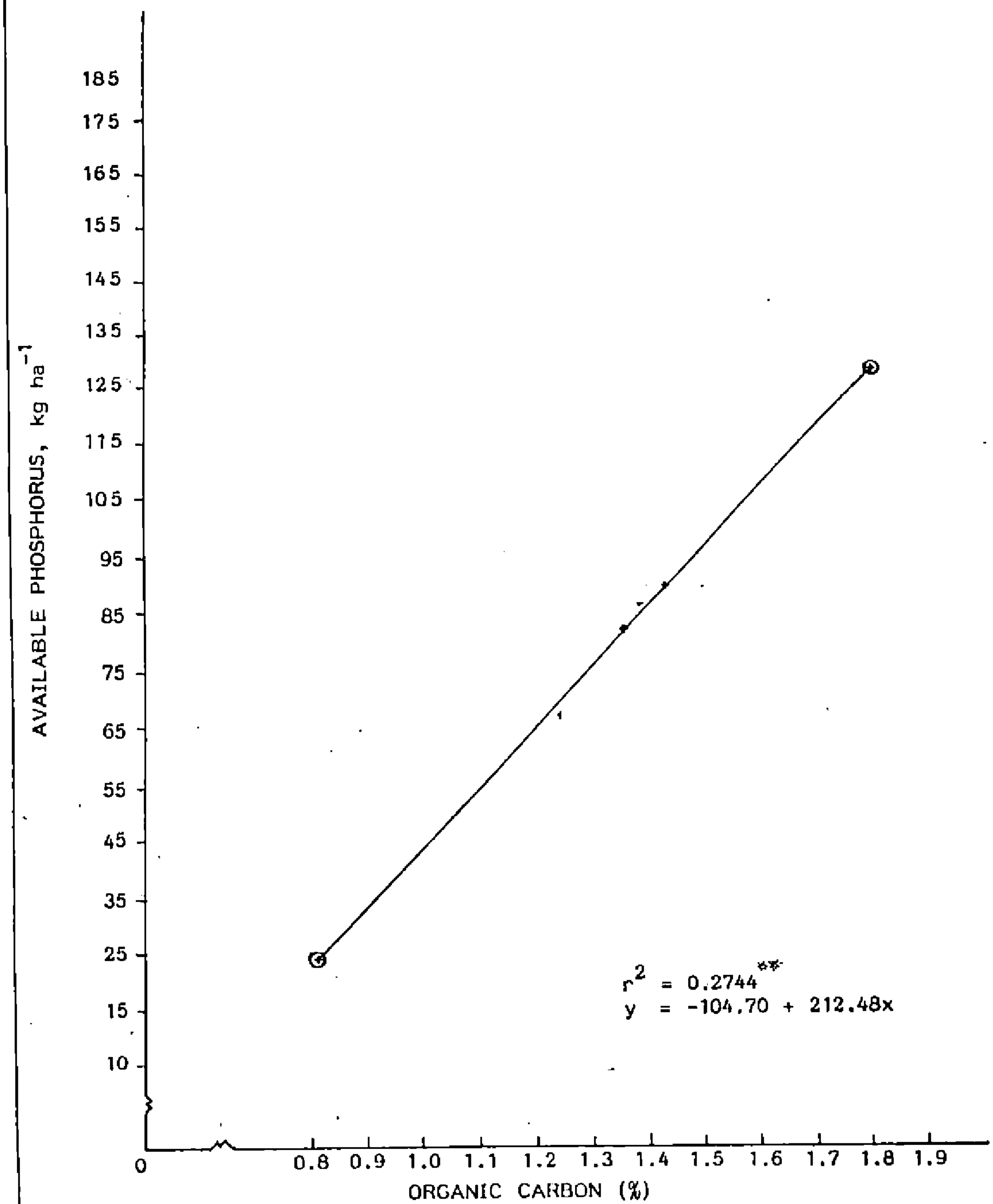
Treatment	Total phosphorus (%)	Available phosphorus, kg ha^{-1}	Fractions of phosphorus, ppm				
			Saloid-P	Fe-P	Al-P	Ca-P	Total Fe-P, Al-P and Ca-P, ppm
CM alone	0.059	132.1	1.928	116.0	33.3	19.3	168.6
GL alone	0.049	34.3	0.028	61.2	28.6	7.3	97.1
CM + GL	0.042	88.6	0.303	71.5	27.7	8.8	108.0
AS alone	0.039	39.9	0.433	55.7	20.0	5.6	81.3
CM + NPK	0.089	129.3	0.794	108.1	30.3	10.7	149.1
GL + NPK	0.056	76.8	0.159	90.6	20.5	9.8	120.9
CM + GL+ NPK	0.049	93.6	0.231	100.1	36.3	12.8	149.2
NPK alone	0.059	70.2	0.722	50.9	24.3	10.0	85.2
SEm±	0.0192	9.65	0.080	4.95	2.24	1.44	
CD (0.05)	NS	28.38	0.235	14.56	6.59	4.24	

receiving application of ammonium sulphate alone continuously for the last 34 seasons. The highest value was recorded by treatment CM + NPK. Repeated applications of the treatments for 34 seasons have not resulted in statistical difference between treatment AS alone which excluded P_2O_5 application and treatments CM + NPK, GL + NPK and NPK alone which received inorganic phosphate to supply P_2O_5 at the rate of 45 kg ha^{-1}. It is possible that because of the generally high total P status of soil, the number of applications over the years of experimentation has not been sufficient enough to bring about differences between the treatments that have included phosphate fertilizers and those that have excluded them. The result obtained in the present study is not in agreement with the results reported by Kurumthottical (1982).

2.5.2. Available phosphorus

Available P content of soil in general, was medium to high and the values ranged from 34.30 to 132.05 kg ha^{-1}. The maximum value was recorded by treatment CM alone which was followed by treatment CM + NPK and these two treatments were significantly superior to other treatments. Treatment CM + NPK was followed by treatments CM + GL + NPK, CM + GL, GL + NPK and NPK alone and there was no significant difference between these four treatments. The lowest value 34.3 kg ha^{-1} was recorded by treatment GL alone which received 90 kg N ha^{-1} as green leaves.

FIG. 4. RELATIONSHIP BETWEEN ORGANIC CARBON AND AVAILABLE PHOSPHORUS IN SOIL



The treatment which received 90 kg N ha^{-1} as ammonium sulphate alone has also recorded a low value (39.85 kg ha^{-1}) as expected and it was on par with treatment GL alone. The values recorded by treatments GL alone and AS alone were significantly lower than those recorded by the rest of the treatments. Correlation analysis indicated that significant variation existed between organic carbon and available P contents of soil ($r = 0.5238^{**}$), (Fig. 4).

In general, application of cattle manure is found to increase the availability of P while that of green leaves tends to reduce it. Cattle manure contains a higher proportion of P compared to green leaves. The cumulative effect of higher content of P in the cattle manure for 34 seasons may be one of the reasons for the increased availability of P in the treatments receiving cattle manure. Addition of organic matter has been reported to increase the availability of P. The beneficial effect of organic matter in increasing the availability of P is reported to be due to the formation of insoluble organic complexes of Fe and Al thereby preventing their reaction with phosphorus in acid soils (Tisdale and Nelson, 1975). But in the present study, the beneficial effects of addition of organic material have been noticed only in the case of cattle manure, whereas application of green leaves reduced the availability of P. In this connection, it may be noted that organic carbon content of the green manured plot was also lower and was on par with those of treatments which had received ammonium sulphate alone and NPK fertilizers alone for the last 34 seasons. The low organic carbon content of the green manured plots may be another reason for the low availability of P in these plots. Similar result of low availability of P in the green leaf applied plot was noticed in an earlier study made in the same experimental plots at Pattambi during 1981-82 (KAU, 1984).

Increase in the available P content of soil due to application of farmyard manure or combined use of NPK + FYM as obtained in this study has been reported by many workers (Havanangi and Mann, 1970; Shinde and Ghosh, 1971; Nambiar, 1985). Phosphorus depletion in the absence of P fertilization was evident in the long term fertilizer experiments with wet land rice conducted at various locations in India (Chhillar and Swarup, 1984; Nambiar, 1985).

2.5.3. Fractions of phosphorus

2.5.3.1. Saloid-P

The saloid-P content of soil was significantly influenced due to treatments. Application of the entire quantity of N in the form of cattle manure was significantly superior to the rest of the treatments. Lowest value was recorded by treatment GL alone which was on par with treatments GL + NPK and CM + GL + NPK. It is interesting to note that these treatments were followed by treatment CM + GL which also received application of green leaves. The results thus clearly indicate that application of green leaves tends to reduce the saloid-P content as the saloid-P contents of all the treatments which had received green leaves were on par and lower than that of treatment AS alone which had not been receiving any kind of P application for the last 34 seasons. The saloid-P content of soil showed the same trend as that of the available P and it varied from 0.006 to 0.326 per cent of total P.

2.5.3.2. Iron-P

Significant difference was noticed in the Fe-P content of soil also as a result of application of manures and fertilizers either alone or in combination. Application of entire quantity of N in the form of cattle manure (CM alone) recorded the maximum value (116.0 ppm). It was followed by treatment CM + NPK and these two treatments were on par. Treatments NPK alone, AS alone and GL alone recorded significantly lower values for Fe-P content. Content of Fe-P in soil also followed almost the same trend as that of available P.

2.5.3.3. Aluminium-P

Application of manures and fertilizers either alone or in combination has resulted in significant difference in the Al-P content of soil also. Highest content (36.27 ppm) was noticed in treatment + GL + NPK and it was on par with treatments CM alone and + NPK. Treatments AS alone recorded the lowest value (20.02 nd it was on par with treatments GL + NPK and NPK alone.

The results indicate that cattle manure has a tendency to increase the Al-P content of soil also.

2.5.3.4. Calcium-P

Significant difference was noticed in the Ca-P content of soil also due to different treatments. Application of the entire quantity of N in the form of cattle manure was significantly superior to other treatments. Lowest value (5.57 ppm) was recorded by treatment AS alone which was followed by treatments GL alone and CM + GL and these three treatments were statistically on par.

Results obtained on the various fractions of inorganic-P in soil indicates that all the fractions of P in soil showed a tendency to increase with cattle manure application. Phosphorus fixed as Fe, Al and Ca was found to vary from 81.3 to 168.6 ppm in the vairous treatments. Maximum fixed P was noticed in the treatment CM alone. Eventhough the fixed P is considered to be unavailable temporarily, it can become available during the changes in the physico-chemical and biological properties of soil during the growth of paddy under submerged conditions (Ponnamperuma, 1978). The higher availability of P in the CM treated plots may partly be due to the fixed P becoming available during the course of crop growth. Eventhough, total P content of soil was not influenced significantly by different treatments, it was also found to increase with cattle manure application.

Correlation studies indicate that significant correlation existed between organic carbon content and Fe-P and Ca-P contents of soil (r = 0.4563** and 0.4149* respectively). Relationship of other P fractions viz., saloid-P and Al-P with organic carbon content was non-significant.

2.6. Potassium status of soil

Data on total, available and fractions of K as influenced by continuous application of manures and fertilizers are presented in Table 5.

2.6.1. Total potassium

Application of organic manures and inorganic fertilizers either alone or in combination has failed to produce significant difference in the K content of soil. The values varied from 0.0657 per cent, recorded by treatment NPK alone to 0.0733 per cent, recorded by treatment GL + NPK. Since the soil contained high content of potassium, the treatments with potassium may not been able to bring about significant difference in spite of the K application for 34 seasons. Moreover, the applied K may be taken up by the crop, and is partly leached from the soil. The results of the study are in good agreement with those obtained in an earlier study in the same soil conducted by Kurumthottical (1982). The values obtained by him varied from 0.065 to 0.073 per cent. This indicates

Table 5. Potassium status of soil

Treatment	Total Potassium (%)	Available Potassium, kg ha^{-1}	Non-exchange-able K, cmol (p^{+}) kg^{-1}
CM alone	0.066	145.0	0.116
GL alone	0.073	145.9	0.100
CM + GL	0.066	170.0	0.136
AS alone	0.071	141.3	0.144
CM + NPK	0.071	82.5	0.120
GL + NPK	0.073	134.6	0.120
CM + GL + NPK	0.071	147.1	0.128
NPK alone	0.065	127.7	0.128
SEm±	0.0033	13.5	0.013
CD (0.05)	NS	39.88	NS

that there was no considerable variation in the total K content of soil due to application of organic manure and inorganic fertilizers with and without K for the last 10 years. It may be noted that both in the present and previous studies, lowest value of total K was recorded by treatment which received an NPK fertilizer schedule of 90:45:45 kg ha^{-1} rather than by treatment which was devoid of any kind of K application for the last 34 seasons.

2.6.2. Available potassium

Significant variation was noticed in the availability of K düe to continuous application of manures and fertilizers. But no specific trend was noticed due to application of cattle manure, green leaves and inorganic fertilizers either alone or in combination. Availability of K was maximum (170 kg ha^{-1}) in the treatment CM + GL which received application of equal amounts of cattle manure and green leaves to supply 90 kg N ha^{-1} and it was on par with all the other treatments except treatments NPK alone and CM + NPK. The treatment CM + NPK recorded the lowest value of 82.5 $kgha^{-1}$ which was significantly lower than the rest of the treatments.

In general the availability of K was medium in most of the treatments and did not decrease even in the plots which received no K either by way of organic manures or chemical fertilizers. This may be due to the continuous transfer of K from the primary minerals which contains about 90 to 98 per cent of total K in the soil to available form.

Contrary to the results obtained in the present study significant increase in the available K status of soil by application of farmyard manure was reported by several workers (Kanwar and Prihar, 1962; Singh et al., 1983; Kaushik et al., 1984). Increase in the availability of K by the application of K fertilizers was also reported by Muthuvel et al. (1977).

2.6.3.1. Non-exchangeable potassium

There was no significant difference in the non-exchangeable potassium content of soil also due to treatments. The values were found to be in the range between 0.100 cmol (p^+) kg^{-1}, recorded by treatment GL alone to 0.144 cmol (p^+) kg^{1}, recorded by treatment AS alone. The treatments which received application of potassic fertilizers also failed to record higher contents of non-exchangeable K. Kurumthottical (1982) has also observed nonsignificant influence of treatments on non-exchangeable K content of soil. This nonsignificant effect of different treatments may be due to the high content of non-exchangeable as well as total potassium in soil.

The results obtained in this study is not in accordance with the results reported by Lal et al. (1990) who has reported increase in the non-exchangeable K in the fertilized and manured plots.

2.7. Calcium status of soil

Data on total and exchangeable Ca content of soil as influenced by long term application of manures and fertilizers are presented in Table 6.

2.7.1. Total calcium

No significant variation was noticed in the total Ca content of soil due to different treatments. The values ranged from 0.015 to 0.024 per cent recorded by treatments NPK alone and CM alone respectively. Based on the study conducted in the same experimental plots at Pattambi, Kurumthottical (1982) has also reported similar results. The values recorded then varied from 0.013 to 0.019 per cent. Both in the previous and present studies, maximum Ca content was noticed in treatment CM alone which received application of cattle manure at the rate of 18 t ha^{-1}.

Contrary to the results obtained in this study Shinde and Ghosh (1971) reported increase in the Ca content of soil due to continuous cropping and manuring.

2.7.2. Exchangeable calcium

Exchangeable Ca content of soil was also found to be uninfluenced by continuous application of manures and fertilizers. The values varied from 0.516 to 0.688 cmol (p^{+}) kg^{-1} which were recorded by treatments AS alone and CM + GL + NPK respectively.

Prasad and Singh (1980) noted a decreased exchangeable calcium content of soil by about half by ammonium sulphate application

Table 6. Calcium and Magnesium status of soil

Treatment	Calcium		Magnesium	
	Total (%)	Exchangeable, cmol $(p^+) kg^{-1}$	Total (%)	Exchangeable, cmol $(p^+) kg^{-1}$
CM alone	0.024	0.652	0.067	0.287
GL alone	0.020	0.567	0.072	0.170
CM + GL	0.019	0.619	0.071	0.286
AS alone	0.020	0.516	0.073	0.184
CM + NPK	0.020	0.527	0.066	0.190
GL + NPK	0.019	0.584	0.074	0.138
CM + GL + NPK	0.021	0.688	0.059	0.295
NPK alone	0.015	0.567	0.072	0.117
SEm±	0.0022	0.0550	0.0146	0.0065
CD (0.05)	NS	NS	NS	0.0190

while FYM and NPK either increased or retained the initial status of exchangeable calcium. Thus the results of the present study are in conformity with the general trend established in permanent manurial experiments elsewhere. The low exchangeable calcium content in the ammonium sulphate applied plot indicates the decalcifying power of ammonium sulphate under conditions of water logging and leaching.

2.8. Magnesium status of soil

The results of the total and exchangeable Mg content of soil are presented in Table 6.

2.8.1. Total magnesium

Total Mg content of soil was uninfluenced by different treatments. The values varied from 0.059 to 0.073 per cent, recorded by treatments CM + GL + NPK and AS alone respectively.

Similar results have been reported by Shinde and Ghosh (1971) and Kurumthottical (1982).

2.8.2. Exchangeable magnesium

Significant variation was observed in the exchangeable Mg content of soil due to continuous application of manures and fertilizers. Treatments CM + GL + NPK, CM alone and CM + NPK were significantly superior to all other treatments. All these treatments involved addition of cattle manure. The treatment, NPK alone which received an NPK fertilizer dose of 90:45:45 kg ha^{-1} recorded significantly lower value than the rest of the treatments. It was followed by treatment which received a combination of green leaves and NPK fertilizers (GL + NPK). The results thus indicate the favourable influence of cattle manure in increasing the exchangeable Mg content of soils also. This is in conformity with the results reported by Kurumthottical (1982).

2.9. Micronutrient status

Data on available micronutrient content of soil viz., Fe, Mn, Cu and Zn as influenced by long term application of manures and fertilizers are presented in Table 7.

2.9.1. Available iron

Continuous application of manures and fertilizers failed to cause significant variation in the available Fe content of soil. The values varied from 354 to 402 ppm, recorded by treatments CM + GL and CM alone respectively. These values are found to be very high when compared to the critical value of 2 ppm reported by Agarwala and Sharma (1979).

2.9.2. Available manganese

Significant variation was noticed in the availability of Mn

Table 7. Micronutrient status of soil

Treatment	Available micronutrients, ppm			
	Fe	Mn	Cu	Zn
CM alone	402	44.08	2.82	6.02
GL alone	368	31.98	1.48	2.08
CM + GL	354	39.21	2.92	3.40
AS alone	382	30.02	1.24	2.22
CM + NPK	399	37.62	2.32	2.64
GL + NPK	391	34.52	2.40	4.21
CM + GL + NPK	361	38.90	2.32	1.59
NPK alone	372	29.09	1.26	1.60
SEm±	14.21	2.78	0.59	0.65
CD (0.05)	NS	8.176	NS	1.912

in soil due to treatments. The maximum and minimum values (44.08 ppm and 29.09 ppm respectively) were recorded by treatments CM alone and NPK alone respectively. Plots which received application of cattle manure registered significantly higher contents of available Mn in soil than those which received NPK fertilizers alone.

The above observation is in conformity with the results reported by Maurya and Ghosh (1972).

The available Mn content of soil was found to be high as the values obtained are well above the critical level of one ppm reported by Randhava et al. (1978).

2.9.3. Available copper

The data revealed that the effects of the treatments were not significant in the available Cu content in the soil. The values were found to be in the range between 1.24 to 2.92 ppm, recorded by treatments AS alone and CM + GL respectively. These values are high as the critical level of Cu in rice soil is only 0.2 ppm (Randhava et al., 1978).

2.9.4. Available zinc

Continuous application of manures and fertilizers has resulted in significant variation in the available Zn content of soil. Maximum content of available Zn (6.02 ppm) was noticed in treatment CM alone. It was followed by treatments GL + NPK and CM + GL. Comparatively lower values were reported for treatments AS alone and NPK alone. Increase in the availability of Zn due to application of farmyard manure has been reported by many workers (Sharma and Meelu, 1975; Kurumthottical, 1982; Prasad and Sinha, 1982). The critical value of Zn in rice soils is 1.5 ppm (Sims and Patrick, 1978). The values obtained in the study ranged from 1.59 to 6.02 ppm.

3. Effect of long term application of manures and fertilizers on chemical characteristics of soil at different stages of crop growth

3.1. Soil reaction

Data relating to the pH of the soil at different stages of crop growth viz., tillering, panicle initiation, 50 per cent flowering and harvest as influenced by long term application of manures and fertilizers are presented in Table 8.

The results indicated that application of organic manures and inorganic fertilizers either alone or in different combination had no significant influence on pH of the soil at any of the growth stages studied. The values at tillering, panicle initiation, 50 per cent flowering and harvest were found to vary from 6.1 to 6.3, 6.0 to 6.2, 6.1 to 6.3 and 5.9 to 6.2 respectively.

No significant variation was noticed in the soil collected before planting also due to continuous application of manures and fertilizers for 34 seasons.

Table 8. Soil reaction at various stages of crop growth

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	6.2	6.2	6.1	6.1
GL alone	6.3	6.2	6.2	6.2
CM + GL	6.2	6.1	6.3	6.2
AS alone	6.1	6.1	6.1	5.9
CM + NPK	6.1	6.0	6.1	6.0
GL + NPK	6.1	6.1	6.2	6.2
CM + GL + NPK	6.1	6.1	6.2	6.1
NPK alone	6.1	6.1	6.1	6.0
SEm±	0.09	0.13	0.14	0.09
CD (0.05)	NS	NS	NS	NS

3.2. Cation exchange capacity

Data on cation exchange capacity of soil at different stages of crop growth are presented in Table 9.

In all stages of crop growth studied, cation exchange capacity of soil was found to be uninfluenced by long term application of manures and fertilizers, alone or in combination. The values at tillering, panicle initiation, 50 per cent flowering and harvest varied from 9.12 to 11.14, 8.55 to 13.31, 8.51 to 13.59 and 7.28 to 14.03 cmol (p^+) kg^{-1} respectively.

In the initial soil samples collected also the effects of the treatments were not significantly different.

3.3. Organic carbon

Table 10 presents data on organic carbon content of soil at different stages of crop growth.

Results indicated that application of manures and fertilizers continuously for the last 34 seasons had influenced significantly the organic carbon content of soil at all stages of crop growth. In the initial stages of growth, viz., tillering and panicle initiation, the treatments CM + GL, GL alone, GL + NPK and CM + NPK had recorded comparatively higher organic carbon content and were statistically on par. But as the stage of growth advanced

Table 9. Cation exchange capacity of soil at different stages of crop growth, cmol (p^+) kg^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	10.46	10.60	11.90	12.90
GL alone	9.95	11.07	11.72	12.74
CM + GL	11.14	11.66	12.36	9.55
AS alone	9.45	9.75	8.51	11.28
CM + NPK	9.66	13.31	9.56	7.28
GL + NPK	9.12	10.07	13.11	14.03
CM + GL + NPK	10.37	11.15	13.59	9.32
NPK alone	9.17	8.55	9.85	8.69
SEm±	1.451	1.047	1.719	1.882
CD (0.05)	NS	NS	NS	NS

Table 10. Organic carbon content of soil at various stages of crop growth, per cent

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	1.17	1.15	1.40	1.54
GL alone	1.23	1.29	1.10	0.99
CM + GL	1.25	1.26	1.44	1.22
AS alone	1.00	1.09	0.94	0.97
CM + NPK	1.12	1.20	1.36	1.21
GL + NPK	1.23	1.20	0.97	1.10
GM + GL + NPK	1.10	1.16	1.02	1.00
NPK alone	0.98	1.01	0.92	0.91
SEm±	0.045	0.049	0.059	0.062
CD (0.05)	0.132	0.143	0.172	0.182

and when the crops attained 50 per cent flowering, the treatments CM + GL, CM alone and CM + NPK continued to maintain higher organic carbon content and they were significantly superior to all other treatments including treatments GL alone and GL + NPK. Though these three treatments continued to maintain comparatively high organic carbon content, the treatment CM alone became significantly superior to the other two treatments at harvest.

At all stages of crop growth studied, lowest organic carbon content was recorded by treatment NPK alone which was followed by treatment AS alone. These two treatments had been receiving only inorganic fertilizers for the last 34 seasons.

The results revealed that though application of green leaves and cowdung has given almost similar organic carbon content in the initial stages of crop growth, green leaf manured plots showed a decreasing trend in respect to organic carbon content towards later stages. The decomposition rate of green leaves is higher compared to cattle manure and that may be the reason for the comparatively lower organic carbon content noticed in the green manured plot in the later stages of crop growth. The trend of the results obtained at the harvest stage is similar to that noticed in the initial soil sample collected also as the application of cattle manure showed a tendency to increase the organic carbon content of soil compared to application of green leaves. Based on the studies conducted at Pusa, Singh (1967) also reported similar results.

3.4. Available nitrogen

Data on available N content of soil at different stages of crop growth are presented in Table 11.

Available N content of soil was found to be medium at all stages of crop growth. No significant variation was noticed in the availability of N due to different treatments at any of the growth stages studied. The results failed to reveal any specific trend also with regard to the availability of N at different stages due to different treatments. Similar result was obtained for the available N content of soil taken before planting of soil also.

3.5. Available phosphorus

Availability of P in all the treatments was medium to high at all stages of crop growth (Table 12). Continuous application of manures and fertilizers for the last 34 seasons had resulted in significant variation in the available P content of soil at all the stages of the crop growth studied. The treatment CM alone recorded the highest available P content at all stages and it was followed

Table 11. Available nitrogen content of soil at various stages of crop growth, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	374.0	342.6	377.6	382.0
GL alone	348.0	413.7	368.5	310.0
CM + GL	369.5	346.2	363.9	325.7
AS alone	340.2	346.2	381.6	305.2
CM + NPK	395.1	378.0	435.2	415.3
GL + NPK	365.4	302.1	419.4	327.8
CM + GL + NPK	319.5	357.9	415.8	370.3
NPK alone	331.2	320.4	378.0	302.1
SEm±	18.12	23.20	33.8	29.5
CD (0.05)	NS	NS	NS	NS

Table 12. Available phosphorus content of soil at various stages of crop growth, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	163.3	161.2	173.2	153.8
GL alone	39.0	29.1	39.3	27.6
CM + GL	107.2	70.2	47.9	55.0
AS alone	46.0	36.8	30.2	31.9
CM + NPK	159.9	96.9	104.8	78.9
GL + NPK	94.7	77.4	51.0	67.7
CM + GL + NPK	117.8	57.3	94.7	54.4
NPK alone	86.9	80.1	85.7	64.5
SEm±	11.40	17.38	24.10	10.69
CD (0.05)	33.53	51.12	70.88	31.44

by. treatment CM + NPK. At panicle initiation and at 'vest, treatment CM alone was significantly superior to all other t tments.

Lowest available P content was recorded by reatment GL alone at all the growth stages and it was followed by treatment AS alone.

The results indicated that application of cattle manure increased the availability of P whereas green leaf application reduced the availability. Similar results were obtained in the initial sample collected before planting of crops also.

3.6. Available potassium

Data on available K content of soil at different stages of crop growth are presented in Table 13. Significant variation was noticed in the available K content of soil at all stages. Available K content of soil of all the treatments except AS alone and NPK alone were found to be in the medium range at all the growth stages. Though no definite trend was noticed in the available K due to different treatments at various growth stages, the treatments AS alone and NPK alone which were devoid of organic matter application had recorded low values at all the growth stages. Of these two treatments, treatment NPK alone had received application of K fertilizers to supply K_2O at the rate of 45 kg ha^{-1}. This supports the view of Kanwar and Prihar (1962) who found increase in the available K status of soil by farmyard manure treatment.

Table 13. Available potassium content of soil at various growth stages of crop growth, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	199.1	124.8	145.2	225.7
GL alone	215.9	176.5	153.0	118.5
CM + GL	211.7	134.1	143.9	149.1
AS alone	143.8	119.0	122.4	98.5
CM + NPK	208.9	124.0	158.1	138.9
GL + NPK	205.0	138.4	116.5	129.9
CM + GL + NPK	207.6	135.0	149.7	158.7
NPK alone	132.6	106.4	136.1	108.8
SEm±	12.6	5.72	7.77	7.46
CD (0.05)	37.11	16.83	10.99	21.94

This they attributed to the K contained in the manures and the greater capacity of organic colloids to hold cations on the exchange surface. The results in the present study also indicate that application of organic manures is required to maintain a significantly higher content of available K in the soil.

In the iniitial soil sample collected before planting also, the treatment NPK alone had recorded low availability of K.

3.7. Exchangeable calcium

Table 14 presents data on exchangeable Ca content of soil at different stages of crop growth.

The effect of treatments on exchangeable Ca content of soil was significant only at the initial stages of crop growth viz., tillering and panicle initiation. Eventhough no regular pattern could be identified on the exchangeable Ca content of soil due to different treatments, the treatment which consisted of application of ammonium sulphate alone, recorded the lowest value at all stages. The result thus indicates the decalcifying power of ammonium sulphate under conditions of intense leaching. Similar trend was noticed in the initial soil sample also.

3.8. Exchangeable magnesium

At all stages of crop growth, exchangeable Mg content of

Table 14. Exchangeable calcium content of soil at various stages of crop growth, cmol (p+) kg^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	0.710	0.686	0.550	0.546
GL alone	0.636	0.573	0.464	0.442
CM + GL	0.665	0.533	0.516	0.499
AS alone	0.533	0.503	0.484	0.407
CM + NPK	0.665	0.619	0.584	0.559
GL + NPK	0.567	0.527	0.481	0.413
CM + GL + NPK	0.602	0.661	0.464	0.499
NPK alone	0.705	0.584	0.395	0.413
SEm±	0.036	0.038	0.038	0.157
CD (0.05)	0.1060	0.1130	NS	NS

Table 15. Exchangeable magnesium content of soil at various stages of crop growth, cmol (p^{+}) kg^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Harvest
CM alone	0.287	0.275	0.269	0.270
GL alone	0.179	0.170	0.158	0.156
CM + GL	0.292	0.251	0.269	0.248
AS alone	0.186	0.147	0.152	0.145
CM + NPK	0.187	0.220	0.200	0.196
GL + NPK	0.141	0.144	0.142	0.304
CM + GL + NPK	0.287	0.305	0.301	0.143
NPK alone	0.117	0.127	0.127	0.118
SEm±	0.054	0.0110	0.0042	0.0036
CD (0.05)	0.0160	0.0320	0.0120	0.0112

soil was influenced significantly by continuous application of manures and fertilizers (Table 15). The treatments CM alone, CM + NPK, CM + GL and CM + GL + NPK recorded comparatively higher values in most of the growth stages. These treatments had received application of varying quantities of cattle manure. The lowest content of exchangeable Mg was noticed at all the growth stages in the treatment which received application of NPK fertilizers alone. Treatments GL alone and GL + NPK which received fairly large quantities of N as green leaves and treatment AS alone recorded comparatively lower values in most of the stages.

The results indicated that application of cattle manure has a favourable influence in increasing the exchangeable magnesium content of soil compared to green leaves.

4. Effect of long term application of manures and fertilizers on crop response

4.1. Yield of grain, straw and dry matter

Data on yield of dry matter at different growth stages viz., tillering, panicle initiation and 50 per cent flowering and yield of grain and straw are presented in Table 16.

All the treatments which have received NPK fertilizers along with organic manures (GL + NPK, CM + GL + NPK and CM + NPK) have recorded comparatively higher dry matter yield at tillering, panicle initiation and 50 per cent flowering. The treatment AS alone recorded the lowest dry matter yield at all the growth stages.

Table 16. Yield of dry matter at different growth stages, grain and straw, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw
CM alone	957	3881	6692	4067	3480
GL alone	1008	4123	6264	2737	2804
CM + GL	772	3747	6263	3451	3205
AS alone	565	2369	5459	2093	2457
CM + NPK	1031	4671	6779	3583	3162
GL + NPK	1365	4256	7282	2384	2516
CM + GL + NPK	1110	5183	8418	3168	2861
NPK alone	1001	3872	5995	2432	2928
SEm±	122	367	507	110	165
CD (0.05)	358	1080	1492	326	486

Data on grain yield obtained indicated that treatment CM alone has recorded the maximum value and it was significantly superior to all other treatments. The growth of crop under this treatment was comparatively low at tillering stage but it steadily improved with advancement in growth stage. Treatment CM alone was followed by treatment CM + NPK in respect to grain yield and this treatment maintained comparatively better growth throughout the growing period. Treatment CM + GL has also recorded higher yield of grain. The growth of crop under this treatment was also low in the initial stages and it improved later as in the case of treatment CM alone. It may be noted that all these treatments which have recorded comparatively higher grain yields received cattle manure at the rate equal to or more than 9 t ha^{-1}. The results thus clearly indicates that application of cattle manure along with inorganic fertilizers is essential to maintain high yields. The beneficial effect of cattle manure is due to its favourable influence on bulk density, organic carbon content, available P and exchangeable Mg.

The lowest grain yield was noticed in the treatment AS alone which recorded the lowest dry matter yield at all stages. This is quite natural as this treatment does not include P and K either from organic or inorganic sources. Continuous crop removal of major nutrients might have depleted these nutrients from soil. The results of the analysis of the soil samples indicated that CEC, organic carbon content, available P, available K and exchangeable Ca and

Mg were lower in this treatment compared to the other treatments. Experiments conducted at IRRI in Phillipines confirmed this result. Though the high yielding varieties showed high response to N, their efficiency decreased considerably over the years in plots receiving no P or K (IRRI, 1976). Eventhough treatments CM + GL + NPK, GL alone and GL + NPK recorded better growth in the initial stage, they failed to give higher grain yield. These treatments received at least 22.5 kg N ha^{-1} in the form of green leaves. Application of green leaves was found to decrease the available P in the soil considerably. Eventhough, the available P content of these plots remained above the critical level at all growth stages, the yield of grain showed high correlation with available P content. The treatment NPK alone also recorded comparatively low grain yield. This treatment had received inorganic fertilizers only indicating the significance of organic manures in increasing the yield. Pooled analysis of the yield data from 1973 to 1985 for the Virippu crop season also showed the superiority of cattle manure application in increasing the yield and the failure of green leaf application to record a higher yield in all the seasons (KAU, 1991). Beneficial effects of cattle manure have been reported by Shinde and Ghosh (1971), Kurumthottical (1982) and Udayasoorian (1988) in increasing the yield of rice in the long term experiments conducted at Bagwai, Pattambi and Coimbatore respectively. Ponnamperuma (1964) attributed the low yield consequent to green manuring of flooded acid soils as mainly due to the higher

FIG. 5. RELATIONSHIP BETWEEN ORGANIC CARBON IN SOIL AND GRAIN YIELD

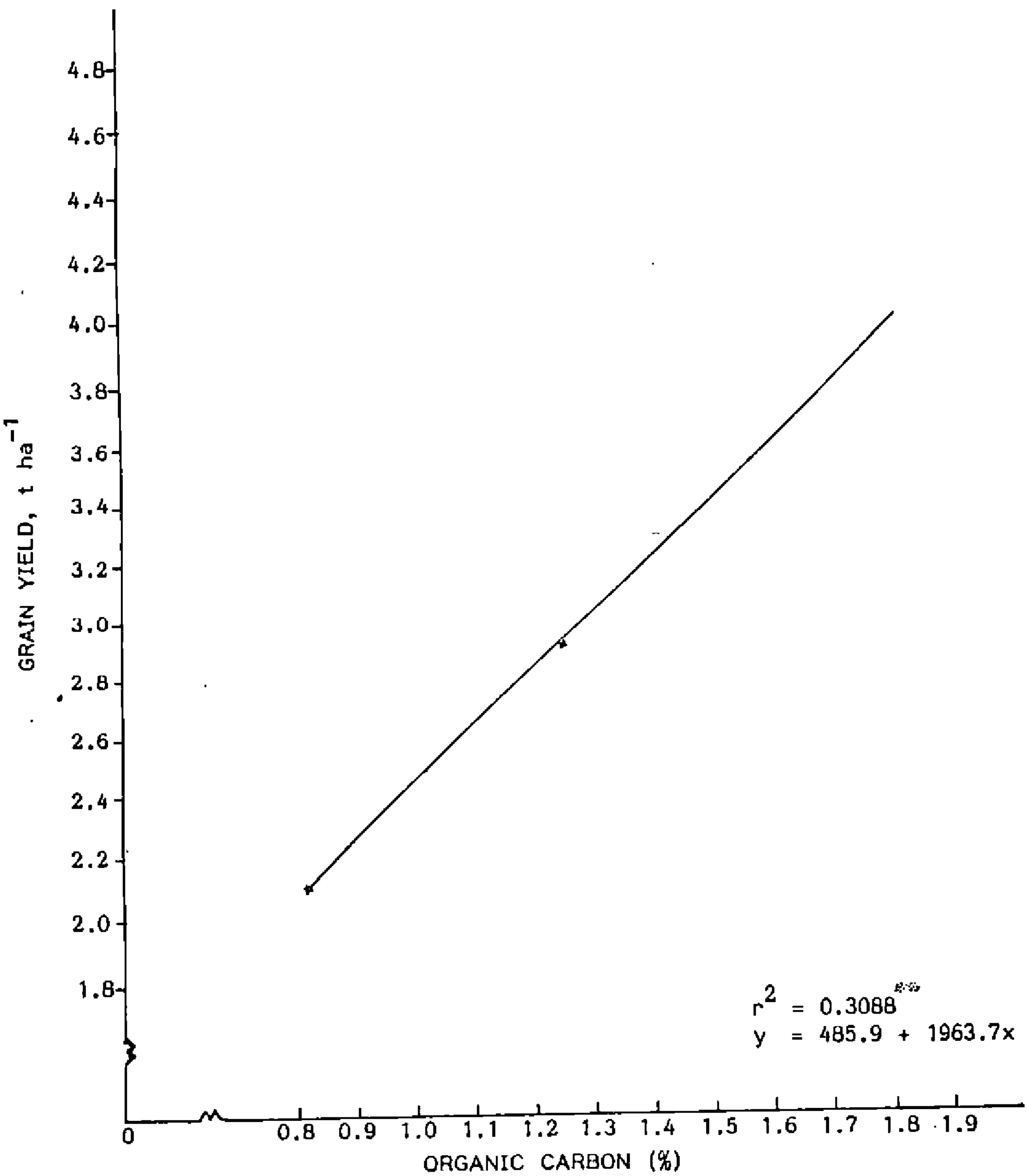
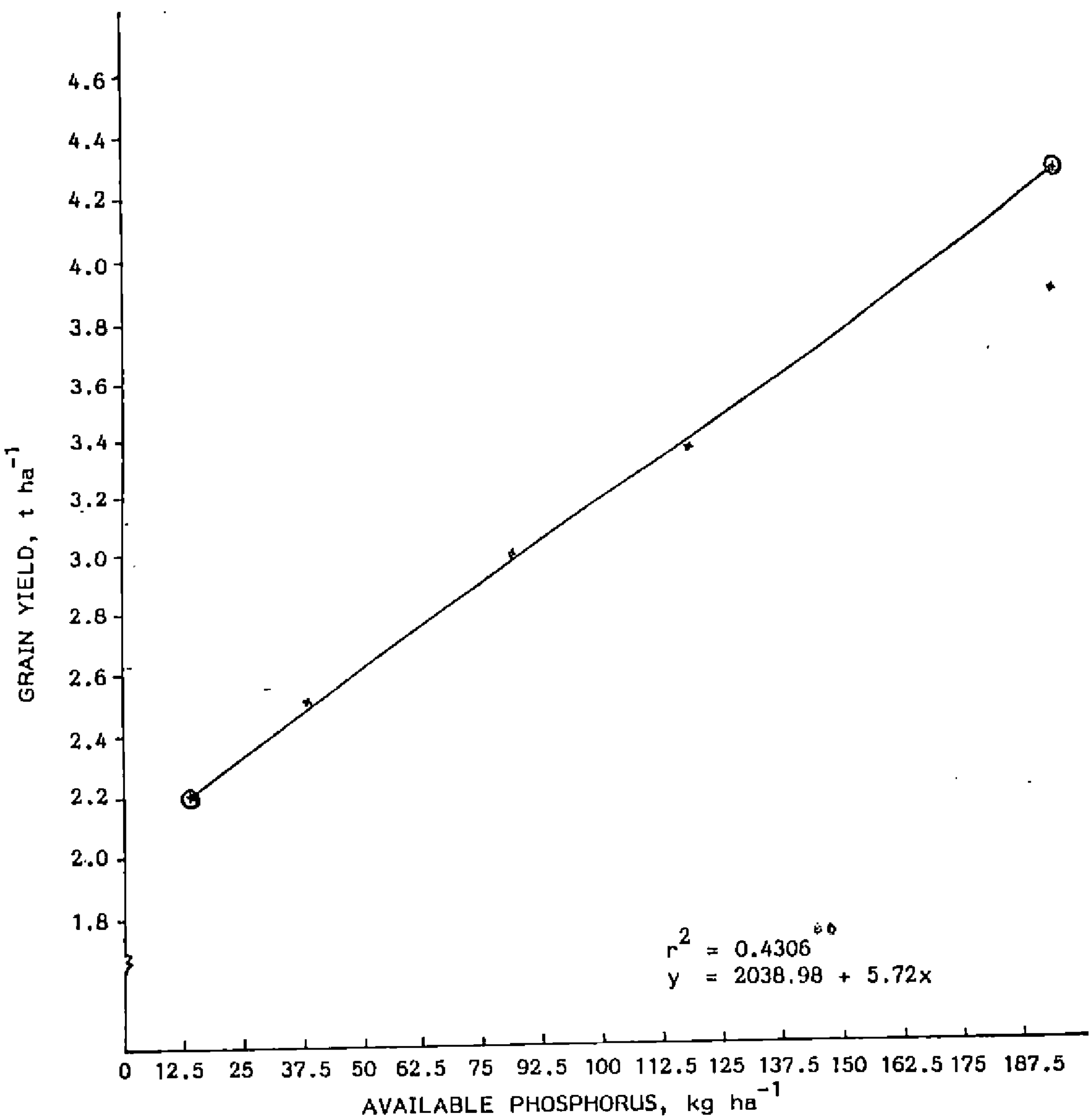


FIG. 6. RELATIONSHIP BETWEEN AVAILABLE PHOSPHORUS IN SOIL AND GRAIN YIELD



concentration of CO_2 lowering the uptake of nutrients and bringing about in consequence a low yield.

The yield of straw also maintained a trend similar to that of grain. Treatments CM alone and AS alone recorded highest and lowest values respectively.

In this context, it may be noted that organic carbon and available P contents of soil were high with cattle manure application and significant correlation existed between organic carbon content and available P content of soil with grain yield (r = 0.5557** and 0.6562** respectively), (Fig. 5 and 6).

4.2. Nutrient content

Data relating to the major and secondary nutrient content of crop at different growth stages viz., tillering, panicle initiation, 50 per cent flowering and harvest as influenced by long term application of manures and fertilizers are presented in Table 17 to 21.

4.2.1. Nitrogen content

Not much variation was noticed in the N content of the crop at any of the stages of growth due to continuous application of manures and fertilizers (Table 17). This may be attributed to the high availability of N in the soil. The values recorded at tillering,

Table 17. Nitrogen content in plant at different growth stages, per cent

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw
CM alone	2.79	1.58	1.22	1.27	0.886
GL alone	3.63	1.58	1.16	1.47	0.742
CM + GL	2.94	1.33	1.32	1.50	0.767
AS alone	3.81	1.92	1.16	1.56	0.903
CM + NPK	3.05	1.37	1.15	1.36	0.838
GL + NPK	3.05	1.45	1.22	1.60	0.539
CM + GL + NPK	2.88	1.52	1.23	1.54	0.889
NPK alone	2.93	1.58	1.41	1.24	0.704
SEm±	0.0263	0.116	0.869	0.122	0.161
CD (0.05)	NS	NS	NS	NS	NS

panicle initiation and 50 per cent flowering varied from 2.88 to 3.81, 1.33 to 1.92 and 1.15 to 1.32 per cent respectively. The N content in grain and straw varied from 1.27 to 1.60 and 0.539 to 0.903 per cent respectively.

4.2.2. Phosphorus content

Continuous application of manures and fertilizers has resulted in highly significant variation in the P content of crop at all the stages of growth (Table 18).

Treatments which received application of cattle manure either alone or in combination with NPK fertilizers or green leaves or a combination of all these (treatments CM alone, CM + NPK, CM + GL and CM + GL + NPK respectively) recorded comparatively higher content of P at all the stages. Application of ammonium sulphate alone recorded the lowest content of P at all stages and it was on par with the treatment which received application of green leaf alone.

In this connection, it may be noted that the treatments which have recorded a higher content of P in the plant recorded comparatively higher yield and highly significant correlation existed between available P content of soil and yield (r = 0.6562**).

From the above observations, it may be concluded that availability of P in the soil is an important factor that controls the yield of paddy.

Table 18. Phosphorus content in plant at different growth stages, per cent

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw
CM alone	0.349	0.285	0.241	0.289	0.201
GL alone	0.221	0.240	0.208	0.229	0.136
CM + GL	0.326	0.285	0.245	0.286	0.171
AS alone	0.217	0.217	0.182	0.223	0.134
CM + NPK	0.343	0.295	0.243	0.263	0.201
GL + NPK	0.286	0.260	0.211	0.269	0.176
CM + GL + NPK	0.333	0.278	0.220	0.284	0.192
NPK alone	0.278	0.288	0.225	0.247	0.183
SEm±	0.015	0.010	0.009	0.015	0.009
CD (0.05)	0.0441	0.0294	0.0255	0.0441	0.0255

4.2.3. Potassium content

Significant influence was not noticed due to different treatments in the K content of crop at any of the stages of growth (Table 19). The values recorded at tillering, panicle initiation and 50 per cent flowering varied from 2.53 to 3.48, 2.18 to 2.65 and 1.48 to 1.75 per cent respectively. At harvest, K content in grain and straw ranged from 0.265 to 0.467 and 1.58 to 1.93 per cent respectively. This non-significant effect of treatment may be due to the high availability of K in the soil associated with different treatments.

4.2.4. Calcium content

Influence of long term application of manures and fertilizers in the Ca content was significant only at tillering and panicle initiation stages (Table 20). At tillering, maximum value was recorded for applicatioon of green leaf alone (3.67 per cent) which was followed by application of ammonium sulphate alone. These two treatments recorded comparatively higher values at panicle initiation stage also. Calcium content in grain and straw was found to be uninfluenced by different treatments. Though significant difference in the Ca content was noticed at the initial growth stages, no similarity was noticed between patterns of availability in the soil and Ca content in crop.

Table 19. Potassium content in plant at different growth stages, per cent

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw
CM alone	2.78	2.45	1.60	0.365	1.93
GL alone	3.30	2.58	1.58	0.265	1.70
CM + GL	3.38	2.65	1.60	0.350	1.83
AS alone	2.61	2.45	1.75	0.300	1.65
CM + NPK	3.10	2.48	1.65	0.313	1.78
GL + NPK	3.48	2.50	1.48	0.301	1.58
CM + GL + NPK	3.25	2.18	1.73	0.467	1.90
NPK alone	2.53	2.15	1.58	0.325	1.70
SEm±	0.41	0.16	0.07	0.019	0.08
CD (0.05)	NS	NS	NS	NS	NS

Table 20. Calcium content in plant at different growth stages, per cent

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw
CM alone	0.279	0.428	0.319	0.189	0.478
GL alone	0.369	0.518	0.319	0.154	0.498
CM + GL	0.133	0.292	0.329	0.189	0.458
AS alone	0.309	0.465	0.398	0.189	0.528
CM + NPK	0.289	0.239	0.279	0.159	0.438
GL + NPK	0.249	0.259	0.309	0.166	0.563
CM + GL + NPK	0.239	0.349	0.299	0.149	0.428
NPK alone	0.279	0.628	0.319	0.189	0.448
SEm±	0.031	0.072	0.003	0.013	0.031
CD (0.05)	0.0918	0.2111	NS	NS	NS

4.2.5. Magnesium content

Only at panicle initiation stage, continuous application of manures and fertilizers had significant influence in Mg content of crop (Table 21). Eventhough significant difference was noticed in the exchangeable Mg content of soil at tillering, 50 per cent flowering and harvest, it was not reflected in the Mg content of crop at the respective growth stages.

4.2.6. Micronutrient content

Data on the content of micronutrients viz., Fe, Mn, Cu and Zn in grain and straw are presented in Table 22. Significant effect of continuous application of manures and fertilizers was noticed only in Mn content in straw. Treatments which received application of N as cattle manure alone and as equal amounts of cattle manure and NPK fertilizers were significantly superior to all other treatments. Significant variation noticed in the available Zn content of soil was not reflected in the content of this micronutrient in grain and straw. In general, the content of all the micronutrients studied was found to be higher than the critical levels fixed for each. Micronutrient contents in the soil was high and that may be the reason for the failure of the long term application of manures and fertilizers to produce a significant change in their contents in grain and straw.

Table 21. Magnesium content in plant at different growth stages, per cent

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw
CM alone	0.165	0.089	0.105	0.066	0.239
GL alone	0.108	0.088	0.120	0.060	0.279
CM + GL	0.149	0.136	0.093	0.066	0.229
AS alone	0.176	0.124	0.120	0.033	0.289
CM + NPK	0.123	0.158	0.132	0.093	0.249
GL + NPK	0.149	0.167	0.114	0.050	0.319
CM + GL + NPK	0.173	0.126	0.114	0.080	0.209
NPK alone	0.149	0.124	0.135	0.040	0.279
SEm±	0.018	0.017	0.015	0.015	0.036
CD (0.05)	NS	0.0488	NS	NS	NS

Table 22. Micronutrient content in grain and straw, ppm

Treatment	Grain				Straw			
	Fe	Mn	Cu	Zn	Fe	Mn	Cu	Zn
CM alone	34.21	58.60	17.11	16.51	360	359	21.31	39.21
GL alone	29.80	49.11	12.29	17.13	310	212	18.62	38.54
CM + GL	36.00	48.23	9.94	16.60	298	274	18.20	38.52
AS alone	44.01	48.33	10.75	16.04	364	216	14.50	33.00
CM + NPK	34.98	54.11	19.54	16.09	389	359	16.20	42.50
GL + NPK	41.16	50.08	16.10	16.31	399	174	14.21	45.75
CM + GL + NPK	41.16	47.22	13.83	16.39	339	166	18.80	42.20
NPK alone	74.99	50.08	11.83	22.46	362	159	18.01	31.89
SEm±	13.21	5.41	2.28	1.14	360	24	2.40	5.82
CD (0.05)	NS	NS	NS	NS	NS	71.9	NS	NS

4.3. Nutrient uptake

Data on uptake of major and secondary nutrients by the crop at different growth stages are presented in Table 23 to 27. Uptake of micronutrients by grain and straw are presented in Table 28.

4.3.1. Nitrogen uptake

Significant variation was noticed only in the uptake of N by grain (Table 23). Significant difference noticed in the dry weight of crop at different growth stages and in straw yield was not reflected on the uptake values. It may be due to the non-significant difference in the N content of plants at different growth stages due to various treatments.

Significant difference noticed in the uptake values of N by grain indicates the greater influence of grain yield on uptake values as there was no significant difference in the nitrogen content of grain. Uptake of N by grain was maximum in treatment CM alone which was on par with treatments CM + GL, CM + NPK, CM + GL + NPK and GL alone. Uptake was minimum in treatment NPK alone which was followed by treatments AS alone and GL + NPK. The results thus clearly indicate that treatments which have received substantial quantity of cattle manure have recorded higher uptake values. The better grain yield obtained in the cattle manured plots have resulted in greater uptake values.

Table 23. Uptake of nitrogen by plant at different growth stages and by grain and straw, kg ha^{-1}

Treatment	Tillering	Panicle initiat-ion	50 per cent flowering	Grain	Straw	Total at harvest
CM alone	26.71	66.32	80.32	52.12	30.60	82.72
GL alone	36.70	65.84	74.10	40.31	20.42	60.73
CM + GL	20.72	48.45	89.41	51.74	24.21	75.95
AS alone	20.61	46.71	63.72	32.42	22.03	54.45
CM + NPK	31.61	64.10	71.81	48.81	25.90	74.71
GL + NPK	38.11	61.71	89.72	38.31	14.21	52.52
CM+GL+NPK	29.53	79.02	103.30	48.48	25.52	74.00
NPK alone	29.64	59.90	83.81	31.20	21.51	52.71
SEm±	4.20	7.51	13.60	4.21	6.12	7.23
CD (0.05)	NS	NS	NS	12.39	NS	21.34

4.3.2. Phosphorus uptake

Significant variation was noticed in the uptake of P by the crop at all the growth stages (Table 24).

At tillering, maximum uptake value (3.90 kg ha^{-1}) was recorded by treatment GL + NPK and it was on par with all other treatments except AS and GL treatments. Minimum uptake (1.25 kg ha^{-1}) was noticed in treatment AS alone which was on par with treatment GL alone. At panicle initiation and 50 per cent flowering, uptake was maximum in treatment GM + GL + NPK and it was on par with all other treatments except treatments AS alone and GL alone as in the tillering stage. Minimum uptake in both the cases was recorded by treatment AS alone which was on par with treatment GL alone as in the tillering stage. The low uptake of P of the treatment AS alone is due to a decrease in dry matter yield as well as low P content whereas the low uptake in the treatment GL alone is mainly due to the low P content of the crop. At harvest, treatment CM alone recorded significantly superior value than all other treatments in the case of grain. The same treatment recorded maximum value for straw also.

4.3.3. Potassium uptake

Eventhough not much difference was noticed in the K content of crop at different growth stages and in grain and straw due to treatments, significant variation was observed in the uptake of K

Table 24. Uptake of phosphorus by plant at different growth stages and by grain and straw, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw	Total at harvest
CM alone	3.29	11.10	16.12	11.81	7.01	18.82
GL alone	2.22	7.39	13.15	6.30	3.81	10.11
CM + GL	2.52	11.33	16.69	9.92	5.39	15.31
AS alone	1.25	5.12	9.87	4.60	3.30	7.90
CM + NPK	3.52	13.81	15.20	9.41	6.41	15.82
GL + NPK	3.90	10.97	15.45	6.39	4.50	10.89
CM+GL+NPK	3.71	14.33	18.67	8.90	5.51	14.41
NPK alone	2.79	10.82	13.47	6.01	5.40	11.41
SEm±	0.40	1.24	1.40	0.56	0.36	0.64
CD (0.05)	1.189	3.641	4.125	1.618	1.071	2.561

Table 25. Uptake of potassium by plant at different growth stage and by grain and straw, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw	Total at harvest
CM alone	25.33	94.24	106.98	14.90	66.89	81.79
GL alone	33.57	105.95	98.39	7.32	47.72	55.04
CM + GL	25.95	98.81	109.14	12.11	58.46	70.57
AS alone	14.11	58.12	94.76	6.19	41.02	47.21
CM + NPK	31.91	115.39	103.46	11.22	56.50	67.72
GL + NPK	47.68	105.82	105.97	7.10	39.31	46.41
CM+GL+NPK	35.43	110.07	146.28	11.02	53.11	64.13
NPK alone	24.61	84.05	94.88	7.88	49.61	57.49
SEm±	5.06	10.63	10.01	0.67	4.13	4.09
CD (0.05)	14.876	31.265	29.447	1.970	12.141	12.030

at all the stages (Table 24). Maximum values at tillering, panicle initiation, 50 per cent flowering and harvest were recorded by treatments GL + NPK, CM + NPK and CM + GL + NPK and CM alone respectively. In all these cases inorganic fertilizers have been applied along with organic manure and these treatments have recorded better dry matter yield also. At all stages, treatment AS alone recorded the minimum value which was on par with NPK treatment alone. Maximum uptakes by grain and straw were recorded by treatment CM alone which was on par with treatments CM + GL and CM + NPK. Uptake by grain was minimum in treatment AS alone while treatment GL + NPK recorded the lowest uptake value for straw. In both cases, treatments AS alone, GL + NPK and GL alone were on par. Though application of green leaves or cattle manure along with NPK fertilizer, have recorded higher uptake in the initial stages, application of cattle manure only showed significant influence in increasing the uptake at later stages.

In the initial stages of crop growth, viz., tillering and panicle initiation stages, uptake was comparatively low in treatment CM alone while treatments which received substantial quantity of green leaves recorded higher values. But as the stage of growth advanced, and when the crop attained 50 per cent flowering, treatment CM alone recorded comparatively higher value than treatments GL alone and GL + NPK. At the time of harvest, uptake of K by grain and by straw became maximum in treatment CM alone.

Thus the uptake patterns shown by the crop at different growth stages and by grain and straw showed trends similar to the dry matter yield.

4.3.4. Calcium uptake

At tillering, panicle initiation and harvest, significant variation was noticed in the uptake of Ca by the crop. At tillering, maximum and minimum values were recorded by treatments GL alone and CM + GL respectively. But at panicle initiation stage, treatment NPK alone had recorded the highest value. As in the case of tillering, treatment CM + GL recorded the minimum value here also. At 50 per cent flowering there was no difference in the uptake due to treatments.

Significant difference was noticed in the uptake of Ca by grain also and treatment CM alone has recorded the maximum uptake and this is mainly due to the increased dry matter production. Minimum value was recorded by treatment GL + NPK. However, uptake by straw was not influenced significantly by different treatments.

4.3.5. Uptake of magnesium

Uptake of Mg by the crop at panicle initiation stage and by grain were influenced significantly by different treatments (Table 27). Significant difference noticed in the Mg content of crop at

Table 26. Uptake of calcium by plant at different growth stages and by grain and straw, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw	Total at harvest
CM alone	2.56	16.34	21.39	7.80	16.61	24.41
GL alone	3.67	20.61	19.80	4.30	13.89	18.19
CM + GL	0.94	10.47	22.13	6.59	14.69	21.59
AS alone	1.73	11.17	21.75	3.98	12.82	16.80
GM + NPK	2.95	11.35	17.46	5.67	14.03	19.70
GL + NPK	3.48	11.17	22.25	3.91	14.30	18.21
CM+GL+NPK	2.71	17.54	25.38	4.80	12.11	16.91
NPK alone	2.77	24.65	19.29	4.01	13.30	17.31
SEm±	0.36	3.05	2.12	0.45	1.24	0.77
CD (0.05)	1.060	8.972	NS	1.335	NS	2.254

Table 27. Uptake of magnesium by plant at different growth stage and by grain and straw, kg ha^{-1}

Treatment	Tillering	Panicle initiation	50 per cent flowering	Grain	Straw	Total at harvest
CM alone	1.60	3.92	7.01	2.61	8.30	10.91
GL alone	1.12	3.83	7.44	1.70	7.80	9.50
CM + GL	1.23	5.16	6.33	2.30	7.32	9.62
AS alone	1.01	2.87	6.59	0.66	6.94	7.60
CM + NPK	1.28	7.32	8.19	3.41	7.79	11.20
GL + NPK	1.98	7.06	8.90	1.10	7.90	9.00
CM+GL+NPK	1.92	6.93	9.83	2.50	6.01	8.51
NPK alone	1.52	4.67	8.31	1.00	8.10	9.10
SEm±	0.29	0.96	1.05	0.49	1.07	1.04
CD (0.05)	NS	2.836	NS	1.446	NS	3.044

panicle initiation stage was reflected in the uptake values. Uptake was maximum in treatment CM + NPK and it was on par with treatments GL + NPK, CM + GL + NPK, CM + GL and NPK alone. Minimum value was recorded by treatment AS alone. Uptake patterns shown by grain reflects the greater influence of yield of grain on uptake values. Significant difference was noticed in total uptake of Mg at harvest also with maximum and minimum values recorded by treatments CM + NPK and AS alone respectively.

4.3.6. Micronutrient uptake

Eventhough, contents of micronutrients viz., Fe, Mn, Cu and Zn in grain were not influenced by continuous application of manures and fertilizers, significant variation was noticed in the uptake of Fe, Mn and Cu (Table 28). In the case of Fe, maximum uptake was recorded by treatment NPK alone and it was on par with treatments CM alone and CM + GL + NPK. Minimum uptake value (0.082 kg ha^{-1}) was recorded by treatment GL alone and it was on par with treatments AS alone, GL + NPK, CM + GL and CM + NPK.

The treatment CM alone has recorded the maximum uptake of Mn which was on par with treatment CM + NPK. Uptake was minimum in treatment AS alone and it was followed by treatments GL + NPK and NPK alone. Application of cattle manure showed favourable influence in increasing the uptake.

Table 28. Uptake of micronutrients by grain and straw, kg ha^{-1}

Treatment	Grain				Straw			
	Fe	Mn	Cu	Zn	Fe	Mn	Cu	Zn
CM alone	0.146	0.238	0.070	0.067	1.253	1.249	0.074	0.137
GL alone	0.082	0.134	0.034	0.047	0.869	0.594	0.052	0.108
CM + GL	0.124	0.166	0.034	0.057	0.955	0.878	0.058	0.124
AS alone	0.092	0.101	0.023	0.034	0.894	0.531	0.036	0.081
CM + NPK	0.125	0.194	0.070	0.058	1.230	1.135	0.051	0.134
GL + NPK	0.098	0.119	0.038	0.039	1.004	0.438	0.036	0.115
CM+GL+NPK	0.130	0.150	0.044	0.052	0.970	0.475	0.054	0.121
NPK alone	0.180	0.122	0.029	0.055	1.060	0.466	0.053	0.094
SEm±	0.017	0.015	0.014	0.012	0.086	0.099	0.010	0.017
CD (0.05)	0.0500	0.0441	0.0410	NS	0.2529	0.2912	0.0294	0.0500

Uptake of Cu by grain was maximum in treatments CM alone and CM + NPK and they were on par with treatments CM + GL + NPK, GL + NPK, CM + GL, GL alone and NPK alone. Minimum uptake was noticed in treatment AS alone.

Different treatments showed no significant influence on the Zn uptake by the grain. The range in the values, however, varied between 0.034 and 0.067 kg ha^{-1}.

In the case of straw, all the micronutrients showed significant influence in the uptake though the contents of these nutrients showed non-significant variation.

The uptake of Fe by straw was maximum (1.253 kg ha^{-1}) in the treatment CM alone and it was on par with treatments CM + NPK, NPK alone, GL + NPK. Minimum value (0.869 kg ha^{-1}) was recorded by treatment GL alone which was on par with treatments AS alone, CM + GL, CM + GL + NPK.

The Mn uptake by straw varied from 0.438 kg ha^{-1}, recorded by treatment GL + NPK to 1.249 kg ha^{-1}, recorded by treatment CM alone.

In the case of uptake of Cu by straw, maximum value (0.074 kg ha^{-1}) was recorded by treatment CM alone and it was on par with all other treatments except treatments AS alone and GL + NPK.

Uptake of Zn by straw was maximum (0.137 kg ha^{-1}) in CM alone which was on par with all other treatments except treatment AS alone. The treatment AS alone recorded the minimum value (0.081 kg ha^{-1}).

In general the pattern of uptake of the micronutrients showed trends similar to the dry matter yield rather than their content in grain and straw.

4.4. Utilization efficiency of nitrogen

The data indicate that maximum utilization efficiency is recorded by treatment CM alone. This may be due to the direct and residual effect of N in the cattle manure. All the treatments which have received cattle manure recorded significantly higher values. Application of inorganic fertilizers or green leaves either alone or in combination decreasedthe utilization efficiency of N.

The results clearly indicate that utilization of N will be maximum when the entire quantity of N is applied as cattle manure alone and application of substantial quantity of N as cattle manure helps to increase the utilization of N from green leaves and inorganic fertilizers, However, the application of entire quantity of N as cattle manure alone is not economical and feasible considering the high cost of manure and low availability. From the results it can be concluded that application of some amount of cattle manure along with inorganic fertilizers or green leaves is essential for maximum utilization efficiency of N applied to the soil.

Table 29. Utilization efficiency of nitrogen, per cent

Treatment	Utilization efficiency
CM alone	91.91
GL alone	67.48
CM + GL	84.39
AS alone	60.50
CM + NPK	82.68
GL + NPK	58.36
CM + GL + NPK	82.22
NPK alone	58.57
SEm±	8.13
CD (0.05)	23.92

Table 30. Quality of grain and straw

Treatment	Grain		Straw	
	Protein content (%)	Starch content (%)	Protein content (%)	Fibre content (%)
CM alone	7.96	57.85	5.54	38.00
GL alone	9.21	51.54	4.64	37.01
CM + GL	9.34	52.29	4.79	31.00
AS alone	9.75	52.57	5.64	32.24
CM + NPK	8.51	51.35	5.21	34.75
GL + NPK	9.99	49.38	3.37	30.10
CM + GL + NPK	9.60	49.18	5.56	34.00
NPK alone	7.96	48.66	4.39	31.63
SEm±	0.76	3.00	0.76	2.99
CD (0.05)	NS	NS	NS	NS

Summary

SUMMARY

A study was conducted to assess the effect of long term application of manures and fertilizers on soil properties, utilization efficiency of nutrients and quality of rice making use of the soil and plant samples taken from the existing permanent manurial trial on rice (dwarf indica) at the Regional Agricultural Research Station, Pattambi. At the time of study, ie. during the first crop season of 1990, 34 seasons had elapsed since the commencement of this experiment at Pattambi. The results obtained and the salient conclusions drawn are summarised below. Yield data obtained from the station records for the Virippu season of 1990 are also statistically analysed and conclusions are made.

1. The influence of long term application of manures and fertilizers on bulk density and water holding capacity of soil was significant. The results clearly revealed the beneficial effects of organic matter addition in improving the bulk density and water holding capacity of soil. The treatments consisting of application of organic fertilizers alone recorded the lowest and highest values of bulk density and water holding capacity respectively. However, particle density and particle size distribution of soil were uninfluenced by different treatments. Aggregate analysis of soil also indicated the favourable influence of organic

matter addition on the stability of soil aggregates. Significant correlation existed between organic carbon and bulk density (-0.5819**) and water holding capacity of soil (0.5476**).

2. Influence of long term application of manures and fertilizers on pH and CEC of soil was not significant. Even the application of ammonium sulphate alone to supply 90 kg N ha^{-1} continuously for the last 17 years has not changed the soil reaction considerably. Addition of organic manure at a high dose of 18 t ha^{-1} has not increased the CEC of the soil. Organic carbon content of soil was influenced significantly by different treatments and treatments receiving application of cattle manure either alone or in combination with green leaves or NPK fertilizers recorded higher values. Lowest organic carbon content was noticed in treatments receiving inorganic fertilizers alone.

3. There was not much difference in the total and available N content of soil due to different treatments. Ammoniacal and nitrate nitrogen contents of soil were also found to be uninfluenced by different treatments. However, significant variation was noticed in the hydrolyzable and non-hydrolyzable nitrogen contents of soil. In both cases, treatments which included application of cattle manure recorded higher values. Significant correlation existed between organic carbon and hydrolyzable nitrogen (0.4113*) and non-hydrolyzable nitrogen contents of soil (0.4187*).

4. Eventhough, total P content of soil was not influenced by different treatments, significant difference was noticed in the available P content of soil. The maximum availability was noticed in the case of application of entire quantity of N in the form of cattle manure alone. Availability of P was lowest in plots which received application of green leaves alone. In general it was found that application of cattle manure either alone or in combination with green leaves or NPK fertilizers showed a tendency to increase the availability of P while green leaves tended to reduce it. Significant correlation existed between organic carbon and available P content of soil ($r = 0.5238^{**}$). Different fractions of soil phosphorus studied viz., saloid-P, Fe-P, Al-P and Ca-P also showed a similar trend.

   Fractionation studies have shown that precipitated P was mostly in the form of Fe-P, followed by Al-P, Ca-P and saloid-P. Total fixed P was highest in the treatment CM alone and lowest in the treatment AS alone.

5. Total K content of soil was not influenced by different treatments. Significant variation was noticed in the available K content of soil. However, no specific trend due to treatments could be identified. Non-exchangeable K content of soil also did not show any significant difference due to different treatments.

6. Total and exchangeable Ca and total Mg contents of soil remained uninfluenced by different treatments. Significant variation was noticed in the exchangeable Mg content of soil. Treatments which received application of cattle manure either alone or in combination with green leaves or NPK fertilizers were significantly superior to other treatments indicating the favourable influence of cattle manure addition on the exchangeable Mg status of soil.

7. Regarding the influence of long term application of manures and fertilizers on the status of available micronutrients in soil viz., Fe, Mn, Cu and Zn, significant variation was noticed only in the content of available Mn and Zn. Treatments which received application of substantial quantity of cattle manure recorded significantly higher content of available Mn than treatments receiving only NPK fertilizers. Treatment which received the entire quantity of N as cattle manure recorded highest content of available Zn in soil and application of inorganic fertilizers alone recorded comparatively lower values.

8. At different stages of crop growth viz., tillering, panicle initiation, 50 per cent flowering and harvest, no significant variation was noticed in the pH of soil due to different treatments.

9. Significant variation was not obtained in the CEC of soil also at any of the stages studied due to different treatments.

10. At all stages of crop growth, organic carbon content of soil was influenced significantly by different treatments. In the initial stages of crop growth viz., tillering and panicle initiation, treatments which received application of cattle manure and green leaves either alone or in combination with NPK fertilizers were statistically on par and recorded higher values. With advancement in stage of growth, application of cattle manure alone to supply the entire quantity of N became significantly superior to all other treatments. At all stages, lowest organic carbon content was noticed in treatments receiving only inorganic fertilizers.

11. Available N content of soil was not influenced significantly due to different treatments at any of the growth stages studied.

12. Significant difference was noticed in the available P content of soil at all stages of crop growth. Application of N in the form of cattle manure recorded the highest value at all stages which was followed by application of half the quantity of N as cattle manure and the remaining half as NPK fertilizers. At all stages, lowest availability was associated with ammonium sulphate alone followed by application of green leaves alone and these treatments were on par.

13. Eventhough the treatments had significant influence in the available K content of soil, no definite trend could be identified in respect to the availability of K at different stages.

14. Only at tillering and panicle initiation stages, exchangeable Ca content of soil was influenced significantly by different treatments. The lowest value at all stages was recorded by the treatment receiving application of ammonium sulphate alone.

15. At all stages of crop growth, treatments had significant influence in exchangeable Mg content of soil. In most of the growth stages, treatments receiving application of substantial quantity of cattle manure recorded higher values and lower values were recorded by treatments receiving NPK fertilizers alone.

16. With regard to the yield of dry matter, treatments receiving application of NPK fertilizers along with green leaves recorded highest yield at tillering while the treatment receiving application of NPK fertilizers along with green leaves and cattle manure recorded highest yield at panicle initiation and 50 per cent flowering. Lowest yield was associated with application of ammonium sulphate alone at all stages. Application of cattle manure alone was significantly superior to all other treatments with respect to the yield of grain and lowest yield was recorded for application of ammonium sulphate alone. Application of green leaves alone also recorded lower yield. Yield of straw

followed a trend similar to that of grain. Significant correlation existed between yield of grain and organic carbon and available P contents of soil (r = 0.5557** and 0.6562** respectively).

17. With respect to the contents of nutrients viz., N, P, K, Ca and Mg in the crop, significant variation was noticed only in the P content of crop at all the growth stages. Calcium content of crop showed difference at tillering and panicle initiation stages and Mg content of crop differed only at panicle initiation stage. Higher content of P in the crop at all stages was recorded by treatments receiving application of 45 t ha^{-1} or more of cattle manure. Lowest content was noticed in the treatment receiving application of ammonium sulphate alone followed by green leaves. With regard to the contents of micronutrients viz., Fe, Mn, Cu and Zn in straw and grain, significant difference was noticed only in Mn content of straw. Application of N as cattle manure alone or as equal amount of cattle manure and NPK fertilizers was significantly superior to other treatments.

18. With regard to the uptake of nutrients, significant variation was noticed in the uptake of N by grain, uptake of P and K by crop at different growth stages and by grain and straw, uptake of Ca by crop at tillering and panicle initiation stages and by grain and uptake of Mg by crop at panicle initiation

stage and by grain. With regard to the uptake of micronutrients viz., Fe, Mn, Cu and Zn by grain and straw, significant variation was noticed in the uptake of all these micronutrients except Zn. Treatments which have received cattle manure either alone or in combination with green leaves or NPK have recorded higher values for the uptake than other treatments.

19. The results on utilization efficiency of N revealed that maximum efficiency was noted in treatment which received application of cattle manure alone and it was on par with treatments receiving substantial quantity of cattle manure along with other sources of N. Lowest value was recorded by treatment receiving green leaves along with NPK fertilizers.

20. Quality of grain and straw as determined by protein and starch contents of grain and protein and fibre contents of straw showed that continuous application of manures and fertilizers either alone or in combination had no significant influence on these parameters.

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Appendix

APPENDIX-I

Meteorological parameters of the experimental site at the Regional Agricultural Research Station, Pattambi, Kerala

Week No.	Month	Rainfall mm	Temperature °C		Relative humidity per cent		Sunshine hours
			Minimum	Maximum	Minimum	Maximum	
19	May	30.4	33.9	21.1	94	65	33.1
20	May	106.0	32.7	20.1	92	65	46.5
21	May	152.8	29.2	19.6	94	77	14.9
22	May-June	129.6	30.2	19.5	92	80	21.5
23	June	81.2	30.0	19.1	93	76	21.4
24	June	217.8	29.0	19.0	93	79	17.1
25	June	114.2	30.7	19.2	95	80	20.0
26	June-July	97.4	30.9	19.2	93	75	26.5
27	July	228.8	28.5	18.6	92	82	9.0
28	July	216.1	28.8	18.7	94	82	11.0
29	July	175.3	28.4	20.0	94	81	5.9
30	July	83.6	29.9	22.1	95	70	31.8
31	July-August	45.3	29.1	22.8	94	77	19.4
32	August	106.2	28.5	22.3	94	80	8.2
33	August	112.1	29.0	22.7	93	77	21.7
34	August	40.1	29.9	22.5	93	75	36.2
35	August-September	7.6	30.6	23.5	94	66	56.3
36	September	27.4	30.6	23.4	93	62	33.0
37	September	00.0	31.6	23.8	94	61	54.8
38	September	5.2	31.2	23.6	94	60	29.4
39	September	5.6	32.1	22.8	94	58	28.0

EFFECT OF LONG TERM APPLICATION OF MANURES AND FERTILISERS ON SOIL PROPERTIES, UTILISATION EFFICIENCY OF NUTRIENTS AND QUALITY OF RICE

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ABSTRACT OF A THESIS

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ABSTRACT

A study was conducted during the first crop season of 1990 to assess the effect of long term application of manures and fertilizers on soil properties, utilization efficiency of nutrients and quality of rice making use of the soil and plant samples taken from the existing permanent manurial trial (dwarf indica) at the Regional Agricultural Research Station, Pattambi. This experiment was started at Pattambi during the first crop season of 1973. The soil of the experimental site is laterite. The experiment is laid out in randomised block design with four replications and eight treatments.

The treatments consisted of application of entire quantity of N - 90 kg ha^{-1}, as organic alone (cattle manure alone, green manure alone and cattle manure + green manure), inorganic 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).

Soil samples were collected from all the replications of the various treatments before planting, at different stages of crop growth viz., tillering, panicle initiation, 50 per cent flowering and harvest. Plant samples were also collected at the above

growth stages. 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 effect of long term application of manures and fertilizers on physical and chemical properties of soil, uptake of nutrients and utilization efficiency of nutrients and quality of grain and straw.

Results of analysis of soil samples collected before planting revealed the beneficial effect of organic matter addition on bulk density, water holding capacity and aggregate stability of soil.

Long term application of manures and fertilizers singly and in combination had no significant influence on the soil reaction and CEC of the soil. The application of ammonium sulphate alone to supply 90 kg N ha^{-1} continuously for the last 17 years has not changed the soil reaction considerably. Addition of organic manures at a high dose of 18 t ha^{-1} for a long period of 17 years failed to increase the CEC of the soil. Results clearly indicated the favourable influence of cattle manure addition in increasing the content of organic carbon.

Prolonged application of manures, fertilizers or their combinations had no significant influence on the content of total and available N, ammoniacal and nitrate N, total P, total K, total and exchangeable Ca and total Mg. Significant variation was noticed in the hydrolysable and non hydrolysable nitrogen content of soil.

Application of cattle manure recorded higher values in both the cases. Though the total P content of the soil was not influenced significantly, highly significant difference was noticed in the available P content of soil due to various treatments. Application of cattle manure either alone or in combination with green leaves or inorganic fertilizers increased the availability of P while application of green leaves alone reduced it. Though significant variation was noticed in the exchangeable K content of soil no specific trend due to treatments could be identified. In the case of exchangeable Mg also favourable influence of cattle manure was significant. Application of cattle manure increased the content of available Zn in the soil.

At different stages of crop growth significant variation was noticed only in the case of organic carbon content and availability of P in the soil due to treatments. As in the case of the soil sample collected before planting application of cattle manure increased the organic carbon content and availability of P at all growth stages. Maximum grain and straw yield were also recorded by the treatment receiving application of cattle manure alone and the results clearly indicated that application of cattle manure along with inorganic fertilizers is essential to maintain high yields. Application of inorganic fertilizers alone, green leaves alone or a combination of green leaves and inorganic fertilizers also failed to give higher grain yields. The beneficial effect of cattle manure may be attributed to its favourable influence on increasing the organic carbon and available P content of soil. Significant correlation existed between organic carbon content and available P content of soil with grain yield.

Regarding the nutrient content in plants only the P content was influenced significantly at all the growth stages and the P content of plants increased with application of cattle manure.

The results obtained clearly indicated that application of cattle manure along with inorganic fertilisers or green leaves is essential for maximum utilization efficiency of N applied to the soil.

The results of the study also indicated that there was no significant variation in the quality of grain as seen from the protein and starch content of grain and protein and fibre content of straw due to prolonged application of manures and fertilizers either alone or in combination.