

**NUTRIENT DYNAMICS UNDER LONG-TERM
PRACTICE OF INTEGRATED NUTRIENT
MANAGEMENT SYSTEM IN RICE-COWPEA
CROP SEQUENCE IN CAUVERY COMMAND
AREA, KARNATAKA**

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Department of Soil Science and Agricultural Chemistry

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BANGALORE

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Thesis submitted to the
UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE
in partial fulfilment of the requirements
for the award of the Degree of
Doctor of Philosophy
in
Soil Science and Agricultural Chemistry

Bangalore

DECEMBER, 2001

Affectionately Dedicated

**To
My parents**

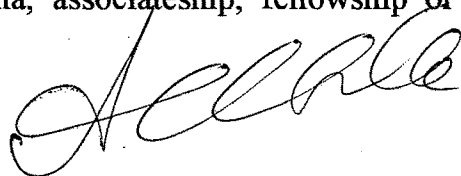
**Smt.CHALLAMMA
and
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**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
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BANGALORE**

CERTIFICATE

This is to certify that the thesis entitled "NUTRIENT DYNAMICS UNDER LONG-TERM PRACTICE OF INTEGRATED NUTRIENT MANAGEMENT SYSTEM IN RICE-COWPEA CROP SEQUENCE IN CAUVERY COMMAND AREA, KARNATAKA" submitted by **Mr. H.C.PRAKASHA** for the award of degree of **DOCTOR OF PHILOSOPHY** in **Soil Science and Agricultural Chemistry** to the University of Agricultural Sciences, Bangalore, is a record of **bona-fide research work** done by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore
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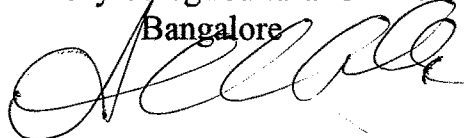


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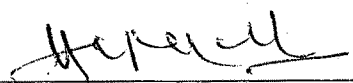
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(H.C.PRAKASHA)

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INTRODUCTION

I. INTRODUCTION

Indian Agriculture although has achieved impressive gains in terms of food grain production, issues concerning soil degradation and environmental pollution remains to be tackled. Irrigation alone is not the panacea for all the yields. In order to meet the challenges of human needs of food, fodder, fibre, fuel wood, etc., we have to look for strategies, which are dependable and sustainable.

Over the last 150 years more and more farmers have learned to augment natural sources of plant nutrients with artificial fertilizers to the point where these chemical fertilizers are now supporting a considerable proportion of humanity. According to Norman E. Borlaug, a Nobel laureate and captain of green revolution, 50 per cent of the increase in crop yield world wide was due to addition of chemical fertilizers and their importance in the future would continue to be so. Thus, his views strongly support the past, current and future contributions of plant nutrients to world food production.

Among the food crops, rice is the major one occupying about 44 million hectares and contributing about 84 million tonnes of the total 200 million tonnes of food grain production in India. Thus, rice, which contributes more than 40% of the total food production, gets lion's share of important inputs such as fertilizers (40%), water (65%) and variety (80%). Though at national level the progress *per se* in agricultural sector is commendable, if one examines partial

factor productivity, yet all is not well especially with respect to response of rice to fertilizers. Rice yield in intensively cultivated irrigated areas is either stagnating or declining in the post-green revolution era depending on the degree of imbalance in fertilizer use, soil degradation and type of cropping systems practised. Recalcitrant organic matter formed due to continuous submergence is considered the smoking gun of rice yield in rice-rice system. Depletion of soil nutrient reserves, emerging nutrient deficiencies or toxicities, degraded soil structure and reduced microbial process (nutrient recycling) on account of puddling and continuous submergence are some of the other important factors responsible for decline in rice yield.

Thus, suffixing productivity gain in the post green revolution period will have to come from more efficient use of inputs involving integrated nutrient management (INM) technologies. However, by nature INM technologies are more knowledge or information intensive and site specific than seed plus high input package, which were a hallmark of green revolution period. Hence, the challenge for rice research system today is to generate and popularize location specific emerging input management technologies for each of the rice based cropping niches that are in vogue as there is no single nutrient management method for sustaining the expected higher level of rice production.

Integrated Nutrient Management (INM) refers to systematic use of all possible nutrient sources at farmers disposal in a way that each of them is used in proper sequence and combination with utmost efficiency and obtain synergistic

effect. Thus, it is all axiomatic that INM takes into consideration nutrient cycles involving soils, cropping systems, irrigation water, nutrient deficiencies or toxicity. Judicious and combined use of organic or green manures, minerals and biofertilizers in tandem with effective genotypes and soil amendments. Thus, INM should spatially and temporarily match nutrient supply for the entire cropping system and not merely that of a single component like rice. Such an approach if successfully practised, indeed may prove ecologically sound and economically viable (Narayana Reddy and Krishnaiah, 1999).

The complex problem of soil fertility management can only be studied by long-term field trials as it synchronizes time for crop, crop rotation, fertilizers and manures to have a measurable effect on soil fertility. Long-term field experiments can be used for preview monitoring of changes in soil fertility and productivity. In the Cauvery Command area of Karnataka, crops are being grown intensively with monoculture, no crop rotation, less or no incorporation of organic manures or green manures, application of over dosage of inorganic fertilizers, as a result, fertility status of the soil is poor. Soils are deficient in macro, secondary and micronutrients consequent to continuous removal from the soil which has lead to decline of soil fertility in the command area. To sustain the productivity and nutrient gains through more efficient use of nutrient inputs, following INM practices envisages holistic and balanced use of chemical fertilizers in conjunction with organic manures or green manures by raising

seasonal legume crops which ultimately help aggrade the degrading soil fertility in intensively cultivated rice irrigated soils.

Thus, under the All India Co-ordinated Rice Improvement Programme on rice an experiment on long term soil fertility management in rice based cropping system was initiated during 1989 at the Regional Research Station, V.C. Farm, Mandya which aimed at concomitant improvement in soil fertility due to organic matters which improve soil to support the full potential of crop yield. The objectives of the study were:

- To study the long-term effect of organic manure and fertilizers on changes in physical, chemical, microbial and bio-chemical properties of the soil.
- To study the long-term effect of organic manure and fertilizers on yield and uptake of nutrients by rice and cowpea crops.
- To study the long-term effect of organic manure and fertilizers on balance of nutrients, sustainability yield index and economics of rice and cowpea production, and
- To establish the relationship between physical, chemical, microbial as well as biochemical properties of soil and the yield of rice-cowpea cropping system as influenced by INM practices.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Long-term field studies provide a vehicle for scientific investigation of structure function relationship that govern the variability of specified cropping system. Further, the information generated can be used to foresee constraints to future productivity, which otherwise would be difficult or impossible to detect in the short-term field studies. To this end of relating yield trends to soil fertility changes as a function of time, a long-term co-ordinated trial with designated treatments imposing balanced and integrated use of nutrients was initiated during 1989-90 at the Regional Research Station, V.C.Farm, Mandya, Karnataka and detailed observations were recorded during 1999-2000.

A review of literature on the long-term soil fertility management and their effect on physical, chemical, microbial and biochemical properties on fertility and productivity of rice and cowpea crops are reviewed as follows:

2.1 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON PHYSICAL PROPERTIES OF SOIL

Among the several physical properties, bulk density, water holding capacity, stable aggregates, porosity, infiltration and hydraulic conductivity are few, which essentially benefit the crop growth under submerged condition.

2.1.1 Bulk density

A decline in bulk density of an *Alfisol* due to the application of organic manures either alone or along with inorganic fertilizers was observed by Parvathappa, *et al.* (1988). A result similar to previous one was reported by Badanur *et al.* (1990) in a vertisol in Karnataka due to the incorporation of crop residues in soil. Application of green manure to wet land rice reduced the bulk density of the soil (Bopari *et al.*, 1992)

Bhardwaj and Omanwar (1992) showed that the increasing nutrient elements (N, NP and NPK) or graded doses of NPK fertilizers reduced bulk density than control. Similarly, treatment of 100 per cent NPK + FYM showed lower BD (1.31) than those under fallow plots (1.32) after 12 years of rice-wheat-cowpea cropping system. The soils fertilized with organic matters were characterized by lower bulk and particle density (Kahle *et al.*, 1992).

Ram-Newaj and Yadav (1994) reported from a field experiment conducted with five cropping systems that the values of bulk density were lower under all the cropping system during end of the study as compared with initial value.

Sarma and Das (1996) noticed that aggregating agents like organic matter, CaCO_3 and $\text{Fe}(\text{OH})_3$ had improved the bulk density of the soil.

2.1.2 Water stable aggregates

Mahimairaja *et al.* (1986) reported that aggregate stability was significantly influenced due to continuous application of fertilizers and manures, whereas, structural coefficients were not significantly affected.

Application of green manure to wet land rice increased the water stable aggregates of the soil (Bopari *et al.*, 1992). Fertilizer application improved the percent water stable aggregates ($>0.25\text{mm}$) on adding FYM or green manure along with NPK fertilizers than applying only fertilizers (Kalane *et al.*, 1995).

Use of aggregating agents viz., organic matter, CaCO_3 and $\text{Fe}(\text{OH})_3$ improved aggregation of the following size ranges, i.e., 2–20, 20–50, 50–250 microns. But all the three aggregating agents in combination recorded highest overall aggregating size ranges under consideration. Increase in 2–20 micron aggregate size was more pronounced as a result of aggregating agent addition. Highest increase in this size was recorded where organic matter and $\text{Fe}(\text{OH})_3$ were applied in combination (Sarma and Das, 1996).

Mishra and Sharma (1997) reported that continuous use of full dose of NPK caused significant influence on the contents of both fine and coarse aggregates in comparison to application of half the dose of NPK and in unfertilized treatments.

Nair (1997) reported based on long-term study that use of chemical fertilizers along with FYM in rice-wheat-cowpea system increased water stable aggregates of surface soil compared to use of chemical fertilizer alone.

2.1.3 Porosity

Mahimairaja *et al.* (1986) noticed that either organic manure or inorganic fertilizers influenced the porosity of soil. However, non-capillary pore space decreased and the capillary porosity increased.

Continuous use of lime, FYM and NPK fertilizers had a marginal increase in pore space of an *Alfisol* (Hanumantharayappa., 1994).

Sarma and Das (1996) reported from the pot experiment on rice that applications of organic manures, CaCO_3 and $\text{Fe}(\text{OH})_3$ as aggregating agents have increased the porosity of the soil.

2.1.4 Infiltration

Acharya *et al.* (1988) reported higher infiltration rate with 100 per cent NPK + FYM and only 150 per cent NPK. Chawla and Chhabra (1991) reported that fertilizer application improved infiltration rate of the soil.

Bopari *et al.* (1992) reported that application of green manure to wet land rice increased the infiltration rate of the soil.

Effect of farm waste and organic manures on soil properties in a field experiment conducted on rice-wheat cropping system for three years

indicated that the application of FYM @ 50 t ha⁻¹ have shown highest infiltration of the soil as compared to control (More, 1994).

Ram-Newaj and Yadav (1994) reported that after 2 years of experimentation the infiltration rate of soil was increased compared to initial value in the cropping systems viz., rice-wheat-green gram, maize-pea-common millet, pigeon pea-wheat-green gram, maize-potato + Indian mustard-black gram and black gram-Indian mustard-maize + cowpea.

2.1.5 Hydraulic conductivity

Bhatia and Shukla (1982) noticed that the application of nitrogenous and phosphatic fertilizers had increased hydraulic conductivity as a result of increased proportion of larger pores in the soil.

There was a significant increase in hydraulic conductivity due to continuous application of inorganic fertilizers and manures. The combination of 100 per cent NPK and 10 tonnes of farm yard manure recorded the highest value of hydraulic conductivity *i.e.*, 2.90 cm h⁻¹ (Mahimairaja *et al.*, 1986).

Irrigation and N levels had no significant impact in changing saturated hydraulic conductivity of the soil. But organic amendments significantly influenced the saturated hydraulic conductivity of the soil (Jagannathan *et al.*, 1987).

Use of aggregating agents like organic matter, CaCO₃ and Fe (OH)₃ improved the hydraulic conductivity of the soil (Sarma and Das, 1996).

2.1.6 Maximum water holding capacity

Sinha *et al.* (1980) found increase in water holding capacity with application of FYM and lime. The use of high doses of chemical fertilizers decreased the water holding capacity as compared to that of control.

Badanur *et al.* (1990) reported an increase in the field moisture capacity as well as maximum moisture holding capacities of an vertisol due to application of crop residues compared to only chemical fertilizers.

Water content of the soil in the control tended to decrease as compared with fallow plots. Bharadwaj and Omanwar (1992) reported that FYM treated plots showed comparatively higher water content at 33 kpa and higher available water content than those of the fertilizer treated plots.

A marginal increase in the water holding capacity of an *Alfisol* due to continuous use of lime, FYM and NPK fertilizers was reported by Hanumantharayappa (1994).

Nair (1997) reported based on long-term study at Pantnager that use of commercial fertilizers along with FYM in rice-wheat-cowpea cropping system increased the available soil moisture of surface soil compared to plots, which received only chemical fertilizers.

2.2 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON CHEMICAL PROPERTIES OF SOIL

2.2.1 Soil reaction

Rabindra and Honnegowda (1986) noticed that application of FYM either alone or in combination with NPK did not affect the soil pH.

Bhriguvanshi (1988) found that the pH of the soil remained almost unchanged by the action of the fertilizer and manure. Lal and Mathur (1988) reported that continuous use of fertilizer lowered the soil pH, while application of FYM alone had maintained the soil pH at initial value.

Panda and Sahoo (1989) reported that continuous application of fertilizers had marginal effect on pH of laterite soils of rice-rice cropping system. Continuous application of NPK fertilizers for 12 years in a rice-wheat system lowered the pH by 0.1 to 0.2 unit, while the pH of unfertilized plot rose from 7.7 to 7.8 after 12 years of cropping (Kumar and Yadav, 1993). However, use of ammonical fertilizers resulted in the reduction in soil pH due to their acidic residual effect.

Sudhir *et al.* (1996) reported that continuous use of only chemical fertilizers at different doses significantly decreased the pH of an *Alfisol*, while application of chemical fertilizers along with FYM maintained the soil pH at initial value.

Soil analysis from long-term experiment in rice-rice sequence indicated that continuous application of chemical fertilizer alone led to the decrease in soil pH. Where as an improvement over initial value resulted under integrated treatments, which received both inorganic and organic source of fertilizers (Basumantary and Talukdar, 1998).

Chitdeswari and Krishnaswamy (1996) revealed that the pH of both typic ustorthents and vertic aquic ustropepts rice soils were found to increase with advancement of crop growth. Katyal and Sharma (1991) also reported that with a changing soil moisture regime from aquic to ustic and aridic to torric, the pH of the soil increased.

2.2.2 Electrical conductivity

Results obtained from a field experiment conducted on bajra (pearl millet)-wheat sequence for eight years revealed that soil pH reduced from 8.5 to 8.3 and electrical conductivity from 0.3 to 0.22 dSm⁻¹ with continuous cultivation using fertilizer application (Chahal *et al.*, 1984).

Kapur *et al.* (1986) reported that continuous application of inorganic fertilizers although brought about a change in soil pH, did not significantly affect the electrical conductivity of the soil.

Subramanian and Kumaraswamy (1989) observed that there was no effect on adding 100 per cent NPK + FYM on electrical conductivity of the soils. Badanur *et al.* (1990) studied the effect of organic matter on soil

properties and found that electric conductivity of soil did not vary much with incorporation of crop residues and green manures over fertilizer application. Chawla and Chhabra (1991) recorded no significant change in electrical conductivity of the soil with long-term use of fertilizers.

Bharadwaj and Omanwar (1994) studied the long-term effect of continuous rotational cropping and fertilization on soil property and reported that EC of the soil was not affected by any of the treatments.

2.2.3 Organic carbon

Rabindra and Honnegowda (1986) studied the long-range effect of fertilizers, lime and manure on fertility of red sandy loam soil and found that continuous use of FYM and judicious combination of organic and inorganics enhanced the organic carbon content.

Organic carbon content increased from initial level of 0.5 to 1.25 per cent with combined application of FYM and NPK fertilizers for 12 years (Panda and Sahoo, 1989). The increase in organic carbon status of soil was due to the addition of FYM either alone or in combination with fertilizers (Subramanian and Kumaraswamy, 1989).

Liu and Shen (1992) reported from long-term experiments conducted in China that the mixed application of inorganic and organic fertilizers increased soil organic matter contents and improved its quality compared to control and inorganic fertilizers alone.

The soils of unfertilized plot showed reduction (about 50%) in organic carbon due to 12 years cropping as compared with initial value. At higher fertility level the organic carbon increased from initial value of 0.45 to 0.54 per cent (Kumar and Yadav, 1993).

More (1994) indicated that addition of farm waste and organic manures had beneficial effect on organic carbon. A field experiment conducted with five cropping systems under irrigated conditions indicated that organic carbon increased from their initial value (Ram-Newaj and Yadav, 1994).

Bharadwaj and Omanwar (1994) observed that continuous cropping without fertilization of NPK led to depletion of organic carbon, whereas, continuous fertilization of NPK had beneficial effect on the buildup of organic carbon in the soil.

Organic carbon contents of an *Alfisol* increased by 17.8 per cent in the plot treated with 100 per cent NPK in the form of fertilizer and 78.3 per cent in the plot treated with 100 per cent NPK along with the FYM (Sudhir and Siddaramappa, 1995).

2.2.4 Cation Exchange capacity

In a study on the use of continuous application of chemical fertilizers and manure in a red acid loam soil of Chotanagpur for over 20 years, observed that cation exchange capacity of soil was reduced by the use of only

chemical fertilizers but was increased due to combined use of compost and fertilizers (Sinha *et al.*, 1983).

The result of long-term experiments being carried out at different centre in India have revealed that application of FYM along with NPK fertilizers increased the cation exchange capacity irrespective of soil types (Subramanian and Kumaraswamy, 1989 and Lokeswarappa, 1997).

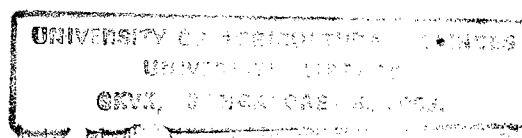
Basumantary and Talukdar (1998) reported that continuous application of chemical fertilizers alone led to decrease CEC of soil, whereas, improvement over initial value resulted when both organic and inorganic sources of fertilizers were used.

2.3 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON MAJOR NUTRIENT STATUS OF THE SOIL

2.3.1 Mineralisation of nitrogen in the soil

Datt and Bharadwaj (1995) studied the mineralisation of N of green manures in an Alfisol. The decomposition of sunhemp under fixed wet land conditions in the absence of rice crop was rapid as it was under vitro conditions. Decomposition released considerable amounts of mineral N and level of $\text{NH}_4\text{-N}$ was significantly greater than $\text{NO}_3\text{-N}$.

Ladha *et al* (1996) examined $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ dynamics in the soil and evaluated legume residues as a N source for succeeding rice crop. $\text{NO}_3\text{-N}$ was dominant in the 30 cm top soil and was higher under legumes



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compared with weedy fallow. The legumes produced 4.9 to 9.1 t above ground biomass ha^{-1} , accumulated 132 and 306 kg N ha^{-1} of which 57 to 81 per cent was derived from N_2 fixation. After harvests, 2.9 to 5.2 t ha^{-1} of residues containing 81 to 162 kg N ha^{-1} were returned to soil. By 3 and 4 weeks after flooding, legume-treated plots had as much of 33 to 40 kg mineral N ha^{-1} in top soil compared with 10 to 13 kg N ha^{-1} in weedy fallow plots. Rice recovered 15 to 31 per cent of the residue N. fallow plots required 25 to 50 kg fertilizer N ha^{-1} to produce plant growth responses to that obtained after the legumes. Below ground residues of the legumes apparently contributed 13 to 37 kg N ha^{-1} to rice. Such dry season legumes that improve productivity as well as soil fertility might ensure sustainability of productivity in rainfed low lands.

Aulakh *et al.* (2000) reported that the incorporation of fresh green manure 2 days prior to transplanting rice was associated with rapid accumulation of mineral N in soil, mostly as $\text{NH}_4\text{-N}$ for 1 to 2 weeks, followed by a slow decline during 2 to 3 week period. Rapid mineralisation of GM-N was supported by the accumulation of 103 kg mineral N ($\text{NH}_4 + \text{NO}_3$) ha^{-1} in GM supplied with 20 kg N ha^{-1} treatment, as compared with 56 kg N ha^{-1} for without incorporation of green manure treatments.

2.3.2 Nitrogen

In an *Alfisol* at Bangalore, relatively higher available nitrogen contents was observed in limed and FYM amended plots as compared to the

plots treated with N alone and those, which did not receive fertilizers (Sharif, 1984).

The results of a large number of long-term fertilizers experiments going on at different centres in India have revealed that application of FYM along with NPK fertilizers increased the available nitrogen status irrespective of soil types (Subramanian and Kumaraswamy, 1989). Deepak Kher (1993) and Prasad *et al.* (1996), found appreciable buildup of available N content of soil under continuous cropping with manuring and fertilization, but significant depletion in available N of the soil was observed under continuous cropping without fertilization.

Solaiappan and Veerabadran (1997) reported that the use of green manures (GM) along with N fertilizer helped in economizing N in wet land rice.

Soil analysis data from a long-term experiment in rice-rice sequence indicated that application of chemical fertilizers alone led to decrease in available N content of soil, whereas, an improvement over initial value resulted under integrated treatments received both inorganic and organic nutrient sources (Basumantary and Talukdar, 1998).

Narayana Reddy and Krishnaiah (1999) reported that N contribution of legume GM crops comes from two sources, one from BNF and another from $\text{NO}_3\text{-N}$ formed in the soil during aerobic phase in summer (catch

crop). $\text{NO}_3\text{-N}$ accumulated in early stages in fact acted as stand dose and it helped in increasing BNF capacity at later stages. They also reported that, to produce one ton of rice, approximately 20 kg N was required and the recovery of applied N was only 30 per cent. Nitrogen availability in rice-rice system can easily be overcome by providing a break in the continuously flooded rice cycle with a rabi non rice semi irrigated crop (crop diversification) especially belonging to pulse crop. This rotation provides soil aeration that helps to decompose soil organic matter releasing N in the process. A 50 per cent substitution of inorganic NPK fertilizers on addition of FYM + GM was found to be the best in several of the Directorate of Rice Research co-ordinated research experiments.

2.3.3 Phosphorus

Hundal and Thind (1993) showed that cowpea green manuring (5 t ha^{-1}) increased all the P forms near the surface layer soil. The values of different P forms declined after rice and maize and this was attributed to immobilization and adsorption by soil and plant uptake.

Kumar and Yadav (1993) reported that a buildup of $9.85 \text{ kg available p ha}^{-1}$ in the soil after 12 cropping cycles by applying 70 kg p ha^{-1} annually in rice-wheat system. The response to phosphorus was relatively higher in rice than wheat.

Prasad *et al.* (1996) studied available nutrient status of a continuously fertilized and manured acid soil and noticed a rise in available

phosphorus of soil due to FYM application and liming. Continuous use of phosphorus fertilizers of different doses raised P status of soil by about five times as compared to the control.

Available P showed an improvement with addition of 75 and 100 per cent NPK and their combined use with different organic N sources (Basumantary and Talukdar, 1998).

Rice requirement of P was nearly one fourth of N viz., each tonne of rice requires about 4–5 kg of P. Only 20–25 per cent applied P was available for the immediate crop and the rest was added to soil pool (Narayana Reddy and Krishnaiah, 1999).

2.3.4 Potassium

Agarwal *et al.* (1993) reported that an increase in CEC as result of FYM addition also increased the proportion of soil K present as exchangeable K. Addition of K and conversion between fixed and exchangeable K limited the degree of depletion resulting from high uptake rates imposed by the crop plants.

The results obtained during 16th cropping cycle showed that the loss of potassium from the soil @ 80 to 180 kg ha⁻¹ y⁻¹ is an alarming situation and its removal from the soil should be accounted while making the fertilizer recommendation (Bharadwaj and Tyagi, 1994).

Verma and Nand-Ram (1994) reported from an 17 years of continuous cropping of rice-wheat-cowpea under long-term fertilizer experiment in Mollisol indicated that successive increase in the graded doses of NPK at 50, 100 and 150 per cent of recommended dose enhanced the water soluble K by 57, 88 and 146 per cent. The original level of available K was maintained by adding 100 per cent NPK or 150 per cent NPK + FYM.

A significant variation in available K, waters soluble K, exchangeable K and non exchangeable K was observed due to manure and potassium addition (Bhagavathiammal and Muthiah, 1996).

The available potassium status of the soil depleted in the case of no K, and K were applied at reduced doses to the soil for the last 21 years. The highest buildup of available K was in the case of soil treated with NPK at recommended doses. Among the treatments, available K content was found to be the highest in FYM treated soil and the lowest in limed soil (Prasad et al., 1996).

2.3.5 NPK

Indulkar and Malewar (1990) indicated that various sources of Zn blended with N and NP carriers had shown additive effect on the availability of nitrogen and phosphorus in rice-gram cropping system. Application of FYM @ 10 t ha⁻¹ resulted significantly higher availability of N and P to the succeeding gram crop with or without inorganic zinc sources.

Grain legumes included in the rice based cropping systems enriched the soil with N when ploughed in as green manure. Withholding P application continuously depleted the soil P to the level of 6 kg ha^{-1} from initial level of 31 kg ha^{-1} . Heavy demand of rice-rice system on soil K lowered the potassium status of the soil (Panda and Sahoo, 1989).

The available nitrogen decreased inspite of continuous application of nitrogenous fertilizers as compared with initial status. The decreasing trend in depletion of available nitrogen was noticed with increasing N and P levels. There was an appreciable buildup of available P due to continuous application of phosphatic fertilizer and in soils of control plots available P decreased. Application of potassic fertilizer increased available K over initial value, while the treatment without potassic fertilizer caused three per cent reduction in available K (Kumar and Yadav, 1993).

Saud and Thakuria (1994) reported that available N, P and K in soil increased with NPK rate. Soil N and K were highest after cowpea was grown alone, while soil P was highest after rice.

Bhardwaj *et al.* (1994) observed that continuous cropping without fertilization led to depletion of available NPK whereas, continuous fertilization of NPK had beneficial effect on available N, P and K of the soil.

Narayana Reddy and Krishnaiah (1999) reported that one tonne of organic manure on an average supplied about 5–8 kg N and K each and 2 kg

of P. Roughly about one third of total N, half of the total P and nearly all K will become available to the crops in the first year and the rest of N and P will be available to the succeeding crop (residual effect). Combined use of chemical fertilizers along with organic manures increased the nutrient use efficiency and their use @ 10 t ha⁻¹ brought about 50 per cent saving in NPK for rice. They also reported that crop residues like rice straw contains 40 per cent C, 0.5 per cent N, 0.1 per cent P and 1.5 per cent K and the unharvested crop residue (root and stubbles) left over after harvest of rice was roughly estimated at 10 per cent of total above ground biomass. For 10 tonnes of biomass (4t grain + 6t straw) one ton of crop residue are left behind, which supplied 5 kg N, 1 kg P and 15 kg K.

2.4 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON SECONDARY NUTRIENT STATUS OF THE SOIL

2.4.1 Calcium, magnesium and sulphur

Yadhuvanshi *et al.* (1985) reported that continuous application of NPK fertilizers and FYM would increase the exchangeable calcium and magnesium contents in the soil. On the contrary it was also reported that continuous use of chemical fertilizers would cause a depletion of calcium and magnesium contents of the soil.

Higher level of NPK would also cause higher crop production and hence cause depletion in the contents of basic cations, if not supplemented by addition from external sources (Magdoff and Amadon., 1990), while

application of composts to the soil promoted high content of Ca and Mg in the soil (Savich and Verme, 1991)

Lal and Mathur (1992) reported that available sulphur content of soil, which ranged from 75 to 82.5ppm was found to be the highest in treatment when N was in ammonium sulphate form and the lowest in control. On the other hand, continuous addition of FYM recorded 12.5ppm of sulphur.

After 17 years of continuous rice-wheat-cowpea cropping with heavy inputs of fertilizer in an Aquic Hapludoll soil in India, total and organic S declined to half without S but increased markedly with S containing fertilizers and addition of S-bearing fertilizers enhanced S availability particularly with an increase in NPK levels (Tiwari *et al.*, 1995).

Prasad *et al.* (1996) studied the available nutrient status of a continuously fertilized and cropped soil and found that lime and FYM treatments increased exchangeable calcium and magnesium status of the soil due to increase in biomass production and its incorporation in the soil.

Basumantary and Talukdar (1999) indicated that integrated treatments receiving chemical fertilizers along with 50 per cent or 25 per cent of organic N through FYM, rice straw or Azolla resulted in significantly higher content of exchangeable Ca and Mg as well as available and total sulphur in the soil. At the end of seven years of cropping both exchangeable and total Ca and Mg depleted over initial value, except a slight buildup of Ca when 50 per

cent organic matter was substituted. Considerable buildup of available and total sulphur was noticed in all the treatments, except in control and when 50 per cent NPK fertilizers was applied.

Deep rooted legume crops recycle nutrients like P, Ca and Mg from deeper layers of soil and make them available for shallow rooted crops like rice (Narayana Reddy and Krishnaiah, 1999).

2.5 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON MICRONUTRIENT STATUS OF THE SOIL

2.5.1 Zinc, Copper, Manganese and Iron

Regular application of ZnSO_4 @ 25 kg ha⁻¹ along with NPK fertilizers to the rice crop resulted in significant buildup of DTPA extractable Zn status in both red and laterite soils. Annual application of FYM @ 10 t ha⁻¹ also had favourable effect in maintaining the DTPA extractable Zn, Fe, Mn and Cu status of the soils. But continuous application of NPK fertilizers lowered the DTPA-Zn status to the level of 0.7ppm from initial value of 1 ppm (Panda and Sahoo, 1989).

Indulkar and Malewar (1990) reported that application of FYM @ 10 t ha⁻¹ resulted in significantly higher available Zn to the succeeding gram crop with or without inorganic zinc sources. They also indicated that various sources of Zn blended with N and NP carriers had shown additive effects on availability of Zn in rice-gram cropping system.

Deepak Kher (1993) indicated that the DTPA-Zn and Ca content in surface soils increased due to application of 100 per cent NPK + Zn and FYM. Marginal increase in the available Fe was found due to 100 per cent and 150 per cent NPK treatments and available Mn decreased under fertilizer treatment.

Availability of Zn, Cu, Mn and Fe decreased as the soils became aridic, but their total contents were increased (Katyal and Sharma, 1991). In addition, they observed that irrespective of soil moisture regime, parent materials from which soils were developed also influenced their total micronutrient contents.

Bhardwaj *et al.* (1994) studied the effect of long-term cropping and fertilization on crop yield and properties of an *Alfisol*. They observed that FYM treated plots had the highest contents of all the nutrients studied in the soil, indicating thereby that FYM when applied along with 100 per cent NPK increased the DTPA extractable micronutrients to a significant extent and depleting of DTPA extractable Fe, Mn, Cu and Zn status of unfertilized as well as fertilized plots.

Application of zinc enriched composted coir pith increased the Fe or Zn ratio at all the stages of crop growth. The acidic nature and high inherent content of Fe (4300 mg kg^{-1}) in the composted coir pith besides prolonged submergence enhanced the availability of Fe, which might had increased the ratio (Chitdeswari and Krishnaswamy, 1996).

Chitdeswari and Kumaraswamy (1997) reported from the experiment conducted in an green house in two deficient Typic ustorthents and vertic Aquic ustropept using rice as the main crop and green manure crop as the residual crop that the higher levels of Zn ($5.0 \text{ Mg Zn kg}^{-1}$) and its enrichment with green manure (composted coir pith + green leaf manure) increased the yield, amount of zinc present in water soluble, exchangeable, organically bound, occluded forms, DTPA-Zn status and Zn content in the plants. Increasing Zn additions with organic manures also resulted in a significant residual effect on subsequent crop.

The status of available Zn and Fe improved considerably with balanced use of fertilizers along with organic manures over 12 years of cropping under rice based cropping system (Pathak and Ghose, 1996).

2.6 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON MICROBIAL AND BIOCHEMICAL PROPERTIES OF SOIL

2.6.1 Microbial biomass carbon, Urease, Dehydrogenase and Phosphatase enzyme activities

It was observed that the treatment, which included addition of nitrogen due to continuous leguminous green manure crops significantly increased the dehydrogenase, phosphatase and urease activities and the soil biomass as compared to the treatments, which included application of NPK fertilizers for 30 years (Bolton *et al.*, 1985).

In an *Alfisol* at Bangalore the highest phosphatase, dehydrogenase, urease and total biomass contents of the soil was found in the case of plots treated with lime along with FYM and chemical fertilizers (Kavallappa, 1989).

Kamalesh *et al.* (1991) noticed that the total microbial biomass and dehydrogenase activity of the soil significantly increased in plots, which received 10 t ha^{-1} of FYM annually for 20 years.

In an *inceptisol* of Coimbatore, the dehydrogenase and phosphatase activities were found to be the highest in FYM treated plots. With higher rates of NPK fertilization, the activities of soil enzymes were also found to be higher and the effect was more pronounced when FYM was applied in combination with fertilizers as reported by Singaram and Kamalakumari (1995).

Sesbania aculeata registered the maximum urease and dehydrogenase activities and *Sesbania speciosa* recorded the maximum phosphatase activity. In general, green manures recorded higher enzyme activities than FYM. The activity of urease and dehydrogenase increased upto 20 DAT and phosphatase activity upto 40 DAT and declined thereafter. The rice rhizosphere recorded higher enzyme activity than non rhizosphere soil. The enzyme activities were positively correlated with organic carbon content (Sriramachandra Sekharan *et al.*, 1997).

The results of the study on rice cultivation under flooded condition indicated that urease activity increased during the active growth stage followed by decrease to initial low levels at harvest and later. Since the level of urease is nearly constant in a particular soil and does not change significantly by flooding (Chandrasekhar Rao and Saroja Raman, 2000)

2.7 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON YIELD PARAMETERS

2.7.1 Growth and yield attributes

Oliveira *et al.* (1992) reported that the cowpea nodules number and weight increased with P rates although increases were not significant. Pooled analysis revealed that dry matter production and yield components like number of effective tillers, filled grains or panicle and 1000 grains weight improved significantly when rice was fertilized with 75 per cent of N, P and K along with FYM @ 10 t ha⁻¹ compared to application of 100 per cent NPK chemical fertilizers alone (Mondal *et al.*, 1994).

Mastan *et al.* (1998) studied the direct and residual cumulative effect of phosphorus in rice-rapeseed-green gram cropping system showed that the number of tillers and panicles m⁻² and number of filled grains per panicle and test weight of rice increased significantly upto 60 kg P₂O₅ ha⁻¹.

Dubey and Verma (1999) reported that application of 100 per cent N through poultry manure, FYM and glyricidia leaf and combination of 50 per cent NPK + 50 per cent organic manure treatments had influenced

growth and yield attributes viz., plant height, panicles m^{-2} and filled grains panicle⁻¹, which were superior over control but were on par with NPK fertilizer application alone.

Solaiappan and Veerabadran (1997) noticed that number of nodules was significantly more in sesbania species, *Sesbania rostrata* had lesser number of root nodules but, it had more stem nodules. Plant height, effective tillers and number of grains per panicle were significantly influenced by incorporation of *Sesbania rostrata*. However, there was no significant effect on 1000 grain weight due to incorporation of GM crops. The efficient utilisation of mineralised N from the incorporated GM crops along with applied fertilizer nitrogen would have increased the availability of N throughout the growth period increasing the growth and yields attributes in rabi rice.

2.8 EFFECT OF LONG-TERM SOIL FERTILITY MANAGEMENT THROUGH ORGANIC AND INORGANIC SOURCES ON YIELD AND UPTAKE OF PLANT NUTRIENTS

2.8.1 Crop yield

Average data of sixteen years showed that incorporation of FYM along with optimal NPK enhanced the production of rice, wheat and fodder yield of cowpea crop (Anon., 1989).

John *et al.* (1989) reported that integrated use of legume green manure or legume residues with organic N fertilizer could offer rice farmers an opportunity to reduce their expensive inorganic fertilizer inputs. The rice yield

following fallow and cowpea cropping with removal of all above ground cowpea vegetation were similar but mean rice yield were 0.9 and 0.7 Mg ha⁻¹ higher following incorporation of green manure and crop residue, respectively. The green manure substituted 34 and 54 kg urea-N ha⁻¹. Cowpea grown for green manure crop or for grain, with incorporation of residues remaining after harvest, made similar positive contributions to rice yield, but growing cowpea to maturity offered the advantage of attaining approximately 1.0 t ha⁻¹ cowpea grain yield.

Azam and Yousaf (1991) showed that rice grain yield was greater in treatments given compost + green manure followed by green manure alone.

During initial two years, 100 per cent chemical fertilizers alone gave 15–30 per cent higher yield but in the following years the combination of organic sources (FYM or green manure) with chemical fertilizers produced more grains compared to fertilizers application alone (Yadav *et al.*, 1992).

Sisworo *et al.* (1992) reported that the application of legume residues (soybean, cowpea, groundnut and mungbean) during rice sowing increased the rice yield and was positively correlated with N applied through residues.

Twelve years data show significant responses of rice and wheat to nitrogen and phosphorus. Potassium did not show any appreciable influence

on yield. The results also indicated that yields started to decline after seven or eight years of continuous cropping (Kumar and Yadav, 1993).

Gill *et al.* (1994) reported that the rice yield with plot received green manure + 100 per cent recommended inorganic fertilizers surpassed the 150 per cent recommended inorganic fertilizer. The plots supplied with green manure + 50 per cent recommended inorganic fertilizers and farm yard manure @ 6 t ha⁻¹ + 50 per cent recommended fertilizers gave significantly more yield than 100 per cent recommended inorganic fertilizers.

Datta and Bharadwaj (1995) reported that use of legume green manuring in rice-wheat cropping on an acid loam soil gave a crop yield equivalent to that obtained on addition of 90 kg fertilizer N applied alone.

Nand-Ram and Ram (1996) showed that continuous cropping without any fertilizers showed decreasing trend in rice and wheat yields. The addition of zinc or FYM along with 100 per cent NPK enhanced the mean grain yield of rice by 12 and 14 per cent and that of wheat by 13 and 16 per cent respectively, compared with 100 per cent NPK alone in a long-term fertilizer experiment on a typic Hapludoll soil of rice or wheat or *Vigna unguiculata* system.

Application of recommended level of N (40 kg ha⁻¹) 50 per cent as urea and 50 per cent as FYM registered the maximum grain and straw yield besides improving the soil fertility status (Chitdeshwari *et al.*, 1997)

A field experiment was conducted during 1993–94 to 1995–96 at CARI, Port Blair, Andaman and Nicobar Islands to study the effects of integrated nutrient management in rice [(*Oryza sativa*)–rice–cowpea (*Vigna unguiculata* (R.))] sequence on crop productivity, soil fertility and economics. Combined use of 50 per cent NPK + 50 per cent poultry manure significantly increased the growth and yield of first rice crop (74%) and second rice crop (79.8%) over the control. The effect of 50 per cent NPK + 50 per cent FYM and NPK dose alone was also comparable. Application of FYM and poultry manure alone or combined with 50 per cent NPK had significant residue effect on the pod yield of cowpea (Dubey and Verma, 1999).

Chitra *et al.* (1999) reported that rice grain yield was higher due to addition of 50 kg N ha⁻¹ + green leaf manure application over other organic manure treatments. Stalin *et al.* (1999) also showed that basal incorporation of green manure @ 6.25 ha⁻¹ in combination with application of 150 kg N ha⁻¹ in 5 splits resulted in the highest grain yield.

Jagadeeswari and Kumarswamy (2000) reported that grain yield of rice was significantly higher in treatments that received FYM or green manure or urban compost @ 12.5 t ha⁻¹ besides N, P and K than when no manure or NPK treatments were applied, thereby highlighting the beneficial effect of organic manures in increasing the crop yield. The results of straw yield also showed similar trend as in grain yield.

Results obtained in the field experiment conducted on inceptisol during two consecutive *kharif* seasons revealed that grain and straw yields of rice increased significantly with increasing levels of NPK fertilizers. Application of FYM @ 10 t ha⁻¹ and BGA inoculation either alone or in combination increased economic yield (Dixit and Gupta, 2000).

2.3.2 Uptake of nutrients

Average data of sixteen years showed that incorporation of FYM along with optimal NPK enhanced the production of rice and uptake of major nutrients by rice and fodder cowpea (Anon., 1989).

Vageesh *et al.* (1990) observed that uptake of N, P, K by rice was highest with application of 150 per cent of the recommended fertilizer rate to both *kharif* and summer crops. Uptake of N and K were high with 50 per cent recommended NPK + 50 per cent N as glyricidia applied during monsoon and 100 per cent of recommended NPK applied during summer. Uptake of K was high with 75 per cent of recommended NPK + 21 per cent N as glyricidia applied in monsoon and 75 per cent of recommended NPK applied in the summer.

Sisworo *et al.* (1992) in their studies on effect of legume residues pertaining to N uptake and N concentration observed increased N uptake by application of legume residues. Further increased grain N concentration was observed due to addition of legume residues at higher levels. The higher rate

of K uptake by the crops under NPK treatments was believed to restrict level of K accumulation in the soil (Agarwal *et al.*, 1993).

Maximum uptake of nutrients (N, P, K and S) in rice was recorded with 75 per cent of recommended dose of N, P and K along with FYM @ 10 t ha⁻¹ compared to 100 per cent NPK fertilizer alone (Mondal *et al.*, 1994).

Azam and Yousaf (1991) reported that N content in grain and straw and N uptake was greater in treatments which were given compost + green manure than the application of green manure alone.

Basal incorporation of green manure @ 6.25 t ha⁻¹ in combination with 150 kg N ha⁻¹ in five splits resulted in highest dry matter production, N content and N uptake of rice (Stalin *et al.*, 1999).

Nitrogen content of rice straw was significantly higher in treatments that received N than in treatments without N. Similar was the case with P and K in rice grain and straw. Uptake of N, P and K was significantly higher in treatment that received manures besides N, P and K than no manure and NPK treatments (Jagadeswari and Kumaraswamy, 2000).

2.8.3 Economic and sustainable yield index (SYI)

Singh *et al.* (1990) reported that taking consideration of the maintenance or buildup soil fertility should be one of the goals of sustainable agriculture. It appeared that conjunctive application of nutrients through

organic and inorganic sources, would eventually create favourable environment for achieving sustainable yields. In a study carried out at Bangalore that SYI was 0.7 when 5 t ha⁻¹ of crop residue was applied to finger millet in conjunction with 50 : 50 : 25 kg NPK ha⁻¹. In another study, in vertic inceptisol of Solapur, application of green leaf manure lopping helped to increase crop yield and SYI, which was raised to the level of 0.73 indicating thereby that the practise had a great relevance.

Dubey and Verma (1999) reported that in rice-rice-cowpea sequence under humid tropical Andaman Islands, integration of 50 per cent NPK + 50 per cent poultry manure or FYM was advantageous in sustaining the crop, soil productivity and obtaining higher net returns.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1 MATERIAL

The ongoing long-term soil fertility management trial in rice based cropping system which was initiated during 1989–90 in collaboration with All India Coordinated Rice Improvement Programme (ICAR) at the Regional Research Station, V.C.Farm, Mandya, Karnataka, India was made use off during 1999–2000 to study the nutrient dynamics of various long term nutrient management practises in rice–cowpea cropping system. Mandya is situated in the Southern Dry Zone (6) at 12°30' N latitude and 76°76' E longitude. It receives an average of 749 mm rainfall annually mainly through South-West monsoon (Anon., 1984). However, majority of the area is irrigated through Krishna Raja Sagar Reservoir constructed across Cauvery river. This research station has been recognized as the premier centre for research, specially in rice. Results of experiments carried out at this station have changed farming practices significantly and there has been considerable improvement in the economic status of farmers of the entire zone.

Information of the effect of nutrient management practises on the nutrient dynamics, soil physical, chemical and biochemical properties, fertility status, yield of crops, sustainable yield index and economics helps a

great deal to the farmers of this zone. A slight modification in the nutrient management practise results in saving of several millions of rupees.

Hence, it was pertinent to initiate the long term soil fertility experiment using both organic manures and inorganic fertilizers. The organic materials such as Farm Yard Manure (FYM) and Green Manure (GM) (Dhaiancha) and inorganic fertilizers viz., urea, single superphosphate and muriate of potash as well as zinc sulphate were used in the experiment.

The chemical composition of the organic materials used in the experiment is given in Table-1.

3.1.1 Field trial

To study the long-term integrated nutrient management using organic and inorganic fertilizers on sustainable soil fertility and productivity, an experiment was conducted at the Regional Research Station, V.C.Farm, Mandya during 1999–2000. Data pertaining to physico-chemical properties of the soil of experimental site are presented in Table-2.

3.1.2 Experimental details

The experiment was carried out on permanent, fixed treatments with rice Var. IR-20 as the main *kharif* (1999) crop and cowpea Var. TVX 944-02 as a succeeding residual summer (2000) crop.

Table-1: Chemical composition of different organic manures used in the experiment (on dry weight basis)

Composition	Farm Yard Manure (120 days)	Dhaiiancha (60 days)
1. Moisture (%)	53	81
2. Organic carbon (%)	52.70	44.10
3. Cellulose (%)	13.10	19.65
4. Lignin (%)	20.30	10.70
5. Protein (%)	3.25	15.30
6. Humic acid (%)	7.90	6.60
7. Fulvic acid (%)	1.80	1.30
8. C : N ratio	27.90	18
9. Nitrogen (N %)	0.53	2.45
10. Phosphorus (P %)	0.21	0.40
11. Potassium (K %)	0.69	1.77
12. Calcium (Ca %)	1.42	0.56
13. Magnesium (Mg %)	0.94	0.25
14. Sulphur (S %)	0.42	0.78
15. Iron (Fe mg kg ⁻¹)	1010	1370
16. Manganese (Mn mg kg ⁻¹)	318	505
17. Copper (Cu mg kg ⁻¹)	132	182
18. Zinc (Zn mg kg ⁻¹)	168	340

3.1.2.1 Treatment details

The experiment consisted of seven permanent treatments and these were replicated thrice using randomized complete block design (RCBD). The details of the permanent treatments (shown in Plan of Layout) used for *kharif* and summer season are given as under :

T₁ – No fertilizers and manure (Control)

T₂ – 100 per cent recommended NPK

T₃ – 50 per cent recommended NPK

T₄ – 50 per cent NPK + 50 per cent nitrogen through Green manure (GM)

T₅ – 50 per cent NPK + 50 per cent nitrogen through Farm Yard Manure (FYM)

T₆ – 50 per cent NPK + 25 per cent of nitrogen through GM + 25 per cent nitrogen through FYM

T₇ – FYM alone @ 10 t ha⁻¹

3.1.2.2 Replication : Three

3.1.2.3 Design : RCBD

3.1.2.4 Plot size

a) Rice (*kharif*)

Gross plot : 20 m x 5 m = 100 m²

Net plot : 19.20 m x 4.60 m = 88.32 m²

b) Cowpea (summer)

Gross plot : 20 m x 5 m = 100 m²

Net plot : 19.60 m x 3.20 m = 62.72 m²

Table-2: Initial physico-chemical properties of experimental site recorded during 1989

I. Physical properties	
1. Soil separates	
Coarse sand (%)	44.56
Fine sand (%)	35.42
Silt (%)	6.60
Clay (%)	13.35
Textural class	Sandy loam
Soil taxonomic class	Typic Rhodustalfs
2. Bulk density (g cm^{-3})	1.67
3. Infiltration rate (cm h^{-1})	2.03
4. Maximum Water Holding Capacity (MWHC %)	20.70
5. Porosity (%)	24.50
6. Hydraulic conductivity ($\times 10^{-5} \text{ms}^{-1}$)	4.10
II. Chemical properties	
7. pH	6.78
8. EC dS m^{-1}	0.13
9. Organic carbon (%)	0.35
10. CEC [$\text{c.mol(p}^+)\text{kg}^{-1}$]	12.30
11. Av. Nitrogen (N kg ha^{-1})	165.00
12. Av. Phosphorus ($\text{P}_2\text{O}_5 \text{ kg ha}^{-1}$)	28.90
13. Av. Potassium ($\text{K}_2\text{O kg ha}^{-1}$)	122.50
14. Exch. Calcium (Ca) [$\text{c.mol(p}^+)\text{kg}^{-1}$]	1.25
15. Exch. Magnesium (Mg) [$\text{c.mol(p}^+)\text{kg}^{-1}$]	0.38
16. Av. Sulphur (S mg kg^{-1})	5.30
17. Zinc (DTPA-Zn) (mg kg^{-1})	0.87
18. Copper (DTPA-Cu) (mg kg^{-1})	2.20
19. Manganese (DTPA-Mn) (mg kg^{-1})	6.40
20. Iron (DTPA-Fe) (mg kg^{-1})	42.3

3.1.2.5 Fertilizer schedule (kg ha⁻¹)

Rice (<i>kharif</i>)	:	100:50:50 kg N:P ₂ O ₅ :K ₂ O ha ⁻¹
Cowpea (summer)	:	Residues of main crop

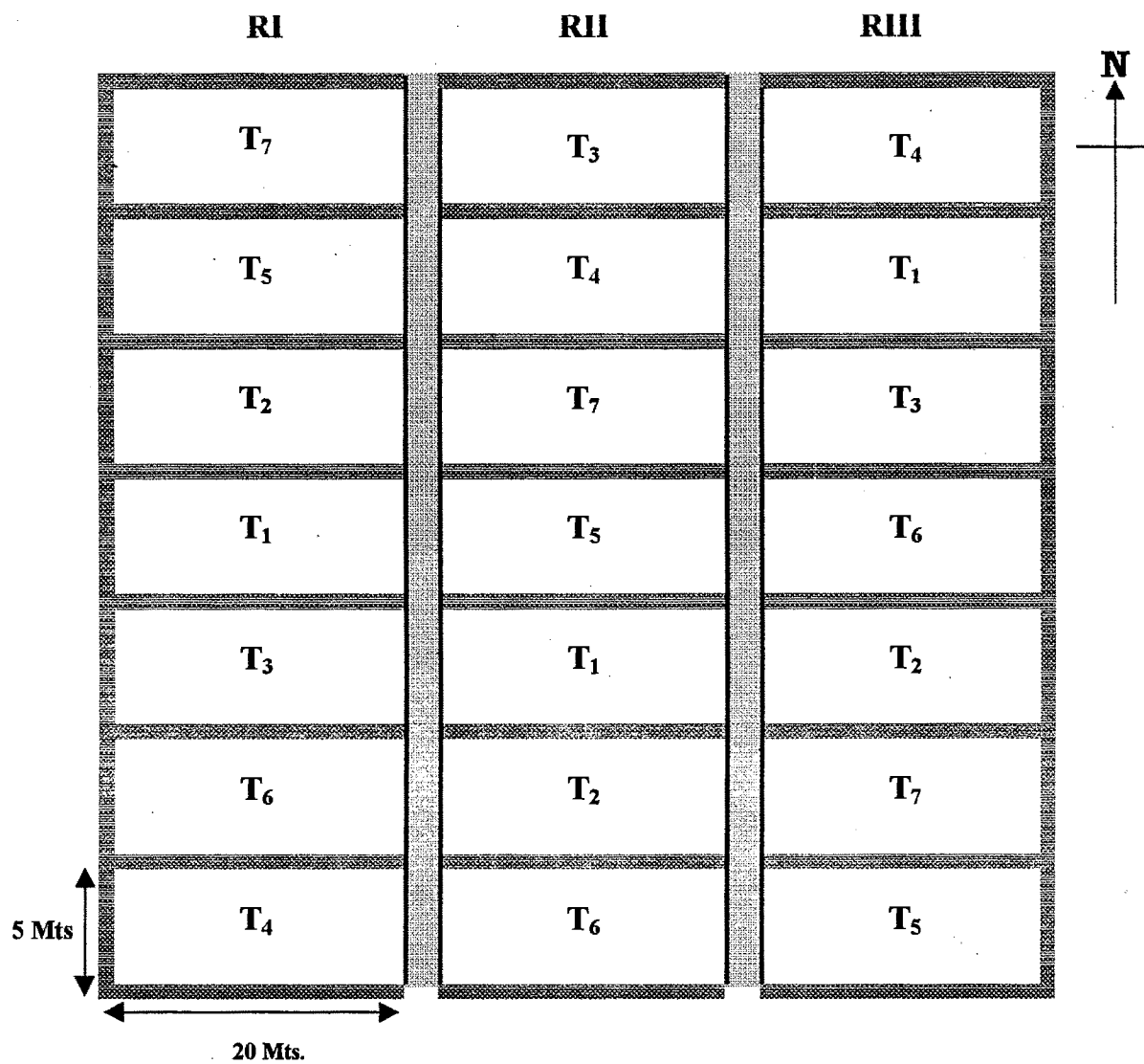
3.2 EXPERIMENTAL METHODS

3.2.1 Organic manures and inorganic fertilizers

Dhaiancha was grown as an *in situ* green manuring (GM) crop in the respective permanent plots receiving green manure treatments during pre-*kharif* season. Farm Yard Manure (FYM) was also applied two weeks prior to the sowing in respective FYM receiving treatments in equivalent quantities of nitrogen and the treatment requirement. At transplanting, half of the nitrogen and full dose of phosphorus and potash were applied. The remaining nitrogen was given in two equal doses of top dressing, 25 per cent each at tillering and panicle initiation stages, respectively. Zinc sulphate was applied @ 20 kg ha⁻¹ to the soil once in three rice crop season to all the treatments except treatment 1 and 7 and in accordance with treatment requirement.

3.2.2 Cultural practises

Twenty five days old rice seedlings were transplanted at a spacing of 20 x 10 cms with three seedlings per hill in well puddled and levelled field. The plots were in saturated water level in the beginning. These were irrigated after 48 hours to maintain 2.5 cm level of submergence for one week. Then, these plots were irrigated to maintain the water level to



PLAN OF LAYOUT

a depth of 5 cm throughout the crop growth except for the last ten days of harvest. The cowpea crop, which received no fertilizer and manures, was taken up as residual crop after field preparation during summer with protective irrigation at a spacing of 45 x 10 cms. Other cultural and plant protection measures were attended to as per the package of practises recommended for this command area.

The crops were harvested at maturity and the grains were separated by using manual operation. The yields were expressed at 14 per cent moisture for grain and oven dry basis for straw.

3.2.3 Soil sampling

Soil samples were collected from each plot of the experiment field at 0–15 cm depth after harvest of rice (*kharif*) and cowpea (summer) crops raised during 1999–2000. Samples were air dried in shade, ground with wooden mallet and passed through 2mm sieve and stored in polyethylene bags.

3.2.4 Plant samples

Grain and straw samples of rice and cowpea crops raised during *kharif* and summer, respectively during 1999–2000 were collected soon after harvest of the crops. The samples were initially air dried and then oven dried at 70°C for 10 hours and later ground using Willey stainless steel mill and stored in paper bags.

3.3 ANALYSIS OF SOIL SAMPLES

Soil samples were analysed for various physical, chemical microbial and bio-chemical properties by following standard analytical techniques.

3.3.1 Physical properties of soil

Soil samples collected after the harvest of rice and cowpea crops were analysed for the physical properties viz., particle size distribution, stable aggregates, bulk density, maximum water holding capacity, infiltration rate, hydraulic conductivity and porosity of the soil.

3.3.1.1 Mechanical analysis (Particle size distribution)

Mechanical composition of soil samples were determined, employing International pipette method (Piper, 1956). The results were expressed as per cent of different particle size groups viz., coarse sand, fine sand, silt and clay.

3.3.1.2 Bulk density

Bulk density of soil samples were determined by core sampler technique (Black, 1965) recording the fresh weight in the field and dry weight in the laboratory. Drying of soil was done in hot air oven to a constant weight. Bulk density was calculated as dry weight of soil per unit volume of the core used to sample in the field.

3.3.1.3 Maximum water holding capacity

Keen Raczkowski cups were used for measurement of maximum water holding capacity of soil as outlined by Piper (1956).

3.3.1.4 Infiltration rate

The infiltration rate was measured in the field using double ring infiltrometer having a height of 30 cm and diameter of 20 cm and 40 cm for the inner and outer cylinders, respectively as described by Richards (1954).

3.3.1.5 Hydraulic conductivity

The hydraulic conductivity measurement was made using plexiglass perimeters as described by McNeal and Reeve (1974).

3.3.1.6 Porosity

Porosity of surface soil was calculated by making use of corresponding bulk density values and standard particle density of 2.65 g cm^{-3} by using the formula as given below:

$$\text{Porosity (\%)} = \left(1 - \frac{\text{Bulk density (BD g cm}^{-3}\text{)}}{\text{Particle density (PD g cm}^{-3}\text{)}} \right) \times 100$$

3.3.1.7 Water stable aggregates

Per cent of stable aggregates was estimated using weighed quantity (35 to 40 gms) of soil clods collected in the field. The clods were broken to small pieces (5 to 8 mm sizes) and subjected to wet sieving for 2

minutes using Yoder sieving apparatus containing a set of sieves between 5 mm and 0.2 mm. Fractions from different sieves were dried, weighed and expressed as per cent of stable aggregates of respective size fractions (5, 2, 0.5, 0.2 mm) (Black, 1965).

3.3.2 Chemical properties

Soil chemical properties determined included soil reaction, electrical conductivity, cation exchange capacity, organic carbon, ~~and~~ and available nitrogen, phosphorus, potassium, exchangeable calcium and magnesium, available sulphur and DTPA extractable zinc, copper manganese and iron.

3.3.2.1 Soil reaction (soil pH)

Soil water suspension at 1 : 2.5 ratio was prepared for determination of soil reaction (soil pH), using pH meter fitted with combined electrode (Jackson, 1973).

3.3.2.2 Electrical conductivity

The soil water suspension prepared for estimation of pH was used for measuring electrical conductivity of soil using conductivity bridge (Jackson, 1973).

3.3.2.3 Cation exchange capacity

Ten gram of soil was leached several times with neutral normal ammonium acetate and washed with water. It was followed by

washing with alcohol to remove excess of ammonium acetate. Soil on the filter paper was leached with 10 per cent potassium chloride solution to replace adsorbed NH_4^+ ions by K^+ ions. Ammonium in the leachate was quantified by Kjeldahl distillation method (Jackson, 1973) and results were expressed in terms of cation exchange capacity by computation.

3.3.2.4 Organic carbon

Finely ground (0.2 mm sieve) soil was used for estimation of organic carbon by wet oxidation method using potassium dichromate and sulphuric acid for oxidation of organic matters (Walkley and Black, 1934).

3.3.2.5 Mineralisation of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ in the soil

Field moist soil samples were thoroughly mixed, and representative sub-samples were extracted immediately by shaking with 2 M KCl solution (1 : 6 soil : solution ratio) for 1 hour on a mechanical shaker followed by filtration. The extracts were analysed for $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ by micro-Kjedhal procedure (Mulvaney, 1996).

3.3.2.6 Available nitrogen, phosphorus and potassium

Twenty grams of soil sample was used for estimation of available nitrogen by following alkaline permanganate method using macro distillation apparatus as outlined by Subbaiah and Asija (1956).

Available phosphorus in soil was extracted with Olsen solution and P in the extract was estimated by chlorostannous reduced molybdo phosphoric blue colour method (Jackson, 1973).

Available potassium in the soil was extracted using neutral normal ammonium acetate solution and K in the extract was measured by a Flame photometer (Jackson, 1973).

3.3.2.7 Exchangeable calcium, magnesium and available sulphur

Exchangeable calcium was estimated by titrating suitable aliquot of ammonium acetate extract of soil against standard EDTA solution using sodium hydroxide and mureoxide indicator.

Exchangeable calcium plus magnesium were estimated by titrating a separate aliquot of ammonium acetate extract of soil against EDTA solution using ammonium chloride and ammonium hydroxide buffer and EBT indicator. Exchangeable magnesium content in the soil was calculated by subtracting exchangeable calcium content from exchangeable calcium plus magnesium content of the soil (Jackson, 1973).

Available sulphur in the form of sulphate sulphur was determined by using Morgan's reagent (sodium acetate – acetic acid buffer, pH 4.8). Sulphur content in the extract was measured turbidometrically using spectrophotometer at 420 nm (Jackson, 1973).

3.3.2.8 DTPA extractable micronutrients

The method developed by Lindsay and Norwell (1978) using DTPA (Diethylene triamine penta acetic acid) was followed for the estimation of Zn, Cu, Mn and Fe.

Ten grams soil was shaken with 20 ml of DTPA extractant for 2 hours for the extraction of micronutrient cations. Atomic absorption spectrophotometer was used for measuring the contents of micro nutrients.

3.3.3 Microbiological properties

3.3.3.1 Microbial biomass carbon

Soil samples passed through 1 mm sieve were used for the assay of microbial biomass C. Ten grams of soil samples were taken in duplicate in 75 ml screw cap bottles. One set of the soil sample was fumigated with 2 ml of liquid chloroform (CHCl_3) for 24 hours and bottles were made air tight by closing the mouth of the bottles with screw caps (Chauhan *et al.*, 1981). The chloroform was subsequently removed by placing the samples overnight in an oven at 50°C . Both fumigated and unfumigated soil samples were extracted with 0.5 M K_2SO_4 by shaking for 30 minutes and filtered through Whatman no.42 filter paper.

Microbial biomass carbon was determined indirectly by ninhydrin reactive – N method. Soil extracts (1 ml) were treated with 4 ml of freshly prepared ninhydrin reagent (100 ml of 0.2 M citrate buffer of pH 5.5 containing $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ mixed with 100 ml of 1:1 methoxy ethanol and

water solution containing 4 g of ninhydrin) and heated in a boiling water bath for 20 minutes. After cooling, 5 ml of 1:1 propanol : water solution was added and mixed. The absorbance was read at 570 nm against the control in which the soil extract was substituted by 0.5 M K_2SO_4 solution. A standard curve consisting of 5 different concentrations of L-leucine standard dissolved in 0.5 M K_2SO_4 was prepared. Microbial biomass carbon was calculated by multiplying NR-N with factor 24.0 (Carter, 1991).

3.3.3.2 Urease activity

The reaction mixture consisted of 10 g soil, 20 ml of 0.2 M citrate buffer (pH 6.7) and 10 ml urea solution of distilled water was added and filtered. One ml of aliquot of the filtrate was mixed with phenol-sodium reagent and the intensity of the colour was read spectrophotometrically after 20 minutes at 630 nm (Hoffmann and Teicher, 1961).

3.3.3.3 Dehydrogenase activity

Five grams of soil samples and 0.2 gram of $CaCO_3$ were taken in the test tubes and treated with 2 ml of 2 per cent 2, 3, 5 triphenyl-tetrazolium chloride (TTC) and 2 ml of distilled water to create an anaerobic condition. Sample was mixed thoroughly with the reagent using glass rod and incubated at 37°C for 24 hours. The amount of triphenyl formazan (TPF) formed in soil was extracted using methanol and filtered through a

funnel plugged with cotton. The soil was repeatedly washed with methanol to remove all reddish colour and diluted to 100 ml. The intensity of reddish colour was measured at 485 nm by taking methanol as blank. The amount of TPF formed was calculated using calibration graph prepared from TPF standard (Casida *et al.*, 1964).

3.3.3.4 Acid phosphatase activity

Two grams of soil was treated with 0.3 ml of toluene and 8 ml of modified universal buffer (pH 6.5) and 2 ml of p – nitrophenyl (PNP) and incubated at 37°C for 1 hour. After 1 hour, 2 ml of CaCl₂ (0.5 M) and 8 ml of NaOH (0.5 N) were added and filtered. The intensity of yellow colour was read at 420 nm against the blank obtained from the soil by following the same procedure, then 2 ml of PNP was added after the addition of 0.5 M CaCl₂ and 0.5 N NaOH., immediately before filtration of soil samples (Tabatabai and Bremner, 1969).

3.4 NUTRIENT UPTAKE BY THE CROPS

Nitrogen in grain and straw samples were estimated by micro Kjeldhal digestion and distillation method using 0.5 g of powdered samples (Piper, 1956). Based on N in grain and straw the nitrogen uptake values were worked out using grain and straw yields and expressed as Kg ha⁻¹.

3.4.1 Estimation of Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Zinc, Copper, Manganese and Iron Uptake by Grain and Straw of the crops.

One gram of the powdered samples were digested with 10 ml diacid mixture (Nitric : perchloric) after pre digestion with 5 ml of concentrated nitric acid for overnight, till white residue was left at the bottom of the flask. Contents were diluted to 50 ml with 6 N hydrochloric acid.

Phosphorus was estimated using a suitable aliquot of the above extract by vanadomolybdophosphoric yellow colour method (Jackson, 1958). Potassium was estimated by feeding the above extract, after suitable dilution to flame photometer (Jackson, 1958).

Calcium and magnesium were estimated by versenate titration method as detailed earlier (Jackson, 1958).

Sulphur was estimated using a suitable aliquot of the above extract by Barium chloride turbidometric method (Bradsley and Lancaster, 1965).

Micronutrients (Zn, Cu, Mn and Fe) were estimated by feeding the digested extract after suitable dilutions to the Perkin Elmer Atomic Absorption Spectrophotometer, Model-530, using the appropriate hollow cathode lamps and were expressed as mg kg^{-1} of grain and straw samples.

3.5 SUSTAINABLE YIELD INDEX

The sustainable yield index was worked out by making use of 11 years' (1989–2000) yield data of rice and cowpea crops by using the formula as given below (Singh *et al.*, 1990):

$$\text{Sustainable Yield Index (SYI)} = \frac{Y - C}{Y_{\text{max.}}}$$

Where,

Y = Mean yield

C = Standard deviation

Y max. = Maximum yield of a year

3.6 STATISTICAL ANALYSIS

The methods outlined by Panse and Sukhatme (1985) were made use for statistical analysis of the data for drawing conclusion on the effect of various treatments on different parameters studied. Simple correlation coefficients ('r') were also worked out for relationships among soil properties and crop yield.

RESULTS

IV. EXPERIMENTAL RESULTS

Intensive cropping to enhance productivity of a land depletes nutrient reserves of the soil at a faster rate. Productivity of lands under intensive cropping is unlikely to be sustained unless new and emerging nutrient deficiencies or imbalances are identified and corrected promptly. Long term coordinated trial on productivity of selected rice based cropping system was initiated during 1989–90 and detailed observations were recorded during 1999–2000 at the Regional Research Station, V.C.Farm, Mandya to monitor the changes in soil fertility and crop productivity under different organic manure and fertilizer treatments.

4.1 PHYSICAL PROPERTIES OF SOIL AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

4.1.1 Mechanical composition of soil

Mechanical composition of soils samples after harvest of both rice and cowpea during 1999–2000 (Table–3) has indicated no change not only among the treatments, but also between the two seasons of the trial. The values did not differ significantly from their initial value obtained during 1989 (Table–1). The values of different fractions of soil have remained the same. Proportion of coarse sand, fine sand, silt and clay was 44.56, 35–42, 6.60 and 13.35 per cent, respectively, thus confirming the textural class of soil viz., sandy loam which did not found to vary due to the effect of various treatments.

Table 3: Mechanical composition of soil as influenced by organic manure and fertilizers after harvest of rice and cowpea crops in rice based cropping system

Treatments	Rice (<i>kharif</i> 1999)				Cowpea (summer 2000)			
	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
T ₁ =Control (no fertilisers and manures)	44.52	35.40	6.51	13.16	44.26	35.57	6.47	13.17
T ₂ =100 per cent NPK	44.67	35.44	6.53	13.28	44.14	35.23	6.50	13.40
T ₃ =50 per cent NPK	44.47	35.46	6.59	13.17	44.29	35.34	6.53	13.30
T ₄ =50% NPK + 50% N--GM	44.41	35.38	6.37	13.58	44.51	35.29	6.34	13.67
T ₅ =50% NPK + 50% N--FYM	44.48	35.55	6.23	13.35	44.62	35.53	6.33	13.42
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	44.64	35.34	6.24	13.50	44.45	35.40	6.37	13.67
T ₇ = FYM @ 10 t ha ⁻¹	44.48	35.50	6.24	13.40	44.46	35.38	6.32	13.52
F test	NS	NS	NS	NS	NS	NS	NS	NS
S.E.m.±								
CD at 5%								
Initial Value (1989)	44.56	35.42	6.60	13.35				

N--= Nitrogen through
GM = Green Manure (*Dhaincha*)
FYM = Farm Yard Manure

4.1.2 Bulk density

Significant differences were observed in bulk density of soil among the imposed treatments. Among the treatments imposed FYM @ 10 t ha⁻¹ (T₇) recorded significantly the lowest bulk density of 1.30 and 1.29 g cm⁻³ followed by combination of organics with fertilizer treatments viz., T₆ (50% NPK + 25% N--GM + 25% N--FYM) recorded the value of 1.35 and 1.32 g cm⁻³, T₅ (50% NPK + 50% N--FYM) recorded 1.35 and 1.33 g cm⁻³ and T₄ (50% NPK + 50% N--GM) recorded 1.36 and 1.34 g cm⁻³. On the other hand, treatment which received only inorganic fertilizers recorded significantly higher value of 1.41 and 1.40 g cm⁻³ under T₂ (100% NPK) and 1.43 and 1.42 g cm⁻³ under T₃ (50% NPK) compared to treatments received organic manures with fertilizer combination (Table-4).

However, bulk density in control (1.67 g cm⁻³) was significantly higher than rest of the treatments and remained the same compared to initial value of 1.67 g cm⁻³ under both rice and cowpea crops.

4.1.3 Porosity

There was improvement in the porosity of the soil in treatments applied for 11 years to both rice and cowpea crops compared to initial status recorded during 1989. Porosity was only 24.50 per cent initially and improved due to the treatment effects in both rice and cowpea crops (Table-4).

Data indicated that porosity was significantly influenced by treatments. The highest porosity was obtained due to FYM @ 10 t ha⁻¹ (T₇)

recorded 42.60 and 43.70 per cent, which was significantly superior over control. The treatments T_6 (50% NPK + 25% N--GM + 25% N--FYM) recorded 35.30 and 37.40 per cent and T_5 (50% NPK + 50% N--FYM) were on par with T_7 . The treatment due to chemical fertilizers viz., T_2 (100 NPK) and T_3 (50% NPK) were on par with control after harvest of rice and cowpea crops, respectively.

4.1.4 Infiltration rate

Improvement in the infiltration rate of the soil was observed due to adoption of various nutrient management practises for 11 years to rice and cowpea (Table-4). Infiltration rate was higher in all the treatments both under rice and cowpea compared to initial value of 2.03 cm h^{-1} . The data as shown in the Table-4 indicated that there was significant increase in infiltration rate over control. The treatment T_7 (FYM @ 10 t ha^{-1}) recorded significantly higher value of 3.57 and 6.80 cm h^{-1} followed by T_6 (50% NPK + 25% N--GM + 25% N--FYM) of 3.30 and 6.40 cm h^{-1} , T_5 (50% NPK + 50% N--FYM) recorded 3.27 and 6.20 cm h^{-1} and T_4 (50% NPK + 50% N--GM) recorded 3.13 and 5.90 cm h^{-1} . Application of inorganic fertilizers @ 100 per cent NPK (T_2) showed values of 3.00 and 5.60 cm h^{-1} and 50 per cent NPK (T_3) of 2.37 and 4.76 cm h^{-1} after harvest of rice and cowpea crops, respectively.

However, the infiltration rate recorded remarkably higher values after harvest of cowpea as compared to rice crop.

Table 4: Physical properties of soil as influenced by long-term application of organic manure and fertilizers in rice based cropping system

Treatments	Rice (<i>kharif</i> 1999)					Cowpea (summer 2000)				
	Bulk density (g cm ⁻³)	Porosity (%)	Infiltration rate (cm h ⁻¹)	Hydraulic conductivity (x 10 ⁻⁵ ms ⁻¹)	MWHC (%)	Bulk density (g cm ⁻³)	Porosity (%)	Infiltration rate (cm h ⁻¹)	Hydraulic conductivity (x 10 ⁻⁵ ms ⁻¹)	MWHC (%)
T ₁ =Control (no fertilisers and manures)	1.65	26.70	2.20	4.17	20.70	1.67	30.80	2.60	4.20	21.20
T ₂ =100 per cent NPK	1.41	32.50	3.00	6.97	25.80	1.40	33.90	5.60	10.20	26.30
T ₃ =50 per cent NPK	1.43	29.80	2.37	6.80	24.30	1.42	32.50	4.76	10.71	24.40
T ₄ =50% NPK + 50% N--GM	1.36	34.80	3.13	8.40	29.90	1.34	35.80	5.90	12.00	30.20
T ₅ =50% NPK + 50% N--FYM	1.35	35.20	3.27	8.30	30.20	1.33	36.80	6.20	12.77	31.20
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	1.35	35.30	3.30	8.50	30.30	1.32	37.40	6.40	12.90	31.40
T ₇ = FYM @ 10 t ha ⁻¹	1.30	42.60	3.57	9.20	32.70	1.29	43.70	6.80	13.50	33.10
F test	*	*	*	*	*	*	*	*	*	*
S.E.m.±	0.013	2.44	0.30	0.39	1.96	0.013	2.55	0.28	1.24	1.77
CD at 5%	0.040	7.52	0.91	1.20	6.03	0.040	7.85	0.87	3.83	5.44
Initial Value (1989)	1.67	24.5	2.03	4.10	20.74					

N--= Nitrogen through
GM = Green Manure (*Dhaincha*)
FYM = Farm Yard Manure

4.1.5 Hydraulic conductivity

There was a marked improvement in hydraulic conductivity due to the long term nutrient management practises for 11 years both under rice and cowpea as compared to the initial value of $4.10 \text{ (} \times 10^{-5} \text{ ms}^{-1}\text{)}$ observed during 1989.

The data in respect of Hydraulic conductivity (Table-4) noticed that the treatment imposed of FYM @ 10 t ha^{-1} (T_7) had recorded the highest significant value of 9.20 and 13.50 ($\times 10^{-5} \text{ ms}^{-1}$) over the control followed by T_6 , T_5 , T_4 which recorded values on par and were significantly superior over fertilizer treatments viz., 100 per cent NPK (T_2) recorded 6.97 and 10.20 ($\times 10^{-5} \text{ ms}^{-1}$) and with 50 per cent NPK (T_3) the values were 6.80 and 10.71 ($\times 10^{-5} \text{ ms}^{-1}$) after harvest of rice and cowpea crops, respectively. However, the hydraulic conductivity was relatively higher after harvest of cowpea compared to rice.

4.1.6 Maximum water holding capacity

Maximum water holding capacity of the soil was improved in all the nutrient management practises adopted for 11 years in rice and cowpea crops. It was only 20.74 per cent during 1989, but all the treatments recorded higher value in 1999–2000 both after the harvest of rice and cowpea except control treatment (T_1) in rice, which had marginally decreased (20.70%).

The data in Table-4 showed that treatment T_7 (FYM @ 10 t ha^{-1}) recorded significantly higher value of 32.70 and 33.10 per cent compared to

control (20.70 and 21.20%) followed by T₆ (30.30 and 31.40), T₅ (30.20 and 31.20) and T₄ (29.90 and 30.20) per cent whose values were on par. The fertilizer treatments at 100 per cent NPK (T₂) recorded 25.80 and 26.30 per cent and at 50 per cent NPK (T₃) recorded 24.30 and 24.40 per cent and which were non-significant compared to control after both the seasons of rice and cowpea crops, respectively.

Comparison of maximum water holding capacity between crops indicated that values were higher after the harvest of cowpea compared to rice.

4.1.7 Water stable aggregates

Water stable aggregates recorded during the initiation of the experiment (1989) indicated a non-improvement trend in control and on the other hand, there was a remarkable improvement due to long-term application of organic and inorganic fertilizers for 11 years both under rice and cowpea as compared to initial values of 25.20, 12.70, 13.50 and 4.30 mm under 0.2, 0.5, 2 and 5 mm sized aggregates, respectively (Table-5).

The plots amended with FYM or GM along with chemical fertilizers (T₇, T₆ and T₅) recorded significantly higher values than the rest of the treatments. The water stable aggregates of size 0.2 mm ranged from 24.95 (T₁) to 37.29 (T₇) per cent. Further, it varied from 11.23 (T₁) to 24.91 (T₇) per cent in case of 0.5 mm size aggregates, from 11.98 (T₁) to 23.35 (T₇) for 2 mm size aggregate and from 3.65 (T₁) to 11.82 (T₇) per cent for 5 mm size aggregates after the harvest of rice crop.

Table 5: Long term effect of organic manure and fertilizers on water stable aggregates (%) in rice based cropping system

Treatments	Rice (<i>kharif</i> 1999)				Cowpea (summer 2000)			
	0.2 mm	0.5 mm	2 mm	5 mm	0.2 mm	0.5 mm	2 mm	5 mm
T ₁ =Control (no fertilisers and manures)	24.95	11.23	11.98	3.65	25.50	11.33	12.10	3.70
T ₂ =100 per cent NPK	32.95	20.18	21.50	8.20	33.10	20.30	22.20	8.65
T ₃ =50 per cent NPK	26.18	15.85	19.96	6.08	26.30	16.00	20.10	6.30
T ₄ =50% NPK + 50% N--GM	35.70	22.80	22.56	9.40	36.67	23.50	22.70	9.67
T ₅ =50% NPK + 50% N--FYM	36.41	23.06	20.44	9.51	36.70	23.30	21.30	10.00
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	36.73	23.22	22.70	10.72	37.30	24.70	22.70	11.30
T ₇ = FYM @ 10 t ha ⁻¹	37.29	24.91	23.35	11.82	37.67	25.30	23.66	12.68
F test	*	*	*	*	*	*	*	*
S.E.m.±	1.72	1.08	0.52	0.17	1.11	0.86	0.71	0.52
CD at 5%	5.31	3.32	1.60	0.53	3.43	2.66	2.18	1.59
Initial value (1989)	25.20	12.70	13.50	4.30				

N--= Nitrogen through

GM = Green manure (*Dhiancha*)

FYM = Farm yard manure

After the harvest of cowpea, the 0.2 mm sized aggregates varied from 25.50 (T₁) to 37.67 (T₇) per cent, from 11.33 (T₁) to 25.30 (T₇) for 0.5 mm size, from 12.10 (T₁) to 23.66 (T₇) for 2.0 mm size and from 3.70 (T₁) to 12.68 (T₇) for 5 mm sized aggregates.

4.2 SOIL CHEMICAL PROPERTIES AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

4.2.1 Soil reaction

Data indicated that the treatments which received organic and inorganics over the years viz., T₇ (FYM @ 10 t ha⁻¹) recorded pH value of 6.75 and 6.81, T₆ (50% NPK + 25% N--GM + 25% N--FYM) of 6.75 and 6.80, T₄ (50% NPK + 50% N--GM) of 6.70 and 6.80 values which are almost similar compared to initial value of 6.78. whereas, the fertilizer treatments decreased the pH over the years under T₂, 100 per cent NPK (6.63 and 6.60) and T₃, 50 per cent NPK (6.40 and 6.44) while in control (T₁) treatment the pH was high as 6.95 and 7.01 as compared to initial value after harvest of rice and cowpea crops, respectively (Table-6).

4.2.2 Electrical conductivity

Significant differences were observed among the treatments with respect to the electrical conductivity after the harvest of both rice and cowpea crops (Table-6). In case of rice, application of organic manure alone (T₇) or by integrated nutrient management approach (T₄, T₅, T₆) had significantly higher electrical conductivity (0.151 to 0.154 dS m⁻¹) than applying inorganic

Table 6: Chemical properties of soil as influenced by long-term application of organic manure and fertilizers in rice based cropping system

Treatments	Rice (<i>kharif</i> 1999)				Cowpea (summer 2000)			
	pH	E.C (dS m ⁻¹)	O.C (%)	CEC [c.mol(p ⁺) kg ⁻¹]	pH	E.C (dS m ⁻¹)	O.C (%)	CEC [c.mol(p ⁺) kg ⁻¹]
T ₁ =Control (no fertilisers and manures)	6.95	0.085	0.30	9.80	7.01	0.090	0.31	10.07
T ₂ =100 per cent NPK	6.63	0.120	0.52	11.90	6.60	0.125	0.53	12.25
T ₃ =50 per cent NPK	6.40	0.097	0.45	10.70	6.44	0.102	0.48	10.78
T ₄ =50% NPK + 50% N--GM	6.70	0.151	0.69	13.60	6.80	0.155	0.71	13.80
T ₅ =50% NPK + 50% N--FYM	6.71	0.154	0.70	13.70	6.77	0.158	0.72	13.80
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	6.75	0.154	0.71	14.00	6.80	0.158	0.73	14.50
T ₇ = FYM @ 10 t ha ⁻¹	6.75	0.152	0.73	14.20	6.81	0.155	0.75	14.90
F test	*	*	*	*	*	*	*	*
S.E.m.±	0.12	0.005	0.014	0.056	0.11	0.011	0.017	0.59
CD at 5%	0.36	0.014	0.041	0.174	0.34	0.034	0.052	1.82
Initial Value (1989)	6.78	0.13	0.35	12.30				

N--= Nitrogen through

GM = Green Manure (*Dhaincha*)

FYM = Farm Yard Manure

nutrients alone (0.120 dS m^{-1} in 100% NPK (T_2), 0.097 dS m^{-1} in 50% NPK (T_3) and control (0.085 dS m^{-1}) treatments. Similar trend was observed after the harvest of cowpea crop. These results indicated that electrical conductivity was improved due to the adoption of integrated nutrient management system compared to the application of inorganic fertilizers alone.

4.2.3 Organic carbon

There was a tremendous buildup of organic carbon in the soil treated with integrated nutrient management practises for 11 years both under rice and cowpea as compared to the initial value of 0.35 per cent observed in 1989. The control received no manure and fertilizer noticed decline in buildup of organic carbon content of soil while compared to other treatments.

Table-6 indicated that the FYM and GM treated plots (T_7, T_6, T_5 and T_4) had shown significantly higher contents of organic carbon viz., 0.73, 0.71, 0.70 and 0.69 per cent than those treated with only chemical fertilizers of 0.52 and 0.45 per cent of organic carbon, respectively, after the harvest of rice crop.

Differences among treatments with respect to magnitude of organic carbon, were found to be almost similar in case of the two sets of soil samples viz., those collected after harvest of rice and cowpea crops. The organic carbon values ranged from 0.30 per cent in T_1 (control) to 0.73 per cent in T_7 (FYM @ 10 t ha^{-1}) in the soil, after harvest of rice crop. The increase in

the organic carbon contents of the soil after harvest of cowpea was found to be marginal.

4.2.4 Cation exchange capacity

The CEC of the soil ranged from 9.80 (T_1) to 14.20 [c.mol(p+) kg^{-1}] (T_7), after harvest of the rice crop and from 10.07 (T_1) to 14.90 [c.mol(p+) kg^{-1}] (T_7) after harvest of cowpea crop (Table-6).

Soil amended with FYM (T_7) caused significantly higher CEC than those treated by only chemical fertilizers. The CEC values were found to be marginally higher in the case of soil samples collected after harvest of the cowpea in comparison to the soil samples collected after rice crop.

4.3 AVAILABLE NUTRIENT STATUS AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

4.3.1 Mineralisation of nitrogen

The data indicates that incorporation of GM or FYM along with fertilizers had influenced the maximum accumulation of nitrogen through mineralisation of organic manures. A rapid accumulation of mineral nitrogen was noticed in rice soil, mostly as $\text{NH}_4\text{-N}$ upto 3rd and 4th week of transplanted rice, followed by a slow decline during crop growth period. On the other hand, $\text{NO}_3\text{-N}$ accumulation was predominant during cowpea growth period as compared to rice crop. The $\text{NO}_3\text{-N}$ was gradually increased during harvest of rice and further increased during cowpea crop growth period.

Table-7: Long term effect of organic manure and fertilizers on mineralisation of $\text{NH}_4\text{-N}$ (mg kg^{-1}) in rice based cropping system

Treatment	Days after transplanting of rice														Days after sowing of cowpea					
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	Mean	1	30	60	90	Mean
T ₁ =Control (no fertilisers and manures)	23.0	25.0	28.1	30.6	26.0	22.0	20.1	21.6	21.1	20.7	19.3	17.1	17.2	15.4	21.9	11.5	8.30	6.6	4.8	7.8
T ₂ =100 per cent NPK	48.9	58.0	63.3	61.1	58.3	57.0	56.0	52.0	46.6	39.0	34.0	32.0	30.3	29.9	47.6	27.0	25.0	25.5	22.7	32.5
T ₃ =50 per cent NPK	31.0	39.0	55.0	53.0	50.0	48.7	48.0	50.0	46.0	34.8	31.3	30.9	28.3	28.0	41.0	20.0	18.5	17.6	17.1	18.3
T ₄ =50% NPK + 50% N-GM	78.8	82.5	91.0	89.0	81.4	77.0	67.0	67.0	63.2	63.0	62.5	62.1	60.7	58.0	71.7	50.1	45.5	41.6	38.4	43.9
T ₅ =50% NPK + 50% N-FYM	72.0	74.0	77.0	80.0	77.0	78.1	74.0	71.0	65.0	61.0	55.0	59.0	57.0	54.0	68.2	42.4	40.1	38.5	35.0	39.0
T ₆ =50% NPK + 25% N-GM + 25% N-FYM	75.0	77.1	84.3	83.0	82.0	79.0	77.0	74.0	70.0	65.0	61.0	56.0	55.3	56.4	71.1	45.4	42.0	38.2	35.7	40.3
T ₇ = FYM @ 10 t ha ⁻¹	53.0	56.0	68.0	65.0	60.1	56.7	53.0	51.0	50.0	51.0	48.0	45.0	43.8	38.9	52.8	32.3	30.2	26.7	24.5	28.4

Among the treatments (Table-7), the plot received 50 per cent NPK + 50 per cent N--GM (T_4) recorded maximum and rapid mineralisation of $\text{NH}_4\text{-N}$ with mean value of 71.66 and 43.90 mg kg^{-1} followed by 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM (71.10 and 40.30 mg kg^{-1}) and 50 per cent NPK + 50 per cent N--FYM (68.20 and 39.00 mg kg^{-1}) after rice and cowpea crops, respectively. Whereas, in case of $\text{NO}_3\text{-N}$, though the values were higher in case of T_4 , T_6 and T_5 plots during initial period of rice and in the later period of cowpea crop growth the values were higher in case of T_6 , T_5 and T_4 plots (Table-8). The mean values recorded was 48.50 mg kg^{-1} (T_4), 46.30 mg kg^{-1} (T_6) and 42.10 mg kg^{-1} (T_5) of $\text{NO}_3\text{-N}$ in the soil after rice. After harvest of cowpea crop, the $\text{NO}_3\text{-N}$ recorded was highest in the T_6 plot (96.60 mg kg^{-1}) followed by T_5 plot (93.90 mg kg^{-1}) and T_4 plot (90.30 mg kg^{-1}). In case of 100 per cent NPK fertilizer treated plots the values of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ recorded were lower. The value being ranged from 47.60 and 32.50 mg kg^{-1} of $\text{NH}_4\text{-N}$ and 34.20 and 51.80 mg kg^{-1} of $\text{NO}_3\text{-N}$ in the soil and the values were lower than FYM treated plots, where the value were ranging from 28.00 and 74.60 mg kg^{-1} of $\text{NO}_3\text{-N}$ in the soil after rice and cowpea crops, respectively. The lowest values of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ were recorded in the control plots.

4.3.2 Available nitrogen

There was a drastic reduction of available nitrogen in the plots treated with chemical fertilizers and in control for 11 years as compared to initial value (165 kg ha^{-1}) recorded during 1989 under both rice and cowpea (Table-9).

Table-8: Long-term effect of organic manure and fertilizers on mineralisation of NO₃-N (mg kg⁻¹) in rice based cropping system

Treatment	Days after transplanting of rice											Days after sowing of cowpea								
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	Mean	1	30	60	90	Mean
T ₁ =Control (no fertilisers and manures)	19.5	20.1	17.0	15.3	12.6	11.0	10.7	10.8	11.0	8.50	13.1	17.3	20.5	23.6	15.1	28.0	34.4	36.0	34.0	33.1
T ₂ =100 per cent NPK	45.6	42.0	38.0	35.0	33.3	30.2	28.2	24.7	22.0	28.4	33.5	37.4	40.1	40.3	34.2	44.0	49.0	54.5	59.7	51.8
T ₃ =50 per cent NPK	34.5	31.0	27.0	25.1	21.5	19.6	17.5	15.2	17.8	20.5	27.3	30.6	34.0	37.2	25.6	41.7	45.4	44.0	41.0	43.0
T ₄ =50% NPK + 50% N-GM	56.7	55.4	51.7	45.7	46.5	43.4	39.7	35.1	36.2	40.0	47.4	55.1	62.2	64.4	48.5	72.2	81.0	95.5	112.5	90.3
T ₅ =50% NPK + 50% N-FYM	52.6	50.1	46.2	43.4	38.1	35.4	31.2	28.3	25.0	33.1	39.4	46.0	55.1	65.7	42.1	77.0	84.5	98.4	115.8	93.9
T ₆ =50% NPK + 25% N-GM + 25% N-FYM	55.0	53.1	52.4	48.1	45.6	41.5	37.7	35.5	32.4	35.3	40.0	47.1	59.0	65.9	46.3	77.1	88.7	101.	119.3	96.6
T ₇ = FYM @ 10 t ha ⁻¹	39.7	33.5	30.3	28.4	25.5	21.7	18.4	15.6	13.7	19.5	27.1	35.0	33.0	50.4	28.0	61.5	75.0	79.5	82.50	74.6

The integrated nutrients received organic + inorganic treatments recorded significantly higher value under treatment T_4 (50% NPK + 50% N--GM) of 279 and 363.40 kg ha⁻¹ and T_5 (50% NPK + 50% N--FYM) recorded 256.50 and 247.80 kg ha⁻¹ compared to treatment which received chemical fertilizers T_2 (100% NPK) whose values were 153.90 and 182.20 kg ha⁻¹ and 140.00 and 160 kg ha⁻¹ with the use of 50 per cent NPK (T_3) treatments. The treatment that received FYM @ 10 t ha⁻¹ (T_7) also scored significantly higher value of 195 and 245.20 kg ha⁻¹ compared to chemical fertilizer application after harvest of rice and cowpea crops, respectively.

Results indicated that greater quantity of available nitrogen was noticed wherever organic materials were used compared to inorganic source of nutrients. Further, higher available values were noticed due to the application of green manure than FYM. In addition, available nitrogen was higher after the harvest of cowpea than rice crop.

4.3.3 Available phosphorus

Available phosphorus was recorded 28.90 kg ha⁻¹ in the soil during 1989 indicating a tremendous decline in the control (9.70 and 6.90 kg ha⁻¹) which received no manures and fertilizers for 11 years under both rice and cowpea crops (Table-9).

The range of available P_2O_5 content of the soil was also very wide among different treatments. The data shows that the treatments viz., T_6 (50% NPK + 25% N--GM + 25% N--FYM) recorded 59.80 and 51.20 kg ha⁻¹,

Table 9: Available nutrient status of the soil as influenced by long-term application of organic manure and fertilizers in rice based cropping system

Treatment	Rice (<i>kharif</i> 1999)						Cowpea (summer 2000)					
	N	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O	Ca [c.mol(p ⁺)kg ⁻¹]	Mg (mg kg ⁻¹)	S (mg kg ⁻¹)	N	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O	Ca [c.mol(p ⁺)kg ⁻¹]	Mg (mg kg ⁻¹)	S (mg kg ⁻¹)
T ₁ =Control (no fertilisers and manures)	118.50	9.70	73.70	0.72	0.07	3.10	128.00	6.90	77.30	0.76	0.12	2.74
T ₂ =100 per cent NPK	153.90	46.80	134.70	1.15	0.21	10.10	182.20	23.80	143.50	1.16	0.25	13.70
T ₃ =50 per cent NPK	140.00	21.70	109.00	0.95	0.18	5.70	160.00	16.80	115.30	0.90	0.20	5.60
T ₄ =50% NPK + 50% N--GM	279.00	56.70	230.70	1.60	0.33	16.30	363.40	50.70	246.60	1.63	0.46	24.95
T ₅ =50% NPK + 50% N--FYM	256.50	56.00	248.60	1.53	0.34	14.70	347.80	49.90	265.50	1.60	0.46	25.14
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	272.00	59.80	282.70	1.63	0.39	16.50	353.40	51.20	301.50	1.65	0.49	26.30
T ₇ = FYM @ 10 t ha ⁻¹	195.00	39.30	225.80	1.06	0.34	14.12	245.20	28.90	243.80	1.72	0.50	26.60
F test	*	*	*	*	*	*	*	*	*	*	*	*
S.E.m. ±	2.81	1.95	3.05	0.14	0.019	1.82	12.45	2.97	4.43	0.08	0.019	0.67
CD at 5%	8.65	6.00	9.41	0.43	0.057	5.62	38.36	9.16	13.67	0.25	0.057	2.06
Initial value (1989)	165.00	28.90	122.50	1.25	0.38	5.30						

N--= Nitrogen through
GM = Green Manure (*Dhaincha*)
FYM = Farm Yard Manure

T₄ (50% NPK + 50% N--GM) recorded 56.70 and 50.70 kg ha⁻¹ and T₅ (50% NPK + 50% N--FYM) recorded 56.00 and 49.90 kg ha⁻¹ which were significantly higher compared to inorganic fertilizers under T₂ (100% NPK) recorded 46.80 and 23.80 kg ha⁻¹ and T₃ (50% NPK) recorded 21.70 and 16.80 kg ha⁻¹. The treatment T₇ (FYM @ 10 t ha⁻¹) also recorded a significant increase in the available P₂O₅ of 39.30 and 28.90 kg ha⁻¹ compared to chemical fertilizer after harvest of rice and cowpea crops, respectively.

Comparison of nutrient status between two crops indicated that unlike available nitrogen, the trend of available phosphorus was higher after the harvest of rice than cowpea crop.

Application of nutrients in combination of organic with inorganics recorded higher available phosphorus after the harvest of both the crops compared to applying of fertilizers individually through inorganic sources and control treatments.

4.3.4 Available potassium

Data on available potassium as influenced by the adoption of various nutrient management practises are presented in Table-9. The available K₂O which was 122.50 kg ha⁻¹ initially was reduced to 73.70 and 77.30 kg ha⁻¹ after 11 years due to continuous cultivation of rice and cowpea without application of manure and fertilizers and adequate nutrient supply into the soil.

The differences in available K_2O content of soil were found to be significant among the organic and inorganic treatments with T_6 recorded highest value of 282.70 and 301.50 $kg\ ha^{-1}$, with T_5 of 248.60 and 265.50 $kg\ ha^{-1}$ and T_4 of 230.70 and 246.60 $kg\ ha^{-1}$ after harvest of two crops.

The available K_2O content of the soil were found to be very low in T_1 , T_3 , T_2 plots which recorded 73.70 and 77.30; 109.00 and 115.30, 134.7 and 143.50 $kg\ ha^{-1}$ after the harvest of both rice and cowpea crop, respectively.

The data revealed that differences in available K_2O content of the soil between the two seasons were marginal with the second set of soil samples (after cowpea) had a slight edge over the first set of soil sample (after rice).

4.3.5 Available sulphur

Available sulphur content was found to be significant between the treatments during both the seasons. After harvest of rice crop, it was found to be the highest (16.50 $mg\ kg^{-1}$) in T_6 , followed by T_4 (50% NPK + 50% N--GM) with values of 16.30 $mg\ kg^{-1}$.

Available sulphur contents of soil after harvest of cowpea crop was also found to be the highest (26.60 $mg\ kg^{-1}$) in T_7 , followed by T_6 (50% NPK + 25% N--GM + 25% N--FYM) and T_5 (50% NPK + 50% N--FYM) with the values of 26.30 and 25.14 ($mg\ kg^{-1}$), respectively and lowest values were observed in control (T_1) with values of 3.10 and 2.74 ($mg\ kg^{-1}$) after the harvest of both rice and cowpea crops, respectively (Table-9).

Trend of available sulphur was remarkably higher after harvest of cowpea compared to rice crop except control and 50 per cent NPK treated plots.

In general, application of organics with or without combination of inorganics recorded higher available sulphur as compared to plots received inorganics alone.

4.3.6 Exchangeable calcium

The data in Table-9 indicates that the plots treated with 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM (T_6) recorded the value of $1.63 \text{ [C.mol(p}^+\text{)kg}^{-1}\text{]}$ which was found to contain significantly higher amounts of exchangeable calcium in the soil after harvest of rice, while plot treated with FYM @ 10 t ha^{-1} recorded significantly higher value of $1.72 \text{ [C.mol(p}^+\text{)kg}^{-1}\text{]}$ of soil after harvest cowpea crop over chemical fertilizers of 1.15 and $1.16 \text{ [C.mol(p}^+\text{)kg}^{-1}\text{]}$ of soil under T_2 (100% NPK) after harvest of both the crops.

A marginal increase of exchangeable calcium was noticed after harvest of cowpea compared to rice crop in all the treatments except at treatment FYM @ 10 t ha^{-1} alone, where exchangeable calcium recorded relatively higher value compared to rest of the treatments after cowpea crop.

4.3.7 Exchangeable magnesium

Exchangeable Mg content of the soil ranged from 0.07 (T_1) to $0.39 \text{ [C.mol(p}^+\text{)kg}^{-1}\text{]}$ (T_6) after harvest of rice and from 0.12 (T_1) to 0.50

[C.mol(p⁺)kg⁻¹] (T₇) after harvest of cowpea crop. The exchangeable Mg of the soil were found to be significantly higher in treatments T₆, T₅ and T₇ plots recorded the values of 0.39 to 0.34 [C.mol (p⁺) kg⁻¹] where, after the harvest of cowpea crop the treatment T₇ recorded the higher value followed by T₆, T₅ and T₄ and the values were ranging from 0.50 to 0.46 [C.mol (p⁺) kg⁻¹] (Table-9).

4.4 MICRONUTRIENT STATUS OF SOIL AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

4.4.1 Micronutrients

Micronutrient status of the soil was improved due to long-term nutrient management practises for 11 years both under rice and cowpea as compared to the initial value of 0.87, 2.20, 6.40 and 42.30 mg kg⁻¹ of Zn, Cu, Mn and Fe, respectively, while control received no manure and treatment received lower doses of chemical fertilizers over the years reduced the micronutrient status of the soil.

4.4.2 DTPA-Zn

The plots subjected to FYM or GM application along with NPK fertilizers (T₄, T₅, T₆ and T₇) recorded significantly much higher amount of DTPA-Zn in the soil, after harvest of rice and cowpea crops. The DTPA-Zn values recorded in respect of those four treatments were 1.80 and 1.62; 1.90 and 1.70; 2.03 and 1.70; and 2.10 and 1.82 mg kg⁻¹ soil respectively, which were significantly higher compared to treatments which received 100 and 50

per cent NPK fertilizers which recorded 0.75 and 0.62 mg kg⁻¹ (T₂) and 0.63 and 0.52 mg kg⁻¹ (T₃) of soil after both the seasons.

The lowest DTPA–Zn values were recorded in T₁ (control) with the value of 0.41 and 0.34 after the harvest of both rice and cowpea crops, respectively (Table–10).

Results indicated that DTPA–Zn content was high wherever organic manures were applied or along with inorganic nutrients under integrated nutrient management practises. Further, it was also high after the harvest of rice compared to cowpea crop.

4.4.3 DTPA – Cu

The DTPA–Cu content of the soil was significantly higher in T₇ (5.73 mg kg⁻¹) followed by T₆ (5.65 mg kg⁻¹), T₄ (5.63 mg kg⁻¹) and T₅ (5.51 mg kg⁻¹) after the harvest of the rice and 5.70 mg kg⁻¹ (T₇), 5.03 mg kg⁻¹ (T₆), 4.70 mg kg⁻¹ (T₅) and 4.53 mg kg⁻¹ (T₄) values after the harvest of cowpea crop.

The least value of 1.39 and 0.92 mg kg⁻¹ were recorded in T₁ (control) after the harvest of rice and cowpea crops, respectively (Table–10).

Results indicated that DTPA–Cu content was significantly higher wherever organic manures were applied individually or in combination with fertilizers compared to fertilizers alone. DTPA–Cu content was reduced in all the treatments under study after the harvest of cowpea compared to rice crop.

Table 10: DTPA extractable micronutrient (mg kg^{-1}) status of the soil as influenced by organic manure and fertilizers in rice based cropping system

Treatments	Rice (<i>kharif</i> 1999)				Cowpea (summer 2000)			
	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe
T ₁ =Control (no fertilisers and manures)	0.41	1.39	2.90	30.20	0.34	0.92	2.10	15.93
T ₂ =100 per cent NPK	0.75	2.84	6.85	42.63	0.62	1.93	5.65	27.40
T ₃ =50 per cent NPK	0.63	1.82	5.40	31.76	0.52	1.50	3.20	18.70
T ₄ =50% NPK + 50% N--GM	1.80	5.63	8.90	44.20	1.62	4.53	6.05	30.33
T ₅ =50% NPK + 50% N--FYM	1.90	5.51	9.06	47.50	1.70	4.70	6.10	30.10
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	2.03	5.65	10.13	48.20	1.70	5.03	6.10	31.50
T ₇ = FYM @ 10 t ha ⁻¹	2.10	5.73	10.40	51.36	1.82	5.70	6.46	31.50
F test	*	*	*	*	*	*	*	*
S.E.m. $\pm$	0.17	0.22	0.92	2.78	0.14	0.28	0.36	2.00
CD at 5%	0.52	0.67	2.84	8.57	0.43	0.84	1.10	6.18
Initial Value (1989)	0.87	2.20	6.40	42.30				

N--= Nitrogen through

GM = Green Manure (*Dhaincha*)

FYM = Farm Yard Manure

4.4.4 DTPA-Mn

Variations in the Mn contents of the soil were found to be significant between most of the treatments in case of both the sets of soil viz., collected after harvest of rice and cowpea crops. After harvest of rice crop, DTPA-Mn was found significantly higher in T₇ (10.40 mg kg⁻¹) followed by T₆ (10.13 mg kg⁻¹) over inorganic treatments received 100 per cent NPK of 6.85 mg kg⁻¹ and 50 per cent NPK of 5.40 mg kg⁻¹ of soil.

On the other hand, after the harvest of cowpea crop, DTPA-Mn was significantly higher in the same treatments viz., T₇ (6.46 mg kg⁻¹), T₆ (6.10 mg kg⁻¹) and T₅ (6.10 mg kg⁻¹), respectively. The lowest DTPA-Mn content was noticed in T₁ and T₃ with values of 2.10 and 3.20 mg kg⁻¹, respectively.

More or less similar trend in respect of the differences in DTPA-Mn content of the soil between the treatments was observed after the harvest of cowpea crop and it recorded relatively lower amount of DTPA-Mn than those collected after harvest of rice crop (Table-10).

4.4.5 DTPA-Fe

Significant differences among treatments were observed regarding the DTPA-Fe content both after rice and cowpea crops. In case of rice, application of FYM @ 10 t ha⁻¹ (T₇) recorded 51.36 mg kg⁻¹ which was significantly higher compared to supplying nutrients through inorganic fertilizers [31.76 and 42.63 mg kg⁻¹ in 50% NPK (T₃) and 100% NPK

(T₂) treatments, respectively) and control (30.20 mg kg⁻¹)]. Farm yard manure @ 10 t ha⁻¹ was on par with other treatments received organic manure with inorganic fertilizers (T₄, T₅, T₆) (Table-10).

Micronutrient status of soil indicated reduction of DTPA-Fe content after harvest of cowpea compared to rice crop, but, the trend was similar to that of rice. Status of micronutrient after the harvest of both the crops revealed that application of organic manure with or without inorganic fertilizers maintained higher DTPA-Fe compared to the application of fertilizer alone.

4.5 MICROBIAL BIOMASS CARBON AND BIOCHEMICAL PROPERTIES OF SOIL AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

Microbial biomass carbon and bio-chemical activities were improved due to long-term integrated nutrient practices for 11 years both under rice and cowpea as compared to the initial value of 177 µg g⁻¹ soil of microbial biomass carbon, 98.20 µg NH₄-N g⁻¹ h⁻¹ of urease activity, 88.50 µg TPF g⁻¹ 24 h⁻¹ of dehydrogenase activity, 81.60 µg PNP g⁻¹ h⁻¹ of phosphatase activity, while control (received no manure and fertilizers treatment) reduced their activities in the soil over the years of study.

4.5.1 Microbial biomass carbon

Microbial biomass carbon in soil was relatively higher after harvest of cowpea compared to rice crop (Table-11), the treatments which

Table 11: Microbial and bio-chemical properties of soil as influenced by organic manure and fertilizers in rice based cropping system

Treatment	Rice (<i>kharif</i> 1999)				Cowpea (summer 2000)			
	Microbial Biomass carbon ($\mu\text{g g}^{-1}$ soil)	Urease ($\mu\text{g NH}_4\text{-N g}^{-1} \text{h}^{-1}$)	Dehydrogenase ($\mu\text{g TPF g}^{-1} 24 \text{h}^{-1}$)	Phosphatase ($\mu\text{g PNP g}^{-1} \text{h}^{-1}$)	Microbial Biomass carbon ($\mu\text{g g}^{-1}$ soil)	Urease ($\mu\text{g NH}_4\text{-N g}^{-1} \text{h}^{-1}$)	Dehydrogenase ($\mu\text{g TPF g}^{-1} 24 \text{h}^{-1}$)	Phosphatase ($\mu\text{g PNP g}^{-1} \text{h}^{-1}$)
T ₁ =Control (no fertilisers and manures)	175	95.43	85.30	80.53	182	104.40	93.30	79.83
T ₂ =100 per cent NPK	195	143.00	104.40	237.13	210	142.03	140.23	217.73
T ₃ =50 per cent NPK	188	139.93	103.50	133.23	190	140.30	135.30	116.80
T ₄ =50% NPK + 50% N--GM	298	152.03	109.90	243.50	310	155.80	149.26	221.33
T ₅ =50% NPK + 50% N--FYM	305	144.83	108.70	240.80	315	143.57	142.40	218.60
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	316	148.73	112.80	241.40	321	152.06	145.06	223.10
T ₇ = FYM @ 10 t ha ⁻¹	320	145.56	103.50	237.40	328	141.53	146.83	218.70
F test	*	*	*	*	*	*	*	*
S.E.m.±	5.55	2.53	4.73	9.33	7.27	2.87	14.62	8.64
CD at 5%	17.10	7.80	14.58	28.74	22.40	8.84	45.06	26.61
Initial value (1989)	177	98.20	88.50	81.60				

N--= Nitrogen through

GM = Green Manure (*Dhaincha*)

FYM = Farm Yard Manure

received organic nutrient sources had recorded significantly higher biomass compared to chemical fertilizers. The treatment, which received FYM @ 10 t ha⁻¹ (T₇) had recorded highest value (320 and 328 µg g⁻¹ soil), followed by T₆ (316 and 321 µg g⁻¹ soil), T₅ (305 and 315 µg g⁻¹ soil). The control recorded lowest value of 175 and 182 µg g⁻¹ soil.

4.5.2 Urease activity

Almost similar trend in urease activity was noticed after harvest of both rice and cowpea crops (Table-11). Highest urease activity of 152.03 and 155.80 µg NH₄-N g⁻¹ soil h⁻¹ was recorded in the treatment which was given 50 per cent NPK + 50 per cent N--GM followed by T₆ (148.73 and 152.06 µg NH₄-N g⁻¹ soil h⁻¹) which were significantly superior over 50 and 100 per cent chemical fertilizers treatments. The control plot recorded lowest value.

4.5.3 Dehydrogenase activity

Dehydrogenase activity was remarkably higher after harvest of cowpea crop compared to rice. The treatment, which received organic sources, demonstrated higher dehydrogenase activity. The values being 112.80 µg TPF-N g⁻¹ soil 24 h⁻¹ was recorded in the treatment T₆ (50% NPK + 25% N--GM + 25% N--FYM) after harvest of rice while after cowpea crop, 149.26 µg NH₄-N g⁻¹ soil ha⁻¹ was recorded in the treatment T₄ (50% NPK + 50% N--GM). The treatment which received organic sources were significantly superior to 50 and 100 per cent NPK fertilizer treatments T₃ (103.50 and

135.30 $\mu\text{g TPF g}^{-1} \text{ soil ha}^{-1}$) and T_2 (104.40 and 140.23 $\mu\text{g TPF g}^{-1} \text{ soil 24 h}^{-1}$), respectively after two seasons. The control recorded the lowest value (Table-11).

4.5.4 Phosphatase activity

The phosphatase activity was maximum again in the organic and inorganic blended treatments compared to chemical fertilizer application. The treatment 50 per cent NPK + 50 per cent N--GM (T_4) recorded the higher value (243.50 $\mu\text{g PNP g}^{-1} \text{ soil ha}^{-1}$) after rice while after cowpea crop, the treatment T_6 recorded higher value of 223.10 $\mu\text{g PNP g}^{-1} \text{ soil ha}^{-1}$ followed by T_5 and T_7 . The control recorded the lowest value (Table-11).

4.6 YIELD PARAMETERS OF RICE AND COWPEA CROPS AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

Yield parameters of rice and cowpea crops differed significantly among the treatments over control (Table-12). The treatment comprising of 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM (T_6) recorded highest values viz., 13.90 tillers per hill, plant height measured 84.40 cm, 230 panicles per m^2 , 118.80 grains per panicle and weighed 25.60 g/1000 grains followed by T_4 (50% NPK + 50% N--GM), T_5 (50% NPK + 50% N--FYM) which were on par with each other. The control (T_1) recorded lowest values compared to rest of the treatments.

In contrast to rice yield parameters, the cowpea yield parameters were recorded higher value in case of T_7 which received FYM @ 10 t ha^{-1}

Table 12: Yield attributes of rice and cowpea crops at harvest stage as influenced by organic manure and fertilizers in rice based cropping system

Treatment	Yield parameters of rice (Kharif, 1999)					Yield parameters of cowpea (Summer, 2000)				
	Tillers (No. hill ⁻¹)	Plant height (cm)	Panicles (No. m ⁻²)	Grains (No. panicle ⁻¹)	1000 grain weight (g)	Nodules (No. Plant ⁻¹)	Pods (No. Plant ⁻¹)	Pods weight (g. Plant ⁻¹)	Pod length (cm)	1000 grain weight (g)
T ₁ =Control (no fertilisers and manures)	6.40	69.47	185	76.50	19.30	13.50	8.33	10.80	8.96	66.00
T ₂ =100 per cent NPK	11.36	80.30	225	105.70	22.20	21.70	13.50	14.50	12.26	109.30
T ₃ =50 per cent NPK	9.20	77.90	219	86.20	20.40	19.10	9.33	12.50	12.96	93.30
T ₄ =50% NPK + 50% N--GM	13.80	83.06	228	115.30	22.63	28.50	14.00	16.60	13.16	120.50
T ₅ =50% NPK + 50% N--FYM	12.70	83.40	225	112.30	24.25	29.30	15.10	17.00	13.70	124.60
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	13.90	84.40	230	118.80	25.60	31.50	16.20	18.20	14.10	127.70
T ₇ = FYM @ 10 t ha ⁻¹	9.40	79.60	190	120.60	21.53	32.70	16.50	18.20	14.20	132.90
F test	*	*	*	*	*	*	*	*	*	*
S.E.m.±	1.25	1.75	10.19	3.70	0.89	2.40	1.30	1.02	0.61	8.06
CD at 5%	5.40	5.39	32.94	11.44	2.75	7.30	4.01	3.14	1.89	24.84

N--= Nitrogen through
GM = Green Manure (Dhaincha)
FYM = Farm Yard Manure

compared to other treatments. The values were 32.70 nodules per plant, 16.50 pods per plant, 18.20 g of pods weight per plant, measuring an average of 14.20 cm per pod and weighed 132.90 g per 1000 grains. Treatment that received 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM (T_6) and 50 per cent NPK + 50 per cent N--FYM treatments were recorded on par with T_7 , which were significantly higher compared to 50 and 100 per cent NPK (T_2 and T_3) fertilizer treatments.

4.7 YIELD AND NUTRIENT UPTAKE BY RICE AND COWPEA CROPS AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

4.7.1. Rice and cowpea yields

The data in Tables-13 and 14 indicated that there was a significant increase in grain and straw yields of rice over control. The treatment T_6 (50% NPK + 25% N--GM + 25% N--FYM) recorded the higher yield of 6394 and 7466 kg ha⁻¹ followed by T_4 (50% NPK + 50% N--GM) recorded 5730 and 6590 kg ha⁻¹ and T_5 (50% NPK + 50% N--FYM) recorded 5625 and 6431 kg ha⁻¹ which were significantly higher over inorganic fertilizers under T_2 (100% NPK) of 5057 and 5685 kg ha⁻¹. The treatment, which received FYM @ 10 t ha⁻¹ (T_7) also recorded significantly higher yield of 4635 and 5144 kg ha⁻¹ and 50% NPK (T_3) recorded yield value of 4169 and 4585 kg ha⁻¹ in grain and straw of rice, respectively.

The yield of cowpea remarkably improved under residues of organic and inorganic treatments compared to only application of chemical

fertilizers. The higher significant grain and stover yields were noticed in the treatment T_7 (FYM @ 10 t ha⁻¹) with values of 1303 and 5082 kg ha⁻¹ followed by T_6 (50% NPK + 25% N--GM + 25% N--FYM) recorded 1278 and 4983 kg ha⁻¹, T_5 (50% NPK + 50% N--FYM) recorded 1136 and 4464 kg ha⁻¹ and T_4 (50% NPK + 50% N--GM) recorded values of 1088 and 4242 kg ha⁻¹ over chemical fertilizer under treatment, T_2 (100% NPK) of 566 and 2226 kg ha⁻¹ and T_3 (50% NPK) of 524 and 2028 kg ha⁻¹, respectively in both grain and stover of cowpea crop. The control (T_1) recorded lowest grain yield (125 kg ha⁻¹) and stover yield (720 kg ha⁻¹) after harvest of cowpea crop.

4.7.2 Nutrients uptake by grain of rice and cowpea crops

Nutrients uptake pattern of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur by rice and cowpea followed more or less same trend as that of grain yield (Table-13). Significantly higher uptake of nitrogen was noticed in T_6 plots (78.70 kg ha⁻¹) followed by T_4 (68.80 kg ha⁻¹), T_5 (65.70 kg ha⁻¹) which were superior compared to 100 per cent NPK fertilizer application (T_2) which recorded the value of 57.20 kg ha⁻¹. The control recorded the lowest value of 15.30 kg ha⁻¹. On the contrary, residual nitrogen uptake in the treatment (T_7) which received only FYM @ 10 t ha⁻¹ was maximum (19.90 kg ha⁻¹) followed by T_6 , T_5 , T_4 which were on par with each other after harvest of cowpea. Here also residual chemical treatments recorded significantly inferior values of 6.30 kg ha⁻¹ (T_2) and 4.00 kg ha⁻¹ (T_3) compared to combination of organic + inorganic sources of fertilizers.

Table 13: Grain yield and nutrients uptake by rice and cowpea crops as influenced by long-term application of organic manure and fertilizers in rice based cropping system

Treatment	Rice						Cowpea							
	Grain yield (Kg ha ⁻¹)	Nutrient uptake (kg ha ⁻¹)					Grain yield (Kg ha ⁻¹)	Nutrient uptake (kg ha ⁻¹)						
		N	P	K	Ca	Mg		S	N	P	K	Ca	Mg	S
T ₁ =Control (no fertilisers and manures)	2729	15.30	8.10	11.80	6.20	5.10	0.90	125	2.00	0.80	2.30	0.40	0.24	0.78
T ₂ =100 per cent NPK	5057	57.20	19.60	33.20	16.70	12.50	2.50	566	6.30	4.70	8.90	1.50	1.00	3.80
T ₃ =50 per cent NPK	4169	36.70	14.20	25.70	12.20	8.90	1.85	524	4.00	1.60	4.80	0.90	0.70	2.10
T ₄ =50% NPK + 50% N--GM	5730	68.80	24.00	38.40	19.10	15.50	5.00	1088	13.90	6.10	17.90	3.00	2.30	7.30
T ₅ =50% NPK + 50% N--FYM	5625	65.70	24.20	39.70	18.90	17.30	4.40	1136	16.80	6.80	17.90	3.70	2.50	8.70
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	6394	78.70	28.20	48.30	21.80	20.30	5.40	1278	17.70	8.00	21.20	4.20	3.10	10.01
T ₇ = FYM @ 10 t ha ⁻¹	4635	35.50	18.50	26.60	13.00	11.60	4.00	1303	19.90	9.20	21.50	4.40	3.20	11.40
F test	*	*	*	*	*	*	*	*	*	*	*	*	*	*
S.E.m.±	122.64	2.36	1.36	4.70	1.30	1.19	0.29	20.32	1.66	0.81	1.75	0.16	0.19	0.40
CD at 5%	377.72	8.24	4.19	14.47	3.99	3.68	0.89	62.61	5.11	2.50	4.76	0.49	0.58	1.25

N--= Nitrogen through
GM = Green Manure (Dhaincha)
FYM = Farm Yard Manure

Phosphorus uptake was maximum in the plot which were given 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM (T_6) recorded the value of 28.20 kg ha^{-1} after harvest of rice, while after cowpea the treatment received only FYM @ 10 t ha^{-1} recorded the maximum uptake of 9.20 kg ha^{-1} followed by T_6 , T_5 and T_4 with the values ranging from 8.00 to 6.10 kg ha^{-1} , while residual chemical fertilizer treated plots recorded values ranging from 1.60 kg ha^{-1} (T_3) to 4.70 kg ha^{-1} (T_2). Control plot observed the least value over rest of the plots (Table-13).

The treatment T_6 recorded significantly higher potassium uptake (48.30 kg ha^{-1}) followed by T_5 (39.70 kg ha^{-1}) and T_4 (38.40 kg ha^{-1}) which were on par with each other and were superior over T_2 (33.2 kg ha^{-1}) and T_3 (25.70 kg ha^{-1}). The control recorded the least value compared to other treatments after the harvest of rice crop (Table-13).

After harvest of residual cowpea crop, the treatment T_7 recorded higher potassium uptake of 21.50 kg ha^{-1} followed by T_6 (21.20 kg ha^{-1}), T_5 and T_4 (17.90 kg ha^{-1}) and were superior to chemical treatments T_2 (8.90 kg ha^{-1}) and T_3 (4.80 kg ha^{-1}) plots.

Calcium and magnesium uptake was maximum in T_6 plot (21.80 and 20.30 kg ha^{-1} , respectively) followed by T_4 of 19.10 and T_5 of $18.90 \text{ kg calcium ha}^{-1}$. The magnesium content of soil was 17.30 kg ha^{-1} in T_5 and 15.50 kg ha^{-1} in T_4 plots which received blended combination of organic with inorganic fertilizers and were significantly superior to chemical

fertilizers application at T₂ (16.70 and 12.50 kg ha⁻¹), respectively of calcium and magnesium after harvest of rice crop (Table-13).

After the harvest of cowpea crop, the treatment T₇ recorded the maximum uptake of calcium and magnesium of 4.40 and 3.20 kg ha⁻¹ followed by T₆, T₅ and T₄ which were on par with each other and superior over fertilizers, respectively after harvest of cowpea crop (Table-13).

Sulphur uptake was maximum at T₆ plot (5.40 kg ha⁻¹) followed by T₄ (5.0 kg ha⁻¹), T₅ (4.40 kg ha⁻¹) and T₇ (4.0 kg ha⁻¹) which were on par and superior to chemical fertilizer plots T₂ (2.50 kg ha⁻¹) and T₃ (1.85 kg ha⁻¹) after harvest of rice crop (Table-13). The control recorded significantly lower value of 0.90 kg ha⁻¹ over rest of the treatments.

In comparison to rice crop, the uptake of sulphur in cowpea was relatively higher. The treatment T₇ recorded highest uptake of sulphur of 11.40 kg ha⁻¹ followed by T₆, T₅ and T₄ plots ranging from 10.01 to 7.30 kg ha⁻¹ and were on par and superior to chemical fertilizer treatment (T₂) of 3.80 kg ha⁻¹. The control recorded the lowest value over other treatments (Table-13).

Uptake of zinc was higher in the plot T₆ which recorded the value of 160.40 g ha⁻¹ followed by T₅ and T₄ which were on par with each other. 100 per cent NPK fertilizer plot T₂ (104.20 g ha⁻¹) recorded significantly inferior values after harvest of rice crop. Whereas in case of residual cowpea crop, the application of FYM @ 10 t ha⁻¹ (T₇) recorded the

Table 14: Straw yield and nutrient uptake by rice and cowpea crops as influenced by long-term application of organic manure and fertilizers in rice based cropping system

Treatment	Rice						Cowpea							
	Straw yield (Kg ha ⁻¹)	Nutrient uptake (kg ha ⁻¹)					Stover yield (Kg ha ⁻¹)	Nutrient uptake (kg ha ⁻¹)						
		N	P	K	Ca	Mg		S	N	P	K	Ca	Mg	S
T ₁ =Control (no fertilisers and manures)	3002	12.20	6.04	46.60	8.40	5.70	1.40	720	2.69	1.74	5.70	2.10	1.20	1.20
T ₂ =100 per cent NPK	5685	52.60	14.10	121.80	20.10	14.80	6.15	2226	11.56	9.15	24.60	7.20	5.40	9.00
T ₃ =50 per cent NPK	4585	35.10	10.10	88.00	14.50	10.70	4.25	2028	11.30	4.50	12.00	6.60	3.60	4.20
T ₄ =50% NPK + 50% N--GM	6590	63.90	17.80	141.10	24.60	17.20	7.75	4242	28.45	18.30	48.30	14.40	10.50	18.90
T ₅ =50% NPK + 50% N--FYM	6431	62.00	17.40	137.80	25.00	18.60	7.40	4464	30.26	20.70	51.90	16.80	10.80	20.40
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	7466	74.40	21.70	168.40	27.00	22.60	8.83	4983	39.50	24.60	58.20	22.80	12.90	22.80
T ₇ = FYM @ 10 t ha ⁻¹	5144	35.90	13.30	101.50	16.30	12.70	6.00	5082	39.80	25.80	60.90	24.60	13.20	24.60
F test	*	*	*	*	*	*	*	*	*	*	*	*	*	*
S.E.m.±	230.90	5.36	1.48	5.42	1.19	1.10	0.28	100.95	5.67	1.11	2.61	2.70	0.33	1.20
CD at 5%	711.56	16.50	4.57	16.70	3.66	3.39	0.86	311.10	17.46	3.42	8.07	0.834	1.02	3.72

N--= Nitrogen through

GM = Green Manure (Dhatancha)

FYM = Farm Yard Manure

highest value followed by T_6 , T_5 and T_4 ranging from 58.70 to 41.20 g ha⁻¹ which were superior compared to 100 per cent fertilizer (T_2) the value being 19.60 g ha⁻¹ after harvest of cowpea (Table-15).

The data in Table-15 shows that the copper uptake was maximum (64.10 g ha⁻¹) in T_6 plots followed by T_4 (57.1 g ha⁻¹), T_5 (51.20 g ha⁻¹) and were superior to chemical fertilizer application (T_2) of 35.40 g ha⁻¹ after harvest of rice crop, whereas, after cowpea the plot T_7 , T_6 recorded the higher value (19.10 g ha⁻¹) and were superior to fertilizers plots (6.40 g ha⁻¹). The control recorded lowest value over other plots.

Manganese uptake was maximum in the plot T_6 followed by T_7 , T_4 and T_5 and the values ranging from 475 to 384 g ha⁻¹ and were superior compared to T_2 and T_3 ranging from 321–210 g ha⁻¹ after harvest of rice (Table-15). After cowpea crop, the plot T_7 recorded maximum value of 46.10 g ha⁻¹ followed by T_6 of 44.90 g ha⁻¹ and were superior over chemical fertilizes (T_2) of 18.30 g ha⁻¹. The control recorded lowest value among the treatments.

Iron uptake recorded higher value in the plot (T_6) recorded the value of 2047 g ha⁻¹ and T_5 and T_6 were on par and were superior to T_2 of 1665 g ha⁻¹ after harvest of rice crop (Table-15). However, after cowpea crop the plot T_7 recorded the higher value of 519 g ha⁻¹, followed by T_6 , T_4 and T_5 which were on par and superior over chemical fertilizer T_2 and T_3 . The control recorded lowest value among the treatments (Table-15).

Table 15: Micronutrient uptake by rice and cowpea grain as influenced by organic manure and fertilizers in rice based cropping system

Treatment	Rice (g ha ⁻¹)				Cowpea (g ha ⁻¹)			
	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe
T ₁ =Control (no fertilisers and manures)	40.90	5.30	131	685	5.90	1.00	3.60	59
T ₂ =100 per cent NPK	104.20	35.40	321	1665	19.60	6.40	18.30	173
T ₃ =50 per cent NPK	66.70	22.20	210	1220	11.90	3.10	11.30	146
T ₄ =50% NPK + 50% N--GM	135.60	57.10	397	1743	41.20	13.70	32.30	433
T ₅ =50% NPK + 50% N--FYM	127.40	51.20	384	1702	38.80	12.10	35.40	416
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	160.40	64.10	475	2047	56.00	19.10	44.90	481
T ₇ = FYM @ 10 t ha ⁻¹	85.00	27.80	407	1283	58.70	19.10	46.10	519
F test	*	*	*	*	*	*	*	*
S.E.m. ±	11.48	5.22	18.44	60.53	5.33	1.72	4.20	50.28
CD at 5%	35.38	16.10	56.82	186.52	16.41	5.29	13.00	154.90

N--= Nitrogen through
 GM = Green Manure (Dhaincha)
 FYM = Farm Yard Manure

4.7.3 Nutrients uptake by straw of rice and cowpea crops

The data in Table-14 indicated that there was significant increase in uptake of nutrients by rice straw over control. The treatment T_6 recorded significantly higher value of 74.40, 21.70, 168.40, 27.00, 22.60 and 8.83 g ha⁻¹ of N, P, K, Ca, Mg and S, respectively followed by T_4 and T_5 which were on par with each other and were superior to chemical fertilizers (T_2) and (T_3). The control recorded lowest value among all the value in rice straw.

Uptake of primary and secondary nutrients by cowpea stover recorded significantly higher value in treatment T_7 of 39.80, 25.80, 60.90, 24.60, 13.20 and 24.60 kg ha⁻¹ and T_6 plot recorded on par and which were significantly superior over 100 per cent NPK fertilizers (T_2) recorded the values of 11.56, 9.15, 24.60, 7.20, 5.40 and 9.00 kg ha⁻¹ of N, P, K, Ca, Mg and S, respectively in cowpea stover.

There was significant increase in uptake of micronutrient by treatments over control (Table-16). The maximum uptake of micronutrients by rice straw was recorded in the T_6 plot. The values being are 325.10, 151.40, 1381 and 2761 g ha⁻¹ of Zn, Cu, Mn and Fe, respectively followed by T_4 and T_5 which were on par with each other and were superior over application of chemical fertilizers T_2 and T_3 . The control recorded lowest value over rest of the treatments.

The uptake of micronutrients by residual cowpea stover was higher in T_7 plot which recorded 307.20, 88.20, 357.90 and 2520 g ha⁻¹

Table 16: Micronutrient uptake by rice and cowpea stover as influenced by organic manure and fertilizers in rice based cropping system

Treatment	Rice (g ha ⁻¹)				Cowpea (g ha ⁻¹)			
	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe
T ₁ =Control (no fertilisers and manures)	93.10	22.00	398	865	33.90	7.20	19.20	252
T ₂ =100 per cent NPK	238.70	83.20	838	2182	111.90	33.00	93.30	972
T ₃ =50 per cent NPK	142.00	41.30	593	1120	68.40	16.20	56.10	555
T ₄ =50% NPK + 50% N--GM	283.50	118.80	1141	2346	236.70	71.40	207.60	1983
T ₅ =50% NPK + 50% N--FYM	275.00	112.00	1204	2241	231.60	78.00	203.70	1974
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	325.10	151.40	1381	2761	305.40	80.70	266.10	2382
T ₇ = FYM @ 10 t ha ⁻¹	180.00	80.40	751	1508	307.20	88.20	357.90	2520
F test	*	*	*	*	*	*	*	*
S.E.m. ±	24.54	12.86	34.44	88.45	13.02	3.75	32.10	75.69
CD at 5%	75.61	39.64	106.12	272.56	40.20	11.58	99.00	233.25

N--= Nitrogen through
GM = Green Manure (*Dhaincha*)
FYM = Farm Yard Manure

followed by T₆ plot which recorded 305.40, 80.70, 266.10 and 2382 g ha⁻¹ of Zn, Cu, Mn and Fe, respectively and were superior over T₂ and T₃. The control recorded the lower value among the treatments (Table-16).

4.7.4 Nutrient balance after 11th cropping of cowpea due to long-term application of organic manure and fertilizers in rice based cropping system

The balance sheet indicating major nutrients was worked out as the difference between total plant nutrients applied through fertilizers and manures during 11th year cropping and the plant nutrients removed by the above ground portion of rice and cowpea crops are presented in Tables-17, 18 and 19.

The data in Table-17 revealed that, among different treatments, nitrogen balance was maximum in T₆ (121.30 kg ha⁻¹) followed by T₄ (110.30 kg ha⁻¹) and T₅ (109.00 kg ha⁻¹). The treatment received 100 per cent NPK (T₂) recorded lowest value (25.30 kg ha⁻¹) while compared to control (30.30 kg ha⁻¹) and 50 per cent NPK (38.80 kg ha⁻¹). Application of FYM alone recorded the balance value of 39.00 kg ha⁻¹.

The data in Table-18 indicated that the treatments received combination of 50 per cent NPK + 50 per cent nitrogen through organic sources had recorded higher phosphorus balance as compared to chemical fertilizers. The treatment received 50 per cent NPK + 25 per cent N--GM + 25 per cent N--YM (T₆) recorded higher value (28.00 kg ha⁻¹) followed by T₇

Table-17: Balance sheet of available nitrogen under continued application of organic manure and fertilizers in rice based cropping system

Treatments	Bench mark values during 1989 (kg ha ⁻¹)	Initial soil test values (summer, 1999) (kg ha ⁻¹)	N applied (<i>Kharif</i> 1999) through organic + inorganic sources (kg ha ⁻¹)	Total (kg ha ⁻¹)	N at the end of Crop sequence (kg ha ⁻¹)	N uptake + Soil N at the end of crop sequence (kg ha ⁻¹)	Balance (kg ha ⁻¹)
T ₁ =Control (no fertilisers and manures)	165.40	129.90	0	129.90	128.00	160.20	30.30
T ₂ =100 per cent NPK	167.60	184.60	100	284.60	182.20	309.90	25.30
T ₃ =50 per cent NPK	159.50	158.30	50	208.30	160.00	247.10	38.80
T ₄ =50% NPK + 50% N--GM	161.30	328.00	100	428.00	363.40	538.30	110.30
T ₅ =50% NPK + 50% N--FYM	168.20	313.60	100	413.60	347.80	522.60	109.00
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	170.00	342.50	100	442.50	353.50	563.80	121.30
T ₇ = FYM @ 10 t ha ⁻¹	166.50	285.30	53	337.30	245.20	376.30	39.00

Table-18: Balance sheet of available phosphorus under continued application of organic manure and fertilizers in rice based cropping system

Treatments	Bench mark values during 1989 (kg ha ⁻¹)	Initial soil test values (summer, 1999) (kg ha ⁻¹)	P applied (<i>Kharif</i> 1999) through organic + inorganic sources (kg ha ⁻¹)	Total (kg ha ⁻¹)	P ₂ O ₅ at the end of Crop sequence (kg ha ⁻¹)	P uptake + Soil P ₂ O ₅ at the end of crop sequence (kg ha ⁻¹)	Balance (kg ha ⁻¹)
T ₁ =Control (no fertilisers and manures)	28.20	7.70	0	7.70	6.90	23.70	16.00
T ₂ =100 per cent NPK	30.40	27.30	50	77.30	23.80	71.35	-5.95
T ₃ =50 per cent NPK	26.30	17.20	25	42.20	16.80	47.20	5.00
T ₄ =50% NPK + 50% N--GM	24.50	58.40	33.20	91.60	50.70	116.90	25.30
T ₅ =50% NPK + 50% N--FYM	32.00	59.70	45.20	104.90	49.90	119.00	14.10
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	23.40	66.50	39.20	105.70	51.20	133.70	28.00
T ₇ = FYM @ 10 t ha ⁻¹	24.40	49.40	21.00	70.40	28.90	96.70	26.30

Table-19: Balance sheet of available potassium under continued application of organic manure and fertilizers in rice based cropping system

Treatments	Bench mark values during 1989 (kg ha ⁻¹)	Initial soil test values (summer, 1999) (kg ha ⁻¹)	K applied (<i>Kharif</i> 1999) through organic + inorganic sources (kg ha ⁻¹)	Total (kg ha ⁻¹)	K ₂ O at the end of Crop sequence (kg ha ⁻¹)	K uptake + Soil K ₂ O at the end of crop sequence (kg ha ⁻¹)	Balance (kg ha ⁻¹)
T ₁ =Control (no fertilisers and manures)	124.50	63.70	0	63.70	77.30	143.70	80.00
T ₂ =100 per cent NPK	151.00	147.30	50	197.30	143.50	332.00	134.70
T ₃ =50 per cent NPK	137.50	110.20	25	135.20	115.30	245.80	110.60
T ₄ =50% NPK + 50% N--GM	140.00	237.30	61.10	298.40	246.60	492.30	193.90
T ₅ =50% NPK + 50% N--FYM	154.00	252.50	91.50	344.00	265.50	512.80	168.80
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	147.80	287.10	76.25	363.35	301.50	597.60	234.25
T ₇ = FYM @ 10 t ha ⁻¹	144.00	180.20	69.00	249.20	243.80	454.30	205.10

(26.30 kg ha⁻¹) and T₄ (25.30 kg ha⁻¹). On the other hand, the treatment which received 100 per cent NPK (T₂) recorded negative balance (-5.95 kg ha⁻¹) and 50 per cent NPK (T₃) recorded only 5.00 kg ha⁻¹ while compared to control, which recorded the value of 16.00 kg ha⁻¹ of phosphorus.

The potassium balance recorded was higher in the treatment T₆ (50% per cent NPK + 25% N--GM + 25% N--FYM) of 234.25 kg ha⁻¹ followed by T₇ (FYM @ 10 t ha⁻¹) being the value of 205.10 kg ha⁻¹ and T₄ (50% NPK + 50% N--GM) of 193.90 kg ha⁻¹. Treatments with 100 per cent NPK and 50 per cent NPK recorded lower value of 134.70 and 110.60 kg ha⁻¹, respectively. Control recorded the lowest value of 80.00 kg ha⁻¹ after harvest of cowpea crop (Table-19).

4.8 RELATIONSHIP BETWEEN SOIL PROPERTIES AND CROP YIELD

4.8.1 Relationship ("r" values) between physical, chemical properties of soil and grain yield of crops

Grain yields of both the crops viz., rice and cowpea were found to be significantly and positively correlated to infiltration rate ($r = 0.76^{**}$ and 0.85^{*}), maximum water holding capacity ($r = 0.66^{**}$ and 0.79^{**}), porosity ($r = 0.47^{**}$ and 0.72^{**}), hydraulic conductivity ($r = 0.74^{**}$ and 0.76^{**}) and with chemical properties viz., organic carbon ($r = 0.84^{**}$ and 0.97^{**}), CEC ($r = 0.68^{**}$ and 0.88^{**}) and microbial biomass carbon ($r = 0.73^{**}$ and 0.96^{**}) in the soil. However, bulk density ($r = -0.80^{**}$ and -0.96^{**}), pH ($r = -0.12$ and -0.19) and EC ($r = -0.75^{**}$ and -0.63^{**}) were negatively correlated with the yields (Table-20).

Infiltration rate exhibited a positive and significant relationship with maximum water holding capacity ($r = 0.80^{**}$), porosity ($r = 0.74^{*}$), hydraulic conductivity ($r = 0.75^{**}$), organic carbon ($r = 0.86^{**}$), CEC ($r = 0.74^{**}$) and biomass carbon ($r = 0.76^{**}$) and negatively correlated with pH ($r = -0.22$) and EC ($r = -0.81^{**}$).

Table-20: Correlation matrix ('r' values) among yield of rice and cowpea crops and various physical, chemical and microbial properties of soil

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1-Rice yield	-	-	-0.80**	0.76**	0.66**	0.47**	0.74**	0.84**	-0.12	-0.75**	0.68**	0.73**
X2-Cowpea yield	-	-	-0.92**	0.85**	0.79**	0.72**	0.76**	0.97**	-0.19	-0.63**	0.88**	0.96**
X3-Bulk density	-	-	-	-0.91**	-0.70**	-0.37**	-0.86**	-0.95**	0.07	0.82**	0.77**	-0.84**
x-4-Infiltration rate	-	-	-	-	0.80**	0.74**	0.75**	0.86**	-0.22	-0.81**	0.74**	0.76**
X5-M.W.H.C.	-	-	-	-	-	0.63**	0.51**	0.76**	0.01	-0.53**	0.60**	0.76**
X6-Porosity	-	-	-	-	-	-	0.57**	0.72**	-0.09	-0.54**	0.63**	0.66**
X7-Hydraulic conductivity	-	-	-	-	-	-	-	0.81**	0.06	0.76**	0.69**	0.65**
X8-Organic carbon	-	-	-	-	-	-	-	-	-0.09	0.40**	0.26	0.28**
X9-pH	-	-	-	-	-	-	-	-	-	-0.78**	0.51	-0.48**
X10-Electrical conductivity	-	-	-	-	-	-	-	-	-	-	0.68**	0.86**
X11-C.E.C	-	-	-	-	-	-	-	-	-	-	-	0.92**
X12-Microbial biomass carbon	-	-	-	-	-	-	-	-	-	-	-	-

*Significant at 5%

**Significant at 1%

Maximum water holding capacity indicated positive correlation with porosity ($r = 0.63^{**}$), hydraulic conductivity ($r = 0.51^{**}$), organic carbon ($r = 0.76^{**}$), CEC ($r = 0.60^{**}$) and biomass carbon ($r = 0.76^{**}$) but no correlation with pH and negatively significant correlations with EC ($r = -0.53^{**}$). Soil porosity had a significant positive correlation with hydraulic conductivity ($r = 0.57^{**}$), organic carbon ($r = 0.72^{**}$), CEC ($r = 0.63^{**}$), biomass carbon ($r = 0.66^{**}$) in the soil. Soil pH and EC of the soil were negatively correlated with the porosity of the soil.

Hydraulic conductivity of the soil was significant and positively correlated with organic carbon ($r = 0.81^{**}$), CEC ($r = 0.69^{**}$) and biomass carbon ($r = 0.65^{**}$) and pH and EC were negatively correlated in the soil. Organic carbon content of the soil indicated positive relationship with EC (0.40^{**}) and biomass carbon (0.28^{**}) and negative correlation with pH ($r = -0.09$). Soil pH had significantly negative correlation with EC (-0.78^{**}), CEC (-0.51^{**}) and microbial biomass carbon (-0.48^{**}). Significant and positive relationship of EC was observed with CEC ($r = 0.68^{**}$) and biomass carbon ($r = 0.86^{**}$) and CEC of the soil also positively correlated with biomass carbon ($r = 0.92^{**}$) in the soil

4.8.2 Relationship ('r' values) (a) between various chemical properties of soil and grain yield of rice (b) among different chemical properties of soil

The relationship of grain yield of rice with organic carbon ($r = 0.97^{**}$), nitrogen ($r = 0.86^{**}$), phosphorus ($r = 0.94^{**}$), potassium

Table 21: Correlation matrix ('r' value) among various chemical properties of soil and grain yield of rice

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1-Rice yield	-	0.97*	-0.21	0.86**	0.94**	0.87**	0.80**	0.86**	0.79**	0.71**	0.79**	0.74**	0.69**
X2-Organic carbon	-	-	0.18	0.91**	0.83**	0.95**	0.83**	0.95**	0.94**	0.93**	0.97**	-0.16*	0.25*
X3-pH	-	-	-	-0.19	-0.20	-0.01	0.01	-0.13	-0.06	0.04	-0.06	-0.16	0.19
X4-Nitrogen	-	-	-	-	0.88**	0.92**	0.80**	0.86**	0.77**	0.81**	0.88**	0.74**	0.59**
X5-Phosphorus	-	-	-	-	-	0.88**	0.81**	0.88**	0.79**	0.74**	0.82**	0.75**	0.67**
X6-Potassium	-	-	-	-	-	-	0.76**	0.95**	0.84**	0.91**	0.95**	0.84**	0.79**
X7-Calcium	-	-	-	-	-	-	-	0.73**	0.67**	0.68**	0.66**	0.51**	0.56**
X8- Magnesium	-	-	-	-	-	-	-	-	0.89**	0.89**	0.91**	0.81**	0.81**
X9-Sulphur	-	-	-	-	-	-	-	-	-	0.89**	0.85**	0.76**	0.76**
X10-Zinc	-	-	-	-	-	-	-	-	-	-	0.92**	0.75**	0.77**
X11-Copper	-	-	-	-	-	-	-	-	-	-	-	0.87**	0.81**
X12- Manganese	-	-	-	-	-	-	-	-	-	-	-	-	0.70
X13-Iron	-	-	-	-	-	-	-	-	-	-	-	-	-

*Significant at 5%

**Significant at 1%

($r=0.87^{**}$), calcium ($r=0.80^{**}$), magnesium ($r=0.86^{**}$), sulphur ($r=0.79^{**}$), zinc ($r=0.71^{**}$), copper ($r=0.79^{**}$), manganese ($r=0.74^{**}$) and iron ($r=0.69^{**}$) was found to be positive and significant. Organic carbon content of the soil indicated significant positive relationship with nitrogen ($r=0.91^{**}$), phosphorus ($r=0.83^{**}$), potassium ($r=0.95^{**}$), calcium ($r=0.83^{**}$), magnesium ($r=0.95^{**}$), sulphur ($r=0.94^{**}$), zinc ($r=0.93^{**}$) and copper ($r=0.97^{**}$) (Table-21).

Available nitrogen of the soil had shown a significant positive relationship with organic carbon ($r=0.97^{**}$), phosphorus ($r=0.88^{**}$), potassium ($r=0.92^{**}$), calcium ($r=0.80^{**}$), magnesium ($r=0.86^{**}$), sulphur ($r=0.77^{**}$), zinc ($r=0.81^{**}$), copper ($r=0.88^{**}$), manganese ($r=0.74^{**}$) and iron ($r=0.59^{**}$).

Available phosphorus exhibited positive and significant relationship with potassium ($r=0.88^{**}$), calcium ($r=0.81^{**}$), magnesium ($r=0.88^{**}$), sulphur ($r=0.79^{**}$), zinc ($r=0.74^{**}$), copper ($r=0.82^{**}$), manganese ($r=0.75^{**}$) and iron ($r=0.67^{**}$) in the soil

Available potassium of the soil indicated significant positive relationships with exchangeable calcium ($r=0.76^{**}$), exchangeable magnesium ($r=0.95^{**}$), available sulphur ($r=0.84^{**}$), DTPA-Zn ($r=0.91^{**}$), DTPA-cu ($r=0.95^{**}$), DTPA-Mn ($r=0.84^{**}$) and iron ($r=0.79^{**}$).

Exchangeable calcium of the soil indicated significant positive relationship with exchangeable Mg ($r = 0.73^{**}$), available S ($r = 0.67^{**}$), DTPA-Zn ($r = 0.68^{**}$), DTPA-cu ($r = 0.66^{**}$), DTPA-Mn ($r = 0.51^{**}$) and DTPA-Fe ($r = 0.56^{**}$). The relationship of exchangeable Mg with available S ($r = 0.89^{**}$), DTPA-Zn ($r = 0.89^{**}$), DTPA-Cu ($r = 0.91^{**}$) and DTPA-Mn and Fe ($r = 0.81^{**}$) showed significant positive correlations. Available S exhibited a significant positive relationship with DTPA-Zn ($r = 0.89^{**}$), DTPA-Cu ($r = 0.85^{**}$), DTPA-Mn ($r = 0.76^{**}$) and DTPA-Fe ($r = 0.76^{**}$).

Among micronutrients DTPA-Zn was having significant positive relationship with DTPA-Cu ($r = 0.92^{**}$), DTPA-Mn ($r = 0.75^{**}$) and DTPA-Fe ($r = 0.77^{**}$). DTPA-Cu is also significant relationship with DTPA-Cu ($r = 0.87^{**}$) and DTPA-Mn ($r = 0.81^{**}$) and DTPA-Mn had a significant positive relationship with DTPA-Fe ($r = 0.70^{**}$) of the soil.

4.8.3 Relationship (“r” values) (a) between various chemical properties of soil and grain yield of cowpea and (b) among various chemical properties of soil

Grain yield of cowpea was found to have strong significant positive relationship with organic carbon ($r = 0.97^{**}$), available nitrogen ($r = 0.94^{**}$) content of the soil. Available sulphur indicated significant positive relationship with DTPA-Zn and DTPA-Cu ($r = 0.92^{**}$), DTPA-Fe ($r = 0.29^{**}$) but negative relationship with DTPA-Mn ($r = -0.27^{**}$). The relationship of DTPA-Zn with DTPA-Mn was not significant and only correlated with DTPA-Fe, DTPA-Cu (Table-22).

Table 22: Correlation matrix ('r' value) among various chemical properties of soil and grain yield of cowpea

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1-Cowpea yield	-	0.97**	-0.19	0.94**	0.82**	0.96**	0.86**	0.98**	0.96**	0.94**	0.90**	-0.19	0.27
X2-Organic carbon	-	-	0.11	0.91**	0.83**	0.94**	0.83**	0.95**	0.95**	0.91**	0.87**	-0.13	0.25
X3-pH	-	-	-	0.18	0.09	0.20	0.23	0.23	0.11	0.21	0.16	-0.16	0.02
X4-Nitrogen	-	-	-	-	0.91**	0.96**	0.82*	0.95**	0.95**	0.91**	0.94**	-0.20	0.30*
X5-Phosphorus	-	-	-	-	-	0.89**	0.75**	0.84**	0.86**	0.79**	0.928*	-0.18	0.30*
X6-Potassium	-	-	-	-	-	-	0.86**	0.96**	0.96**	0.92**	0.95**	-0.22	0.33*
X7-Calcium	-	-	-	-	-	-	-	0.90**	0.84**	0.83**	0.80**	-0.41**	0.37**
X8- Magnesium	-	-	-	-	-	-	-	-	0.96**	0.95**	0.90**	-0.23	0.28*
X9-Sulphur	-	-	-	-	-	-	-	-	-	0.92**	0.92**	-0.27	0.29*
X10-Zinc	-	-	-	-	-	-	-	-	-	-	0.90**	-0.25	0.20
X11-Copper	-	-	-	-	-	-	-	-	-	-	-	-0.26	0.37**
X12- Manganese	-	-	-	-	-	-	-	-	-	-	-	-	-0.06
X13-Iron	-	-	-	-	-	-	-	-	-	-	-	-	-

*Significant at 5%

**Significant at 1%

4.8.4 Relationships (“r”) between various microbial, bio-chemical and chemical properties of soil and grain yield of rice

Grain yield of rice indicated significant positive relationship with microbial biomass carbon ($r = 0.73^{**}$), urease activity ($r = 0.83^{**}$), dehydrogenase activity ($r = 0.86^{**}$) and phosphatase activity ($r = 0.87^{**}$) in the soil. Significant relationship was also observed among soil microbial biomass carbon, urease activity, dehydrogenase activity and phosphatase activity of the soil. The values being 0.63^{**} , 0.64^{**} , 0.76^{**} for the relationship between soil microbial biomass carbon and urease, dehydrogenase and phosphatase activities, respectively (Table-23)

Microbial and enzyme activities studied exhibited a strong positive relationships with organic carbon, available N, P and K content of the soil, with the lone exception, however, the relationship of pH was negatively correlated with all the parameters studied in the soil. Organic carbon content of the soil showed significant and positive relationship with microbial biomass carbon ($r = 0.92^{**}$), urease activity ($r = 0.81^{**}$), dehydrogenase activity ($r = 0.80^{**}$) and phosphatase activity ($r = 0.89^{**}$) of the soil.

4.8.5 The relationship (“r” values) between microbial, bio-chemical and chemical properties of soil and grain yield of cowpea

The grain yield of cowpea was found to exhibit positive correlation with microbial biomass carbon ($r = 0.96^{**}$), urease activity

Table-23: Correlation matrix ('r' value) among microbial, biochemical and chemical properties of soil and grain yield of rice

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1-Rice yield	-	0.83**	-0.21	0.86**	0.94**	0.87**	0.73**	0.83**	0.86**	0.87**
X2-Organic carbon	-	-	-0.13	0.83**	0.86**	0.94**	0.92**	0.81**	0.80**	0.89**
X3-pH	-	-	-	-0.19	-0.20	-0.01	-0.01	-0.48**	-0.40**	-0.20
X4-Nitrogen	-	-	-	-	0.88**	0.92**	0.85**	0.68**	0.69**	0.75**
X5-Phosphorus	-	-	-	-	-	0.88**	0.76**	0.80**	0.78**	0.91**
X6-Potassium	-	-	-	-	-	-	0.95**	0.71**	0.72**	0.81**
X7- Microbial biomass	-	-	-	-	-	-	-	0.63**	0.64**	0.76**
X8- Urease	-	-	-	-	-	-	-	-	0.96**	0.83**
X9- Dehydrogenase	-	-	-	-	-	-	-	-	-	0.84**
X10- Phosphatase	-	-	-	-	-	-	-	-	-	-

*Significant at 5%

**Significant at 1%

Table-24: Correlation matrix ('r' value) among microbial, biochemical and chemical properties of soil and grain yield of cowpea

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1-Cowpea yield	-	0.97**	-0.19	0.94**	0.82**	0.96**	0.96**	0.75**	0.64**	0.84**
X2-Organic carbon	-	-	0.11	0.91**	0.82**	0.94**	0.93**	0.80**	0.66**	0.88**
X3-pH	-	-	-	0.18	0.09	0.20	0.28*	-0.20	-0.19	-0.16
X4-Nitrogen	-	-	-	-	0.91**	0.96**	0.95**	0.72**	0.64**	0.79**
X5-Phosphorus	-	-	-	-	-	0.89**	0.84**	0.74**	0.68**	0.77**
X6-Potassium	-	-	-	-	-	-	0.94**	0.73**	0.63**	0.82**
X7- Microbial biomass	-	-	-	-	-	-	-	0.648*	0.54**	0.79**
X8- Urease	-	-	-	-	-	-	-	-	0.73**	0.81**
X9- Dehydrogenase	-	-	-	-	-	-	-	-	-	0.64**
X10- Phosphatase	-	-	-	-	-	-	-	-	-	-

*Significant at 5%

**Significant at 1%

($r = 0.75^{**}$), dehydrogenase activity ($r = 0.64^{**}$) and phosphatase activity ($r = 0.84^{**}$) in the soil (Table-24).

Microbial biomass carbon content of the soil showed positive and significant relationship with urease activity ($r = 0.64^{**}$), dehydrogenase activity ($r = 0.54^{**}$), phosphatase activity ($r = 0.79^{**}$), organic carbon ($r = 0.91^{**}$), pH ($r = 0.11^{**}$) of soil. Similarly, significant and positive relationship was observed between soil urease, dehydrogenase, phosphatase activities and other properties like organic carbon, available N, P and K content of the soil.

4.9 SUSTAINABLE YIELD INDEX (SYI) AS INFLUENCED BY ORGANIC MANURE AND FERTILIZERS IN RICE BASED CROPPING SYSTEM

4.9.1 SYI for rice

Sustainable yield index due to long-term incorporation of organic and inorganic fertilizers (Table-25) indicated that the maximum value was recorded in the treatment which received FYM 10 t ha⁻¹ (T₇) recorded 0.89 with mean yield (5756.30 kg ha⁻¹) of 11 years followed by treatment which received 50 per cent NPK + 50 per cent N--GM (T₄) of 0.83 with mean yield of 5354.60 kg ha⁻¹. The control recorded lowest value of 0.33 with mean yield of 2174.90 kg ha⁻¹ over other treatments.

4.9.2 SYI for cowpea

Long-term residual effect of organic and inorganic fertilizers (Table-26) shows that the treatment T₆ (50% NPK + 25% N--GM + 25% N--FYM) recorded maximum SYI of 0.66 with mean yield of 902.30 kg ha⁻¹

Table 25: Yield stability of rice due to long-term application of organic manure and fertilizers in rice based cropping system

Treatment	Average rice yield (kg ha ⁻¹) (1989-1999)	Sustainable Yield Index (SYI)
T ₁ =Control (no fertilisers and manures)	2174.90	0.33
T ₂ =100 per cent NPK	5291.80	0.82
T ₃ =50 per cent NPK	4258.20	0.66
T ₄ =50% NPK + 50% N--GM	5354.60	0.83
T ₅ =50% NPK + 50% N--FYM	5330.60	0.82
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	5756.30	0.89
T ₇ = FYM @ 10 t ha ⁻¹	3977.10	0.61

Table 26: Yield stability in cowpea due to long-term application of organic manure and fertilizers in rice based cropping system

Treatment	Average rice yield (kg ha ⁻¹) (1989-1999)	Sustainable Yield Index (SYI)
T ₁ =Control (no fertilisers and manures)	240.60	0.17
T ₂ =100 per cent NPK	617.40	0.45
T ₃ =50 per cent NPK	472.60	0.36
T ₄ =50% NPK + 50% N--GM	785.30	0.58
T ₅ =50% NPK + 50% N--FYM	826.50	0.61
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	902.30	0.66
T ₇ = FYM @ 10 t ha ⁻¹	831.60	0.62

followed by application of FYM alone of 0.62 with mean SYI of 831.60 kg ha⁻¹, T₅ (50 per cent NPK + 50 per cent N--FYM) of 0.61 with mean yield of 826.50 kg ha⁻¹ and were superior to T₂ (100% NPK) recording 0.45 with mean yield of 617.40 kg ha⁻¹. The control recorded lowest SYI of 0.17 with mean yield of 240.60 kg ha⁻¹ over rest of the treatments.

4.10 ECONOMIC RETURN

Economics of rice and cowpea production due to long-term application of organic and inorganic fertilizers is presented in Table-27. The net return obtained was maximum by adopting integrated nutrient management practices compared to application of organic or inorganic fertilizers alone.

The treatment which received 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM (T₆) gave the highest net returns Rs.35,937.00 followed by application of 50 per cent NPK + 50 per cent N--GM (T₄) (Rs.30,826.00) and 50 per cent NPK + 50 per cent N--FYM (T₅) of Rs.26,942.00. Use of only FYM @ 10 t ha⁻¹ gave moderate net returns of Rs.24,515.00. On the other hand, application of inorganic fertilizers did not result in substantial profit. Further, applying higher quantities of inorganic fertilizers was also not economical compared to lower doses in the present study.

Table 27: Economics of rice and cowpea production due to long-term application of organic manure and fertilizers in rice based cropping system

Treatment	Paddy yield (t/ha)		Cowpea yield (t/ha)		Gross return (Rs ha ⁻¹)	Additional return over control (Rs ha ⁻¹)	Additional cost over control (Rs ha ⁻¹)	Net return over control (Rs ha ⁻¹)
	Grain	Straw	Grain	Straw				
T ₁ =Control (no fertilisers and manures)	2.73	3.00	0.13	0.72	18,260	-	-	-
T ₂ =100 per cent NPK	5.10	5.69	0.57	2.23	39,421	21,161	2,832	18,299
T ₃ =50 per cent NPK	4.17	4.59	0.52	2.03	33,096	14,836	1,416	13,420
T ₄ =50% NPK + 50% N--GM	5.73	6.59	1.09	4.24	52,033	33,773	2,947	30,826
T ₅ =50% NPK + 50% N--FYM	5.63	6.43	1.14	4.64	52,278	34,018	7,076	26,942
T ₆ =50% NPK + 25% N--GM + 25% N--FYM	6.39	7.47	1.28	4.98	59,208	40,948	5,011	35,937
T ₇ = FYM @ 10 t ha ⁻¹	4.64	5.14	1.30	5.08	49,065	30,805	6,000	24,805

Legend

Urea	Rs/kg		Rs/kg
SSP	= 3.89	Paddy straw rate	= 0.75
MOP	= 2.82	Cowpea seed rate	= 14.00
ZnSO ₄	= 3.68	Cowpea stover rate	= 00.75
Paddy seed rate	= 40.00	FYM rate	= 00.60
	= 5.00	Green manure (Dhaincha)	= 00.75

DISCUSSION

V. DISCUSSION

Fertilizers are the predominant inputs used in crop production and accounts for half of the energy used in the world agriculture. The introduction of fertilizer responsive high yielding varieties led to the intensive use of inputs particularly fertilizers. Use of heavy fertilizer doses over the years without organic matter has resulted in degradation of soils and also caused environmental hazards. Despite a huge concern expressed by the environmentalists, bureaucrats and scientists, the farming community resorted completely to chemical fertilizers for immediate and short benefits.

A similar trend is being practised in the Cauvery Command area of Karnataka. The need of the hour is integration of organic and inorganics for wholesome soil development and sustainance of productivity. In this context, the present investigation was undertaken during *kharif* 1999 and summer 2000 to examine the impact of long-term application of plant nutrients in different combinations through organic manure and fertilizers in rice-cowpea crop rotation system on changes in physical, chemical, microbial and biochemical properties of soil, yield and nutrient uptake, sustainability and economics of rice and cowpea crops at the Regional Research Station, VC Farm, Mandya. Results of experiment presented in chapter four are discussed in the following paragraphs.

5.1 SOIL PHYSICAL PROPERTIES

The physical properties like mechanical composition, bulk density, water stable aggregates, water holding capacity, porosity, infiltration and hydraulic conductivity are the important properties for maintaining sustained productivity. Infact, a good soil tilth is a precursor to high crop productivity. Further, the binding of soil particles into stable aggregates is essential for the production of optimum soil tilth. Soil, climate and nature of fertilizers and organic materials added have a direct bearing on the rate of organic matter decomposition. Return of crop residues and green manures have favourable effect on all soil physical properties.

5.1.1 Mechanical composition (soil texture)

There was no change in the soil texture or proportion of various sized particles due to the long-term adoption of rice-cowpea crop rotation and application of various plant nutrients from organic and inorganic sources after 11 years compared to the initial value as seen in the Table-3. It is too early a period to expect major impact on changes in mechanical composition of the soil. The reduction in size of the particles would require several years or decades or centuries. Therefore, it was implied that plant nutrients supplied through both organic and inorganic sources did not have any impact on the changes in soil texture after 11 years. Similarly, adoption of rice-cowpea rotation did not affect particle

size. Similar results are in conformity with the reports of Kavallappa (1989) and Parashuram (1998).

5.1.2 Bulk density

The long-term trial conducted over 11 years indicated that the FYM added at 10 t ha^{-1} (T_7) significantly reduced the bulk density of 1.30 and 1.29 g cm^{-3} followed by the treatment T_6 (50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM) recorded value of 1.35 and 1.32 g cm^{-3} , T_4 (50 per cent NPK + 50 per cent N--GM of 1.36 and 1.34 g cm^{-3} . The treatment which received only inorganic fertilizers recorded higher BD value ranging from 1.44 to 1.43 g cm^{-3} and control recorded the highest bulk density of 1.65 and 1.67 g cm^{-3} after the harvest of rice and cowpea crops, respectively, which remained unchanged over initial value of 1.67 g cm^{-3} . The decrease in bulk density in the treatment supplied with FYM alone and combination of organic and inorganics might be due to increase in organic carbon content of the soil due to addition of FYM and green manure which on decomposition helped the process of soil aggregation and thus increase the porosity of the soil. This in turn quite naturally reduce the bulk density of the soil. This is in agreement with work carried out by Bharadwaj and Omanwar (1992), More (1994), Tripathi and Chaubey (1996), Mishra and Sharma (1997). The reduction in bulk density was also due to inclusion of pulse crop in rice based cropping system, which increased the organic matter in the soil as a result of addition of crop residues and presence of

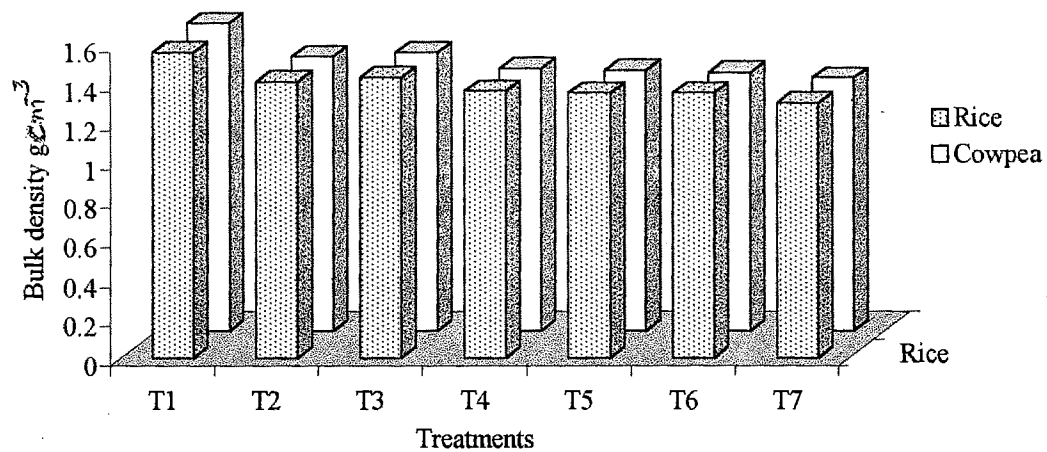


Fig.1: Bulk density of the soil as influenced by INM practices in Rice-Cowpea cropping system

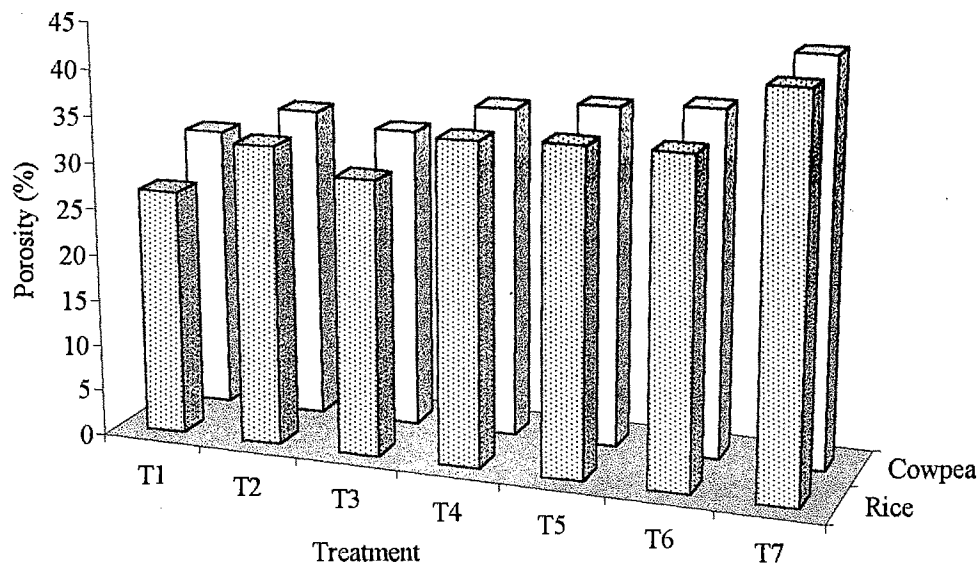


Fig.2: Porosity of the soil as influenced by INM practices in Rice based cropping system

crop throughout the year (Fig.1). This is in conformity with findings of Ram– Newaj and Yadav (1994), Rawat *et al.* (1996) and Despande *et al.* (2000).

5.1.3 Water stable aggregates

Water stable aggregates in any soil besides promoting better air circulation and root penetration of crop plants, offer maximum resistance to soil erosion without which silt and clay particles would be the first victims of erosion. Soil organic matter and aggregates are closely related because organic matter soon after its addition to soil will be attacked by microbes giving rise to a variety of decomposition products and new product which will combine physically and chemically with inorganic soil particles forming water stable aggregates.

Soil aggregates of all sizes viz., 0.2, 0.5, 2.0 and 5.0 mm determined in the present study were found to be significantly higher in the plots treated with FYM alone followed by combination of FYM or GM along with fertilizers. The control, which received no manure and fertilizers, recorded lower aggregate sizes and the values were still lower while compared to initial value recorded during 1989. These observations would imply that FYM and GM played a favourable role in building up of water stable aggregates of all sizes in the soil. Readily decomposable organic matter from FYM and GM had an advantage of releasing various humic fractions which might have helped soil particles to bind together and

also with extensive root system of cowpea provided the protective cover to the soil aggregates leading to formation of higher water stable aggregates. These results are in accordance with the research findings reported by Rawat *et al.* (1996). Sarma and Das (1996) also reported that the clay particles bridged with cations as organo-metallic complex of humic material and in *Alfisol* Fe also did act in co-ordination with organic matter and stabilized the micro aggregates. This is also in accordance with the findings of Mishra and Sharma (1997).

5.1.4 Porosity

Continuous application of FYM or Dhaincha over the years either alone or in combination with fertilizers recorded significantly higher porosity than other treatments. The pore space varied from 42.60 and 43.70 (FYM @ t ha⁻¹) to 35.20 and 37.40 per cent (50% NPK + 50% N--FYM) which were significantly higher compared to chemical fertilizer plots after harvest of rice and cowpea crops, respectively (Fig.2). This might probably be due to clay which were firmly held together by inorganic cementing or organic bonding agents and stabilize the micro-aggregates leading to an increase in the porosity of the soil. The lower bulk density in the organic source treatments of the present study also enhanced increase in porosity of the soil. These are in conformity with findings of Jagannathan *et al.* (1987), Hanumnantharayappa (1994) and Sarma and Das (1996).

5.1.5 Infiltration rate

The infiltration rate of soil after 11 years of cropping in rice based cropping system increased significantly with FYM or Dhaiancha applied either alone or in combination with fertilizers. The data ranging from 3.57 and 6.80 cm h⁻¹ (FYM @ 10 t ha⁻¹) to 3.13 to 5.80 cm h⁻¹ (50% NPK + 50% N--GM) were superior compared to application of 100 per cent NPK fertilizers after harvest of rice and cowpea crops, respectively (Fig.3). The increase in infiltration rate with different organic sources might be due to improvement in water permeability as compared to fertilizer plots. The highest infiltration rate with addition of organic and green manures could be due to increase in degree of aggregation with increasing organic carbon content of soil. This is in agreement with the results reported by More (1994). However, infiltration rate was relatively higher after harvest of cowpea as compared to rice crop. This might also due to presence of crops throughout the year by inclusion of pulse crop, which not only penetrate roots deep into the soil but also leave root as well as stover residues in the soil, which has improved the physical properties. This is also in accordance with the work carried out by Ram-Newaj and Yadav (1994), Acharya *et al.* (1988) and Despande *et al.* (2000).

5.1.6 Hydraulic conductivity

The hydraulic conductivity of the soil increased significantly due to continuous application of organic manures along with fertilizers under both rice and cowpea crops as compared to control and initial value.

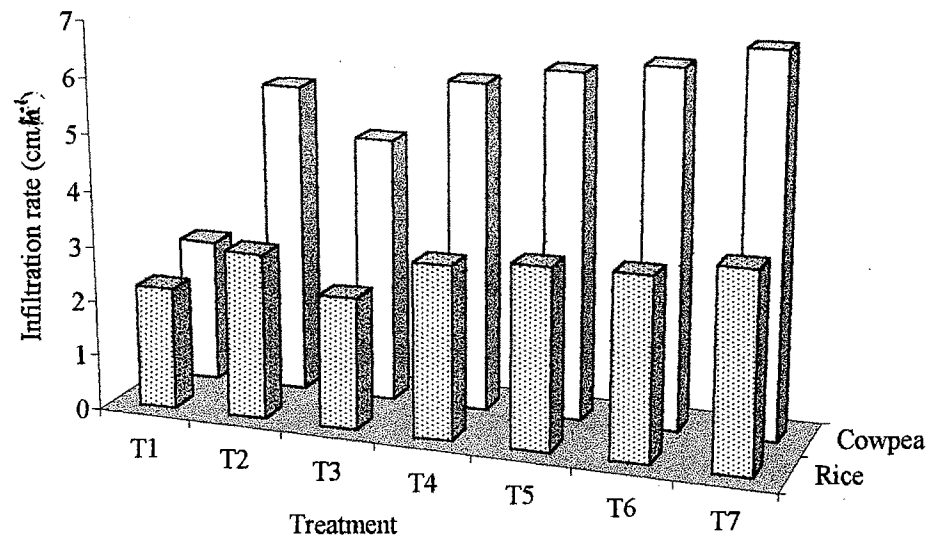


Fig.3: Infiltration rate of the soil due to organic manure and fertilizers in Rice based cropping system

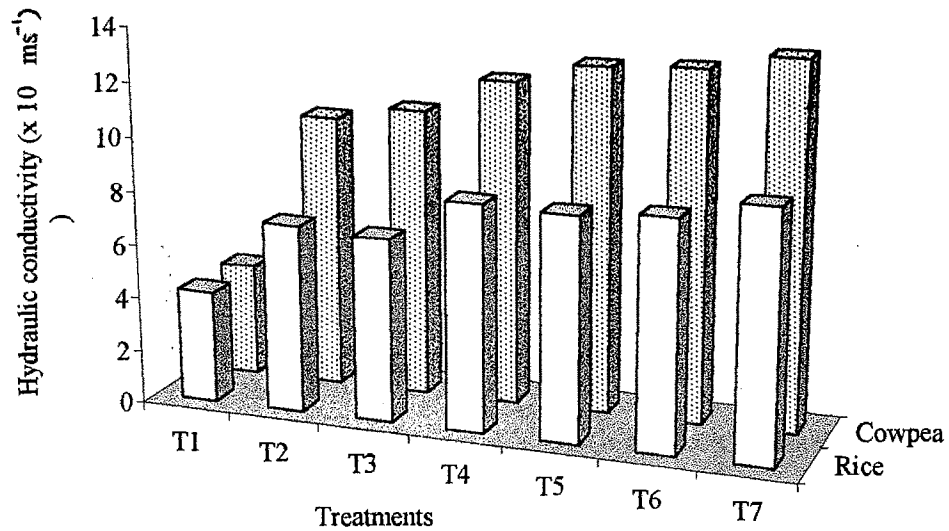


Fig.4: Hydraulic conductivity of the soil due to organic manure and fertilizers in Rice based cropping system

The increase in hydraulic conductivity might be due to incorporation of organic matter and subsequent increase in porosity of the soil (Fig.4). Mahimairaja *et al.* (1986), Jagannathan *et al.* (1987), Sarma and Das (1996) also opined that the increase in macroaggregates synthesized was due to organic amendments in the soils, which ultimately increased the amount of conducting pores in the soil and enhanced hydraulic conductivity of the soil.

It was interesting to observe that hydraulic conductivity was substantially higher in all the treatments applied to the cowpea compared to rice. Lower hydraulic conductivity in rice might be due to compaction of soil due to puddling while increase in hydraulic conductivity in cowpea was because of pulverization due to interculture operations. Deep root system of cowpea crop also improved the hydraulic conductivity of the soil. This is in accordance with the observations of Ram-Newaj and Yadav (1994).

5.1.7 Maximum water holding capacity

It is a well known fact that the moisture retention capacity of a soil is directly related to its porosity and indirectly related to bulk density. Soil moisture is closely related to the plant growth as it serves as a solvent carrier of plant nutrients helping to keep the plant cells turgid, regulate their temperature and also responsible for most of the chemical and biological activities taking place in soil that are in one way or the other related to plant growth (Fig.5).

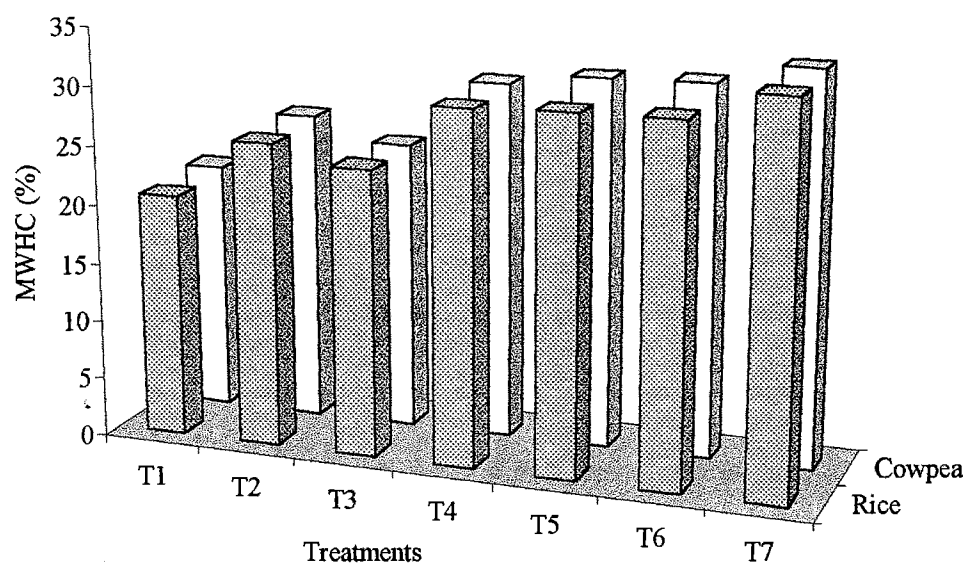


Fig.5: MWHC of the soil as influenced by INM practices in Rice based cropping system

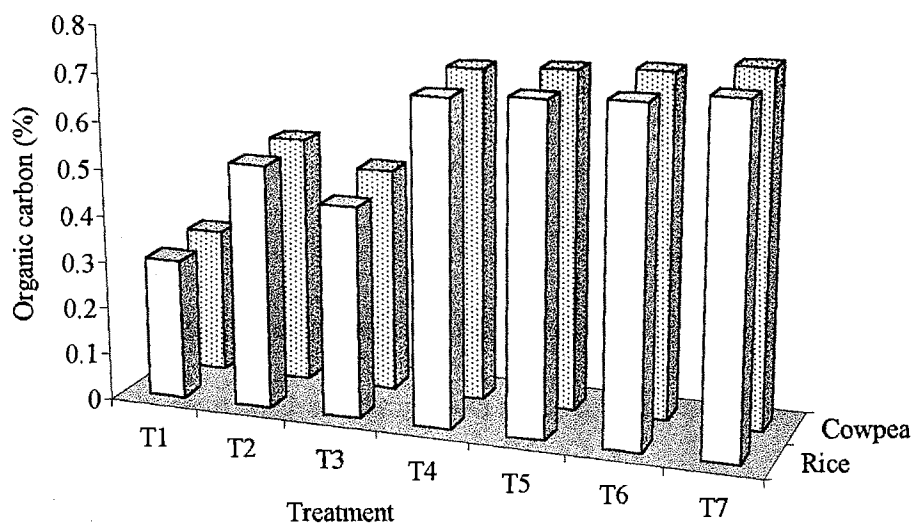


Fig.6: Organic carbon of the soil as influenced by INM practices in Rice based cropping system

In this study, the plot which received FYM or GM and their combination with inorganic fertilizers had recorded significantly higher values ranging from 32.70 and 33.10 per cent to 29.90 and 30.20 per cent, after the harvest of rice and cowpea crops, respectively. The increase in the non-capillary pore space of the soil brought about by favourable interaction of clay and humus could have lead to overall increase in moisture holding capacity of the soil. These are in agreement with reports of Kavallappa (1989) and Kalane *et al.* (1995). In contrast to the above, a significantly lower moisture holding capacity was recorded in treatment which received only inorganic fertilizers. There was a slight reduction of maximum water holding capacity in control (20.70%) while compared to initial value of 20.74 per cent recorded during 1989. This was obvious due to the fact that these treatments did not include either FYM or GM leading to build up of low organic matter in the soil, consequently, reduction of micro aggregates formation and ultimately low water holding capacity of the soil. The maximum water holding capacity of the soil recorded after harvest of residual cowpea was higher compared to rice crop irrespective of treatment. Inclusion of a pulse crop in the cropping system increases the crop residue and presence of crop throughout the year also increased infiltration rate of the soil, these attributed to increase in maximum water holding capacity of the soil. These are in conformity with the results of Ram-Newaj and Yadav (1994) and Chaphale (2000).

5.2 SOIL CHEMICAL PROPERTIES

5.2.1 Soil reaction

There was no significant change in soil pH due to the continuous use of 50 per cent NPK + 50 per cent nitrogen through organic sources like FYM or GM or FYM alone treatments and the values were almost similar to the initial value. The inorganic fertilizer treatments decreased the pH over the years of study, while in control it increased compared to initial value after harvest of rice and cowpea crops, respectively (Fig.7). Continuous application of NPK fertilizer for 11 years lowered the pH while the pH of unfertilized plot rose to 6.98 over initial value of 6.78. The use of ammonical fertilizers resulted in the reduction in soil pH due to their acidic residual effect. This is in agreement with the findings of Kumar and Yadav (1993), Sudhir *et al.* (1996) and Basumantary and Talukdar (1998).

5.2.2 Electrical conductivity

The electrical conductivity values of the soil were found to be significantly higher in plots which received GM or FYM along with chemical fertilizers in comparison to those plots treated with fertilizers alone and control. The relatively higher soluble salt contents observed in INM practises as compared to addition of chemical fertilizers could be attributed to increase in CO₂ concentration, bicarbonates and organic salts of Fe, Mn and NH₃ addition and also the release of calcium from organic

sources over the years and subsequent formation of some of the soluble salts of calcium. This is in conformity with findings of Chahal *et al.* (1984) and Bharguvanshi (1988).

5.2.3 Organic carbon

Organic matter is an index of soil physical, chemical and microbial and biochemical properties from the point of view of their effect on plant growth. It is estimated by measuring organic carbon content of the soil and multiplying the same with factor, 1.724.

In the present study, there was a marked variation in organic carbon contents of the soil, which increased significantly with incorporation of FYM alone, and FYM or Dhaiancha in combination with chemical fertilizers. The FYM treated plots recorded 0.73 per cent and was 0.71 per cent due to combination of 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM which were significantly superior to application of chemical fertilizers with values of 0.52 and 0.45 per cent of organic carbon when 100 and 50 per cent NPK was applied to the rice (Fig.6). The increase in organic carbon content was found to be marginal after cowpea crop recorded the value of 0.75 per cent in FYM treated plots which substantially increased the organic carbon per cent compared to initial value of 0.35 per cent. The control plot also noticed declining trend as compared to the initial value after 11th year cropping of both rice and cowpea crops. The buildup of organic carbon attributed to increased crop yield compared to other

treatments, which naturally added more biomass to the soil and also external application of FYM or *in situ* growing of green manure in turn influenced better root growth and more residues being left on the surface and subsurface of the soil. These observations are in conformity with the findings of those of Panda and Sahoo (1989), Subramanian and Kumaraswamy (1989), Kumar and Yadav (1993), More (1994), Ram-Newaj and Yadav (1994), Bharadwaj and Omanwar (1994) and Sudhir and Siddaramappa (1995).

5.2.4 Cation exchange capacity

The CEC of the soil ranged from 9.80 and 10.70 [c.mol (p⁺) kg⁻¹] in control and 14.20 to 14.90 [c.mol (p⁺) kg⁻¹] in FYM treated plots after harvest of rice and cowpea crops, respectively (Fig.8). It was also of interest to note that the treatment, which received 100 and 50 per cent NPK and control plots, had drastically reduced their CEC values while compared to initial value recorded during 1989. It was obvious that application of FYM or GM would lead to an increase in the amounts of organic colloid viz., humus of the soil and hence the CEC of the soil increased and vice versa with respect to treatments that received no organic materials. Subramanian and Kumaraswamy (1989), Lokeswarappa (1997) and Basumantary and Talukdar (1998) have reported results similar to the one observed in the present study.

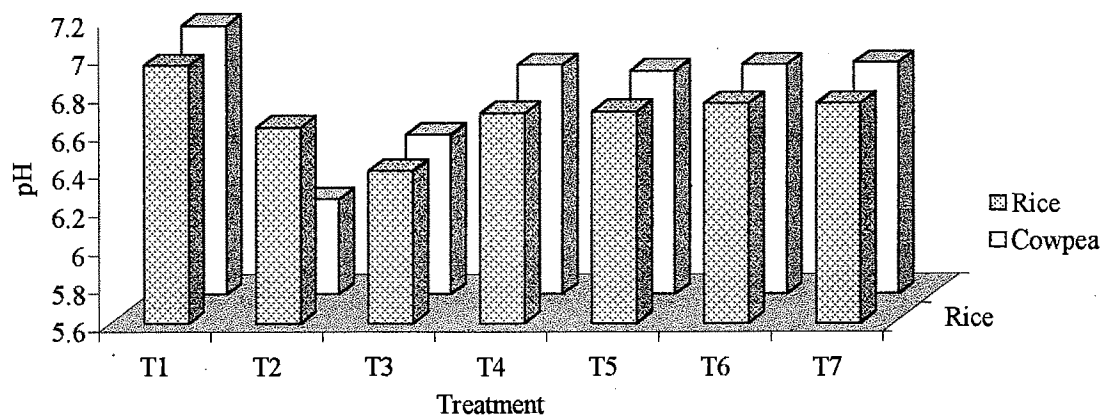


Fig.7: pH of the soil as influenced by organic manure and fertilizers in Rice based cropping system

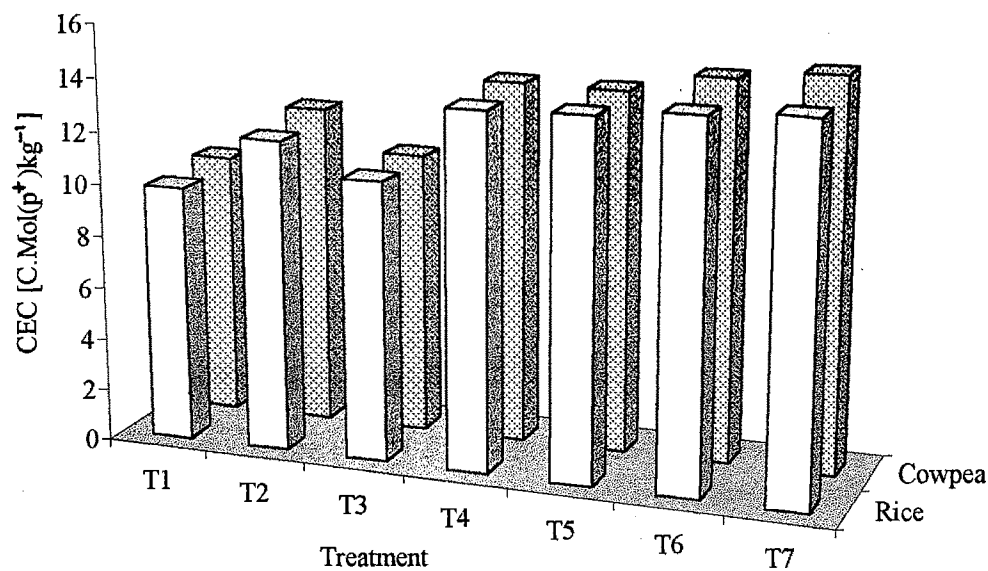


Fig.8: Cation exchange capacity of the soil as influenced by organic manure and fertilizers in Rice based cropping system

5.3 SOIL FERTILITY

Fertility status of the soil is monitored by physical and chemical behaviour, which control the availability of nutrient elements necessary for plant growth. The microorganisms play a vital role in the mineralisation of various plant nutrients in the soil. Manures and fertilizers are applied mainly to supply the plant nutrients, the effect of their continuous application in soils needs study as they are likely to bring about beneficial or harmful effects in the soil characteristics.

The plots that received chemical fertilizers and control treatments, which received no manure and fertilizers, noticed a decline trend in the buildup of major and micro nutrients as compared to initial values recorded during 1989. This might be attributed to low organic matter accumulation, no external supply of nutrients into the soil sufficiently either from organic and inorganic sources and also due to continuous depletion of these nutrients by crops over the years.

5.3.1 Mineralisation of nitrogen

The data in the Fig. 9 & 10 shows that incorporation of GM or FYM along with fertilizers had influenced the maximum accumulation of nitrogen through mineralisation of organic manures. A rapid accumulation of mineral nitrogen was noticed in rice soil, mostly as $\text{NH}_4\text{-N}$ upto 3rd and 4th week of transplanted rice, followed by a slow decline during crop growth period. On the other hand, $\text{NO}_3\text{-N}$ accumulation was predominant during

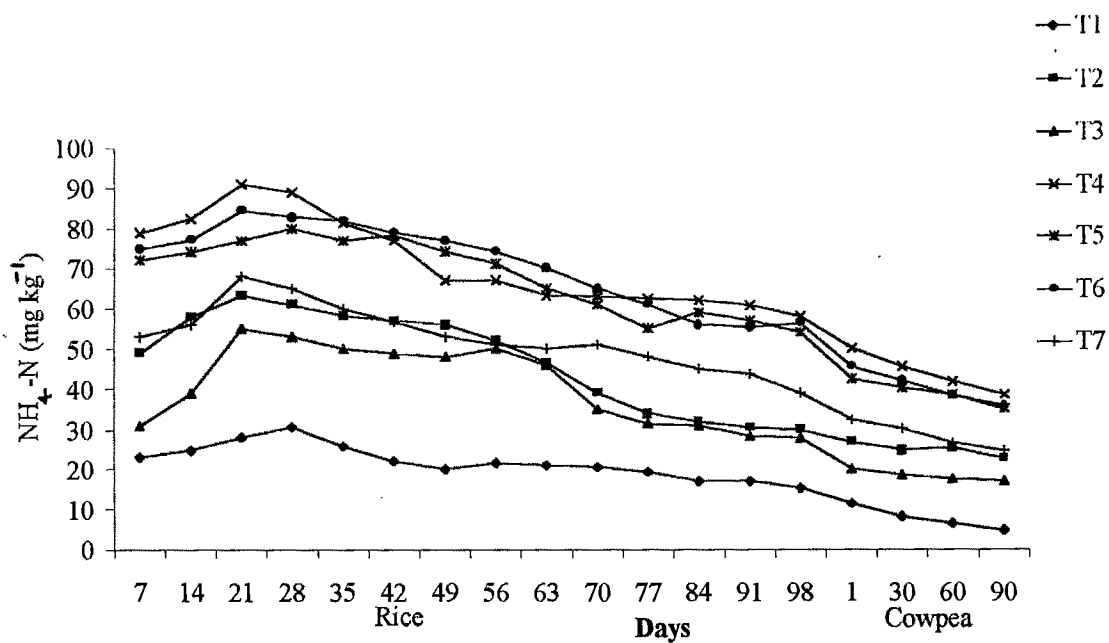


Fig.9: Long term effect of organic manure and fertilizers on mineralisation of $\text{NH}_4^+\text{-N}$ in rice based cropping system

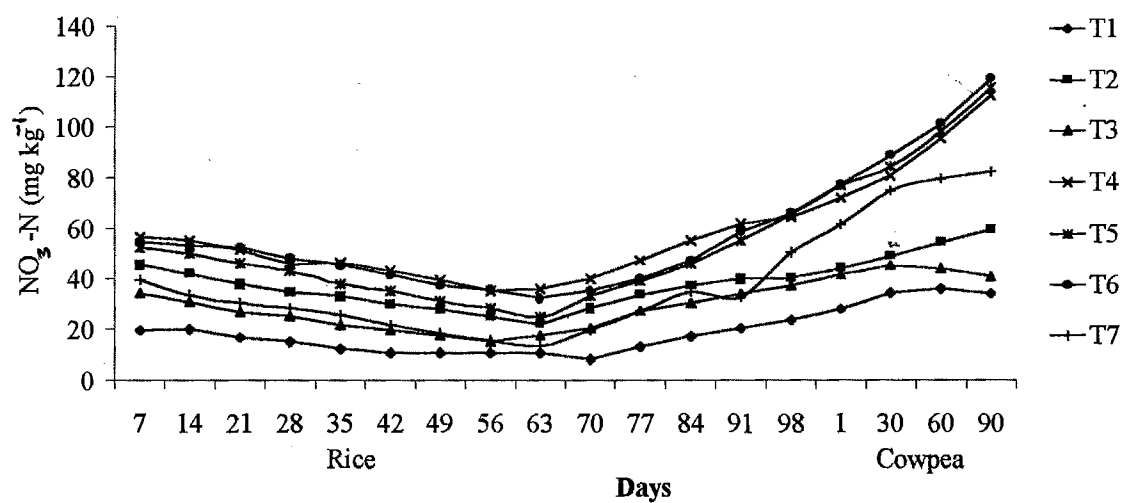


Fig.10: Long term effect of organic manure and fertilizers on mineralisation of $\text{NO}_3^-\text{-N}$ in Rice based cropping system

cowpea crop growth period as compared to rice crop. This presumably due to reduced nitrification in the partially anaerobic rice soils that resulted from frequent irrigation and on the other hand, $\text{NO}_3\text{-N}$ increased mainly due to soil which was under partially anaerobic condition turned into aerobic condition under cowpea crop growth period and enhanced the nitrification process from $\text{NH}_4\text{-N}$ to $\text{NO}_3\text{-N}$ in the soil. In addition to this an improvement in $\text{NO}_3\text{-N}$ was also due to N_2 fixation and mineralisation of biomass in the soil. This is in agreement with the findings of Ladha *et al.* (1996) and Aulakh *et al.* (2000).

Among the treatments, the plot received 50 per cent NPK + 50 per cent N--GM noticed rapid and maximum mineralisation of $\text{NH}_4\text{-N}$ followed by 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM and 50 per cent NPK + 50 per cent N--FYM treated plots. The narrow C : N ratio of GM resulted in rapid mineralisation and allowed to serve as efficient source of nitrogen. This is in agreement with the findings of Yadvinder-Singh *et al.* (1988) and Datt and Bharadwaj (1995).

Efficient use of GM and FYM-N may be due to synchrony between nitrogen release from GM and FYM and crop plant demand. Unlike fertilizer, nitrogen from FYM is less prone to losses through leaching of $\text{NO}_3\text{-N}$ due to steady and continuous mineralisation of nitrogen. Thereby, accumulation of $\text{NO}_3\text{-N}$ was more in case of treatments received

organic sources especially in case of FYM treated plots. This is in conformity with the findings of Kheera *et al.* (1999).

5.3.2 Available nitrogen

The integrated nutrient supply through organic and inorganic sources have recorded higher value of available nitrogen viz., 50 per cent NPK + 50 per cent N--GM (279 and 363.40 kg ha⁻¹), 50 per cent NPK + 50 per cent N--FYM (256.50 and 347.80 kg ha⁻¹) these were significantly higher compared to application of chemical fertilizers (100% NPK) with values of 153.90 kg ha⁻¹ and 182.20 kg ha⁻¹ and FYM @ 10 t ha⁻¹ also recorded significantly higher value (195 and 245.20 kg ha⁻¹) compared to chemical fertilizers after harvest of rice and cowpea crops, respectively after 11th year of long term cropping (Fig.11).

Increase in available nitrogen due to FYM or Dhaiancha application might be because of direct addition of nitrogen through Dhaiancha and FYM to the available pool of the soil. The increase in available nitrogen also could be due to buildup of organic matter, which caused greater soil microbial proliferation leading to conversion of organically bound N to inorganic form. Similar results were also reported as observed in the study by Ganapathi (1991), Deepak Kher (1993), Prasad *et al.* (1996), Solaiappan and Veerabadran (1997) and Basumantary and Talukdar (1998).

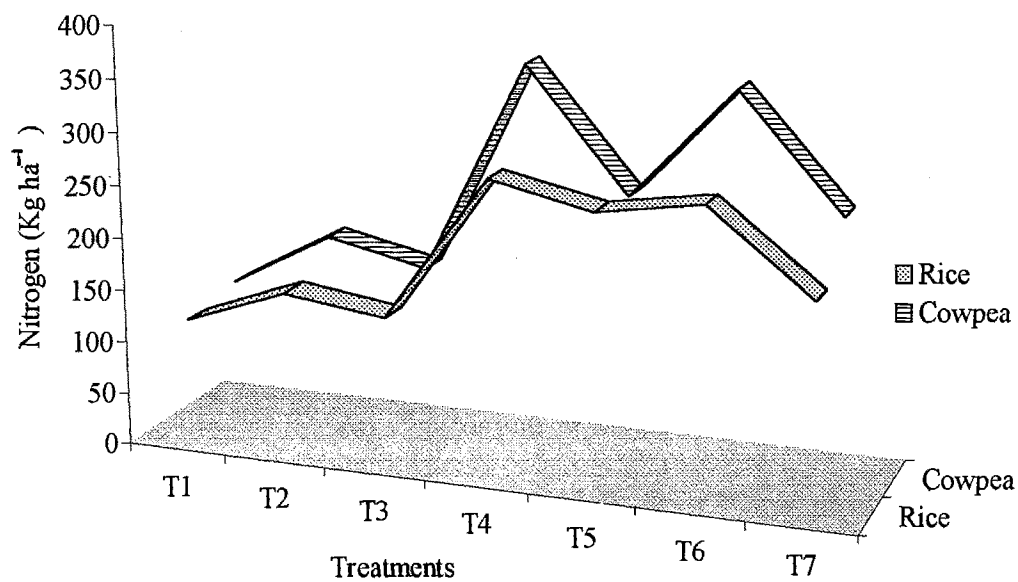


Fig.11: Available nitrogen of the soil as influenced by organic manure and fertilizers in Rice based cropping system

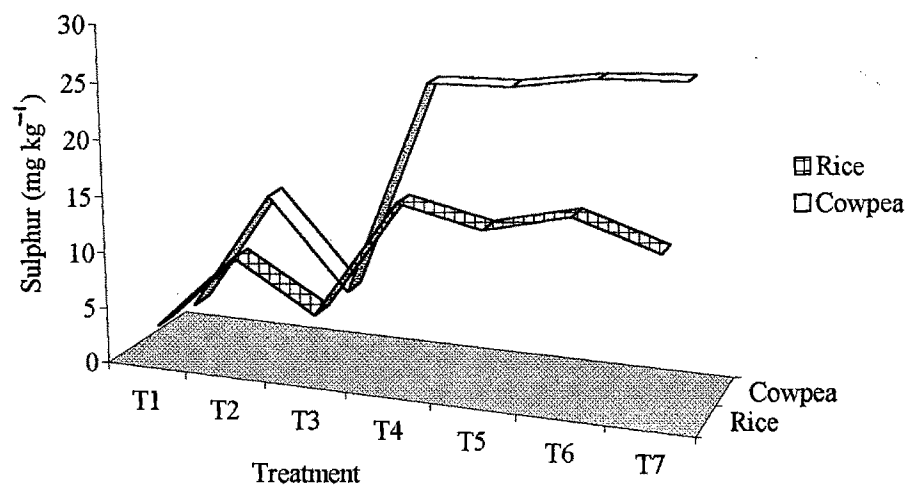


Fig.12: Available sulphur of the soil as influenced by organic manures and fertilizers in Rice based cropping system

It was also noticed that values of available nitrogen were remarkably higher after harvest of cowpea in comparison to rice crop which might be due to nitrogen contribution of legume green manure crops which come from two sources, one from biological nitrogen fixation and another from $\text{NO}_3\text{-N}$ formed in the soil during aerobic phase in summer (catch crop). Nitrate-N accumulated in early stages in fact act as reserve dose of nitrogen and helped to increase biological nitrogen fixation capacity in later stages. This was in agreement with the findings of Narayana Reddy and Krishnaiah (1999).

5.3.3 Available phosphorus

Long-term incorporation of organic materials to meet 50 per cent N along with 50 per cent NPK fertilizers recorded significantly higher value ranging from 59.80 and 51.20 kg ha^{-1} to 56.00 and 49.90 kg ha^{-1} and were significantly superior to 100 per cent NPK fertilizers application of 46.80 and 23.80 kg ha^{-1} after harvest of rice and cowpea crops, respectively (Fig.13). Increase in available phosphorus due to FYM or Dhaiancha might be because of the addition of phosphorus through organic sources to the available pool of the soil. In addition to being a source of phosphorus, FYM or GM is known to promote the release of native soil phosphorus and reduce fixation of phosphorus through chelation of organic ligand. Acharya *et al.* (1988) reported that incorporation of FYM along with NPK maintained the available phosphorus at higher level compared to NPK

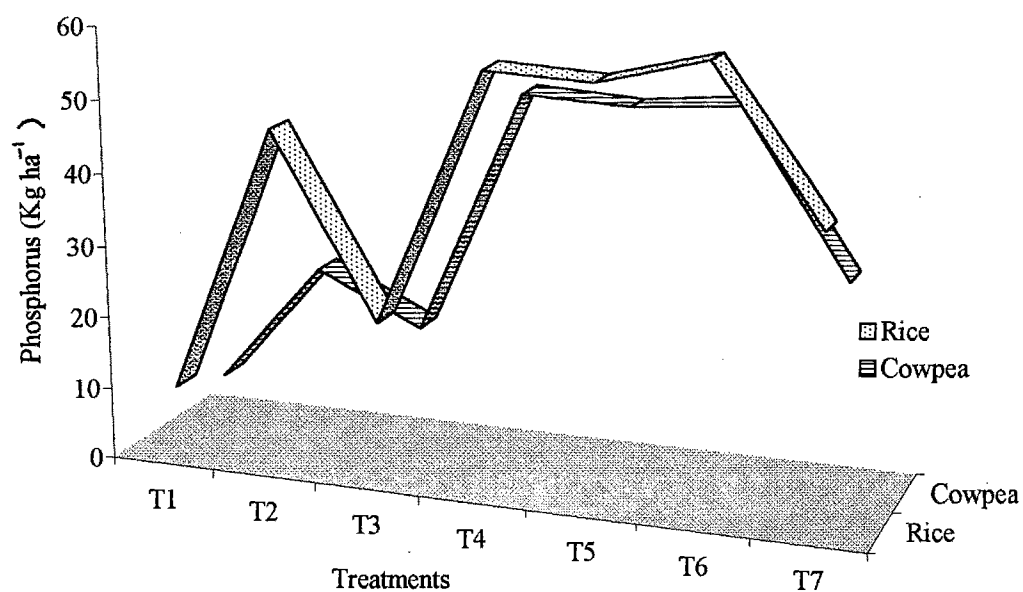


Fig.13: Available phosphorus of the soil as influenced by organic manure and fertilizers in Rice based cropping system

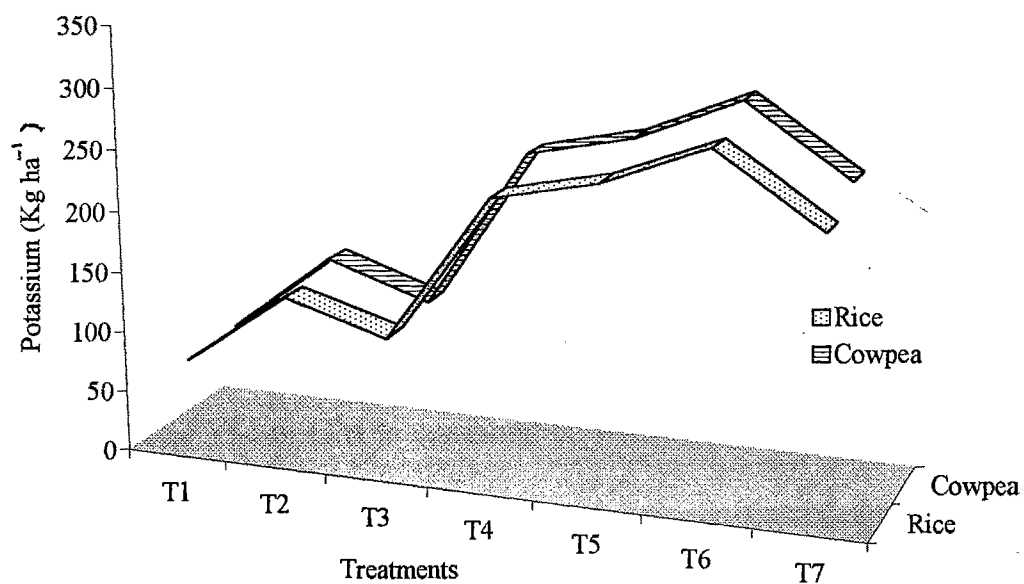


Fig.14: Available potassium of the soil as influenced by organic manure and fertilizers in Rice based cropping system

alone. The appreciable buildup in available phosphorus status in plots which received fertilizers plus organic manures might be attributed to the influence of organic manure in increasing the labile phosphorus in soil from complexing of cations like Ca^{2+} and Mg^{2+} which are mainly responsible for fixation of phosphorus. Similar results were also reported by Subramanian and Kumaraswamy (1989), Hundal and Thind (1993), Kumar and Yadav (1993), Prasad *et al.* (1996), Basumantary and Talukdar (1998). The amount of phosphorus was remarkably higher after harvest of rice and relatively lower after harvest of cowpea. The reason being that only 20–25 per cent applied P becomes available to the immediate crop and rest adds to soil pool which lead to increase the available P status of soil after harvest of rice crop. The pooled P was efficiently utilized by succeeding cowpea crop that lead to reduction in its quantity after cowpea. This is in agreement with observations of Indulkar and Malewar (1990), Saud and Thakuria (1994) and Narayana Reddy and Krishnaiah (1999).

5.3.4 Available potassium

The available potassium significantly increased in the plots, which received FYM or GM in combination with fertilizers as compared to fertilizers alone and was depleted in case of fertilizers and control treatments for the last 11 years of study.

FYM or Dhaiancha in conjunction with fertilizer increased the available potassium due to the direct addition of potassium to the available

pool of the soil (Fig.14). The beneficial effect of FYM and Dhaiancha on the available potassium might be ascribed to the reduction of potassium fixation and release of potassium due to the interaction of organic matter with clay (Tandon, 1988). Increase in available potassium was due to increase in CEC as a result of FYM or GM addition, which in turn increased the proportion of soil K present as exchangeable K. This is in agreement with the findings of Acharya *et al.* (1988), Agarwal *et al.* (1993), Bharadwaj and Omanwar (1994), Verma and Nand-Ram (1994) and Bhagavathiammal and Muthaiah (1996). Over the years of study low content of available potassium was noticed in the control was probably due to the continuous depletion of K by crop uptake. This is in conformity with the findings of Prasad *et al.* (1996).

The reason for marginal increase in available K content after the harvest of cowpea irrespective of treatments might be attributed to minimum leaching loss compared to submerged condition and low uptake of K by the succeeding crop in comparison to the previous rice crop. Recycling of nutrients by deep rooted cowpea crop from the deeper layer of soil and also due to continuous addition of K through mineralization of crop residues over the years might have enhanced the K content. This is in conformity with findings of Narayana Reddy and Krishnaiah (1999).

5.3.5 Exchangeable calcium

Application of FYM alone or FYM and GM in combination with chemical fertilizers recorded significantly higher calcium content than the chemical treatments. The reason for reduction of exchangeable calcium content of the soil in the chemical fertilizer treated plots could be due to removal of calcium by the crops at quantities greater than that was added from external sources to the soil (Fig.15). Yadhuvanshi *et al.* (1985) and Lal *et al.* (1990) have also reported a decline in exchangeable calcium content of the soil in the plots that received only chemical fertilizers. FYM and GM being an additional source of calcium would increase the exchangeable calcium content of the soil upon their decomposition over chemical fertilizers. This is in agreement with the findings of Prasad *et al.* (1996) and Basumatary and Talukdar (1999).

An increase of exchangeable calcium was noticed after harvest of cowpea compared to rice crop in all the treatments and amount of exchangeable calcium was still higher in FYM treated plots. The deep rooted legume crops recycle nutrients like Ca and Mg from deeper layers of soil and attributes for higher exchangeable calcium after pulse crop. This is in accordance with the findings of Narayana Reddy and Krishnaiah (1999).

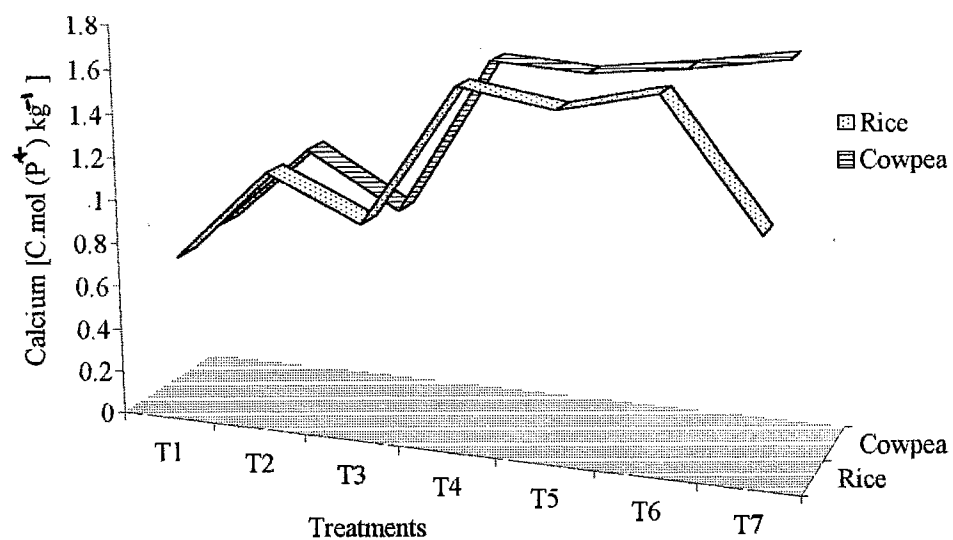


Fig.15: Exchangeable calcium content of the soil as influenced by INM practices in Rice based cropping system

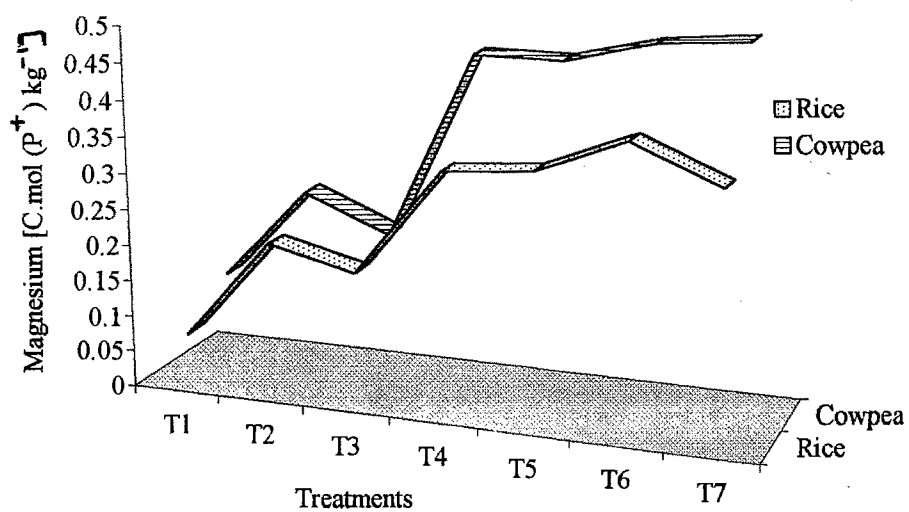


Fig.16: Exchangeable magnesium content of the soil as influenced by INM practices in Rice based cropping system

5.3.6 Exchangeable magnesium

Long-term cropping of a soil could considerably reduce its exchangeable magnesium reserve, if the nutrient is not supplied from external sources. This was evident from the present study, where exchangeable Mg content was found to be significantly lower in plots subjected to only NPK fertilizers in comparison to the plots treated with FYM alone or FYM and Dhaiancha combination of fertilizer plots (Fig.16). FYM has been reported to be a fairly good source of Mg and contribute substantial amounts of Mg to the soil upon its decomposition. These are in accordance with the observations of Lal *et al.* (1990), Prasad *et al.* (1996) and Basumantary and Talukdar (1999).

5.3.7 Available sulphur

Long-term continuous application of organic sources in combination with 50 per cent NPK fertilizers increased the available sulphur over control and 50 per cent NPK fertilizer treated plots. There are reports (Kavallappa, 1989 and Lal and Mathur, 1992) that the addition of sulphur containing fertilizers, FYM and GM to the soil, would substantially increase the available sulphur content of the soil (Fig.12).

Relatively higher contents of soil available sulphur was noticed after the harvest of cowpea in all the treatments and the values were significantly higher in the treatments which received FYM or Dhaiancha in combination with 50 per cent NPK fertilizer treatments. This

might be due to conversion of sulphide form formed under reduced condition of submergence (*kharif* rice) to sulphate form under oxidised condition in aerobic phase (cowpea summer). The increase in sulphur was also due to FYM or Dhiancha which directly added sulphur to the available pool of soil and because of the fact that leaching loss of sulphur is minimum during summer as compared to submerged condition in *kharif* season.

5.3.8 DTPA-extractable micronutrients

The dramatic increase in food grain production was mainly a result of intensification of agriculture rather than a contribution from the marginal increase in area. With intensification of agriculture, the soils have been depleted of all the nutrients, including micronutrients. Infact, the reports on micronutrient deficiency increased since the late 1960s following the introduction of modern crop varieties. At that time, intensive cultivation necessitated increased dependence on chemical fertilizers with the accompaniment of decreasing emphasis on the use of organic manures. With these changes in fertilization practises the past inadvertent accessions of micronutrients ceased. The deficiency problem was also aggravated by the high demand of modern crop varieties for micronutrients.

Deficiencies of micronutrient elements have been reported from many parts of India wherever intensive cropping is practised with only high analysis fertilizers. Lal and Mathur (1989) observed decrease in available zinc in the soil due to continuous cultivation. However, available

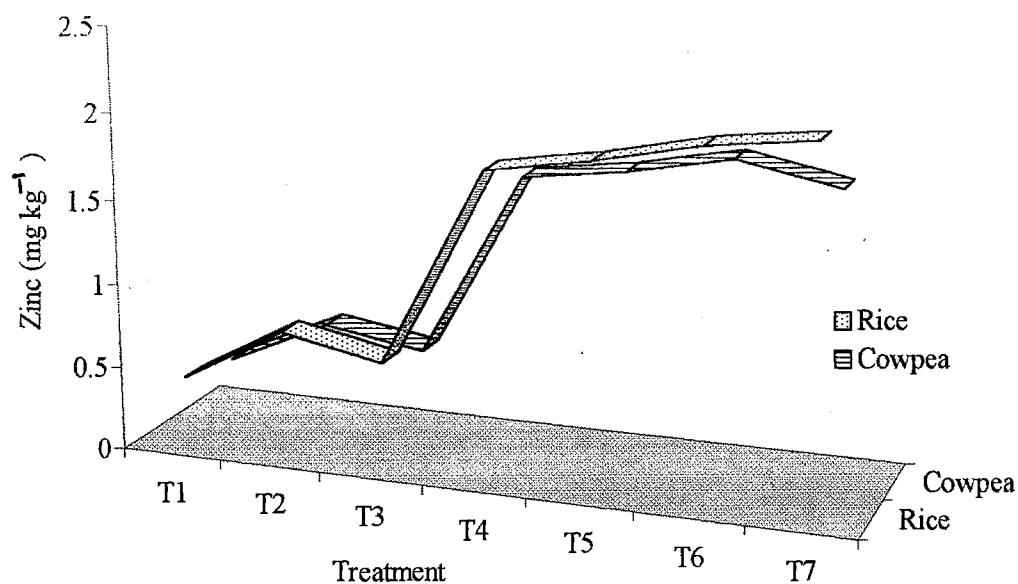


Fig.17: DTPA-Zn content of the soil as influenced by INM practices under Rice based cropping system

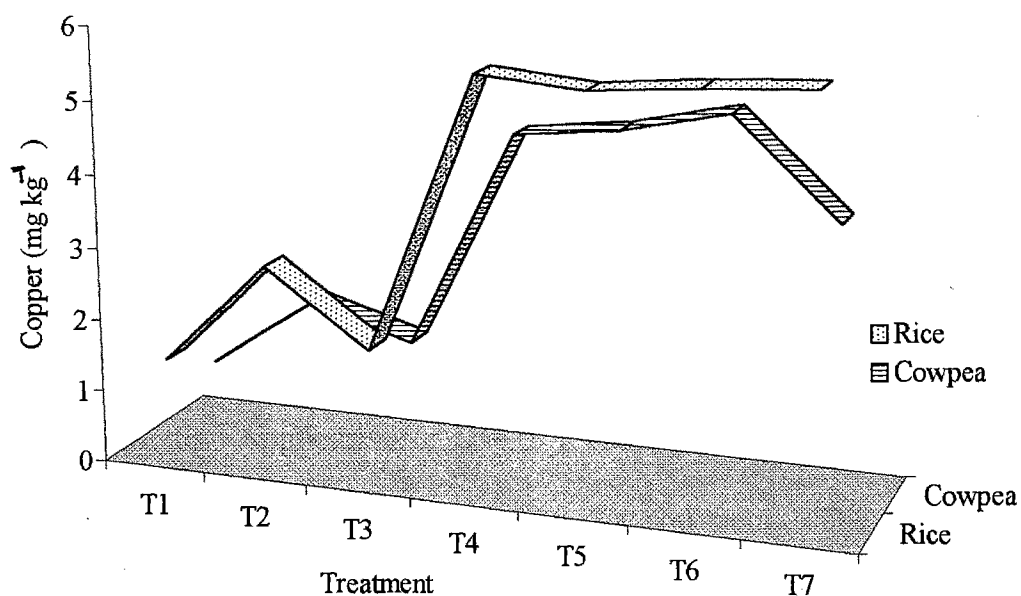


Fig.18: DTPA-Cu content of the soil as influenced by INM practices under Rice based cropping system

evidence suggested that balanced application of fertilizer did not impair the productivity of soil even under continuous cropping (Pillai *et al.*, 1987 and Kabeerathuma *et al.*, 1993).

DTPA extractable Zn, Cu, Mn and Fe of the long-term cropping were found to be highest in FYM or GM treated plots along with fertilizers (Fig.17 to 20). The DTPA Zn, Cu, Mn was highest in FYM treated plots followed by treatments 50 per cent NPK + 25 per cent N--GM +25 per cent N--FYM, 50 per cent NPK + 50 per cent N--FYM and 50 per cent NPK + 50 per cent N--GM plots and were significantly superior over plots supplied with chemical fertilizers. Lowest value was recorded in the control. Addition of organic manures or green manures along with fertilizers have increased the organic matter content of the soil as observed in the present study and have enhanced the microbial activity in the soil, consequently, the release of complex organic substances (chelating agents) were known to form stable complexes with organic ligands which decreased the susceptibility to precipitation, fixation, oxidation and leaching of micronutrients. Application of GM or FYM was also an additional source of micronutrients, which was added to the soil pool. The plots, which received only chemical fertilizer and control treatments showed lower value of micronutrients, due to low organic matter content in these plots. These results are in conformity with findings of Deepak Kher (1993), Kabeerthuma *et al.* (1993) and Rajeev Kumar *et al.* (1993).

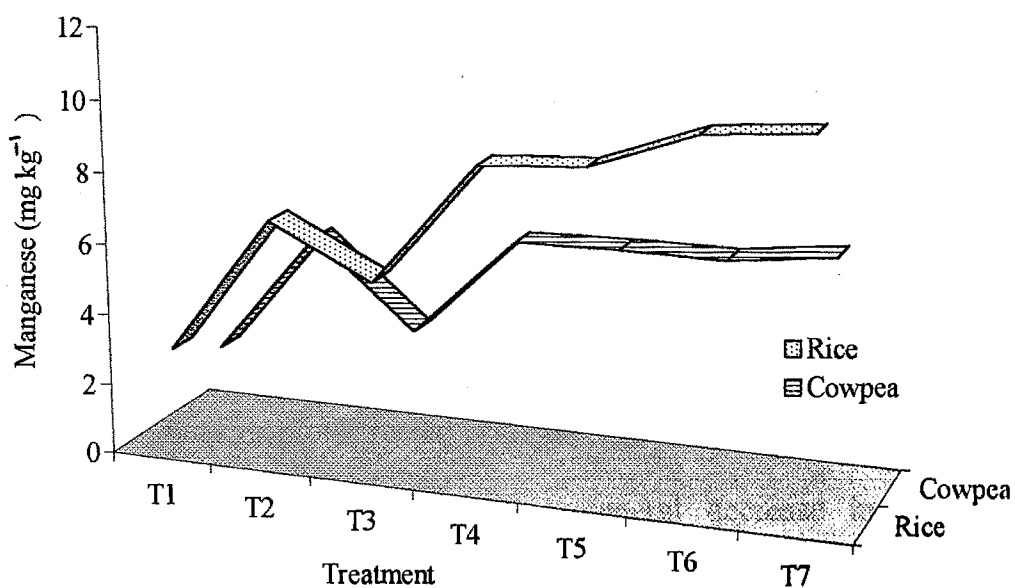


Fig.19: DTPA-Mn content of the soil as influenced by INM practices under Rice based cropping system

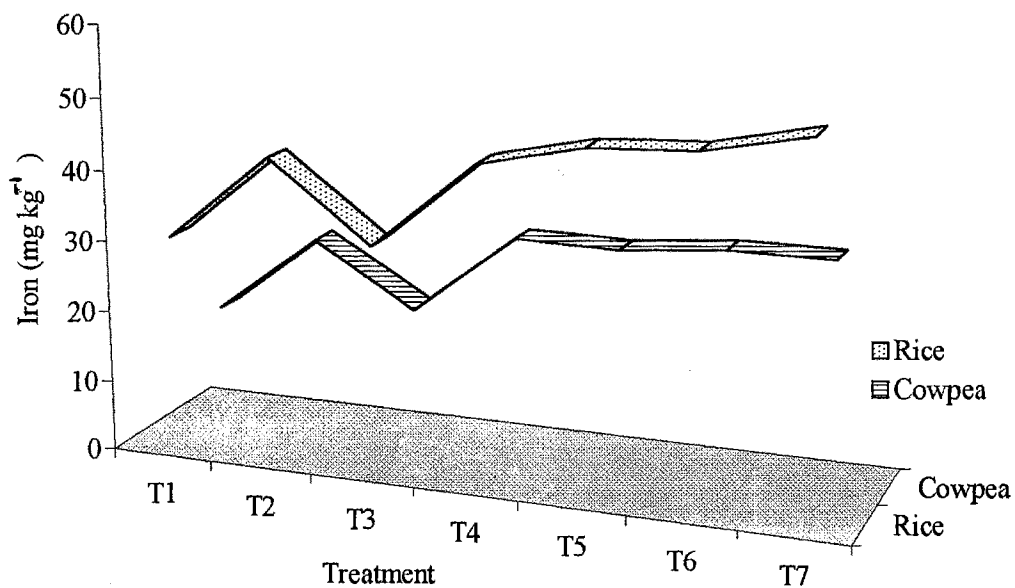


Fig.20: DTPA-Fe content of the soil as influenced by INM practices under Rice based cropping system

The substantial decrease in the available micronutrients was noticed after harvest of cowpea crop as compared to rice crop. This is attributed to utilisation of available micronutrients by the succeeding pulse crop grown on residual fertility. This is also in agreement with the findings of Indulkar and Malewar (1990). In general, a lower available Zn, Cu, Mn and Fe contents were observed in plots treated with fertilizer as well as in control plots than in plots treated with the organic materials. Bharadwaj and Omanwar (1994) also observed a general decrease in status of micronutrients in fertilized as well as unfertilized plots.

5.4 MICROBIAL STUDIES

5.4.1 Microbial Biomass carbon

Microbial biomass refers to the labile fraction of soil organic matter that constitute living microorganisms smaller than 5 to 10 μm^3 . It is generally expressed in milligrams of carbon per kilogram of soil or microgram of carbon per unit dry weight of soil. Microbial biomass carbon content in soil is an index of soil microbial activity. The activities of soil microorganisms play a major role in nutrient recycling, organic matter decomposition and turn over (Biederbeck *et al.*, 1984).

In the present investigation, microbial biomass carbon content in soil was found to be significantly higher in plots that received organic nutrient sources along with chemical fertilizers than chemical fertilizer treatments alone (Fig.21 & 22). The reason for increased microbial biomass

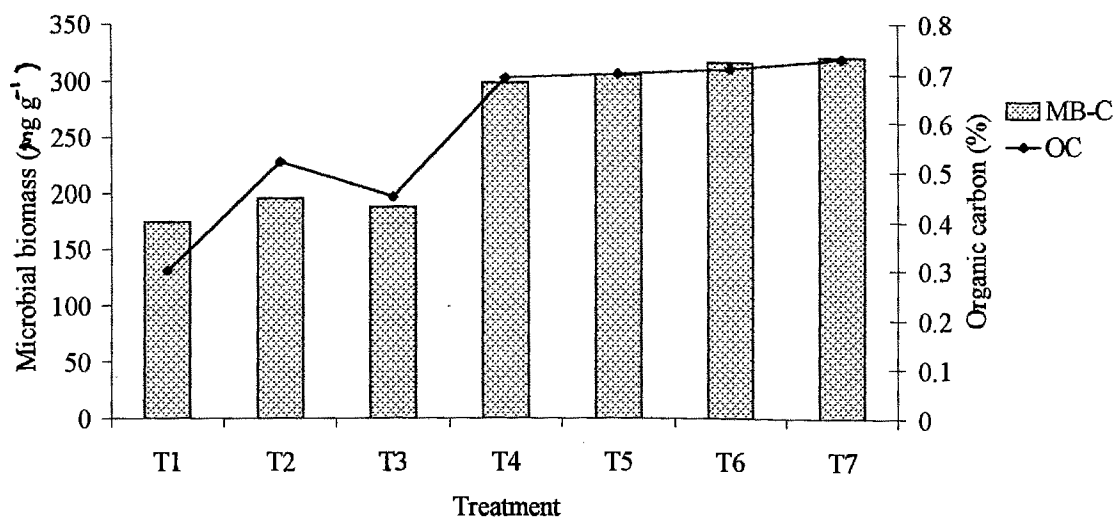


Fig.21: Relationship between organic carbon and microbial biomass carbon due to INM treatments under Rice

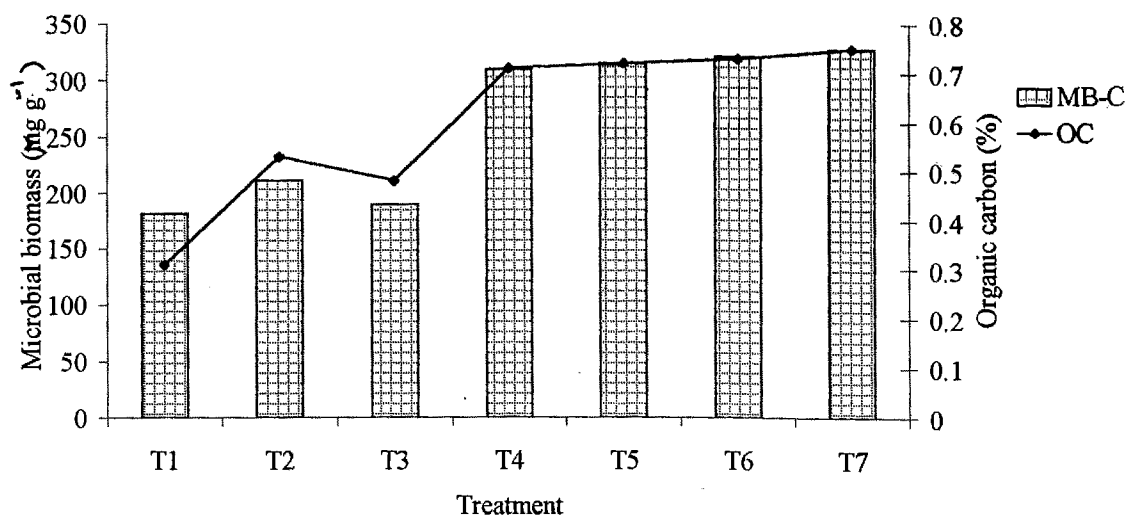


Fig.22: Relationship between organic carbon and microbial biomass carbon due to INM treatments under Cowpea

carbon was due to increasing organic carbon status of the soil by long term incorporation of FYM or Dhaiancha over the years. These results are in agreement with the reports of Kamalesh *et al.* (1991). Collins *et al.* (1992) have also reported that the microbial activity is closely related to the soil organic matter content which is positively affected by organic matter amendments such as crop residues.

An increase in microbial biomass carbon content of soil was observed with increased concentration of nutrients and organic matter as noticed in this study. Kavallappa (1989) also reported that the results were similar to the one being reported here.

Microbial biomass carbon in soils was relatively higher after harvest of cowpea crops as compared to rice crop. The reason being organic matter was marginally higher after harvest of cowpea crop, where increase in organic matter content of soil is a good source of carbon and nutrients, which favoured congenial atmosphere for proliferation of microorganisms. In addition to this, rhizosphere root exudates of cowpea crop also rendered as a good source of substrate for microbial multiplication.

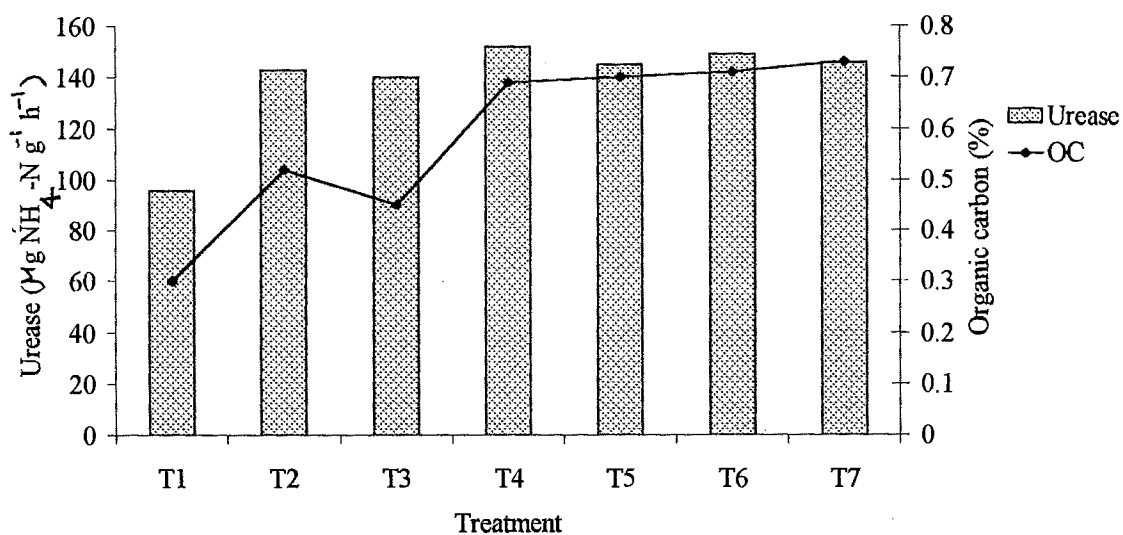


Fig.23: Relationship between organic carbon and Urease activity due to INM treatments under Rice

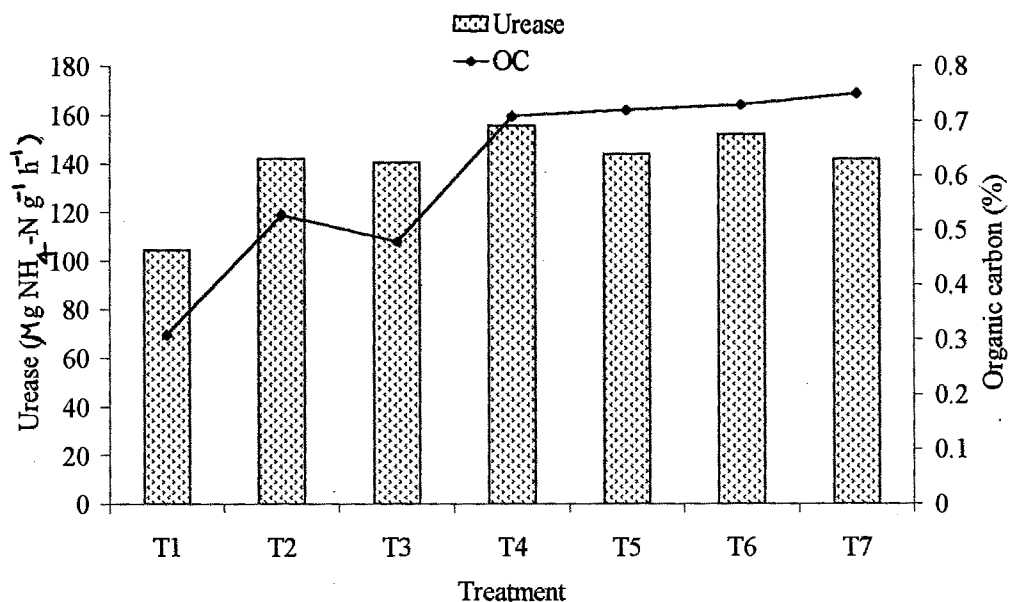


Fig.24: Relationship between organic carbon and Urease activity due to INM treatments under Cowpea

5.4.2 Urease activity

It was noticed that urease activity was higher in the plot that received 50 per cent NPK + 50 per cent N--GM followed by 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM, 50 per cent NPK + 50 per cent N--FYM and FYM alone @ 10 t ha⁻¹ and were superior over chemical fertilizer application (Fig.23 & 24). This could be attributed to their higher N content and faster decomposition and release of NH₄-N. This is in agreement with reports of Singaram and Kamala Kumari (1995) and Sriramachandrasekharan *et al.* (1997) and Chandrasekar Rao and Saroja (2000).

5.4.3 Dehydrogenase activity

Significantly higher dehydrogenase activity was recorded in the soil due to combined effect of organic and inorganic fertilizer compared to chemical fertilizer treatment (Fig.25 & 26). The population of soil microbes was triggered by the addition of organic manures through FYM or Dhaiancha and chemical fertilizers and consequently increased the dehydrogenase activity in the soil. Similar findings were reported by Singaram and Kamala Kumari (1995) and Sriramachandrasekharan *et al.* (1997).

Urease and dehydrogenase activities were recorded higher after the harvest of cowpea as compared to rice crop. This might be attributed to increase in organic carbon and available nitrogen of soil as noticed in the present study, which had encouraged higher enzyme

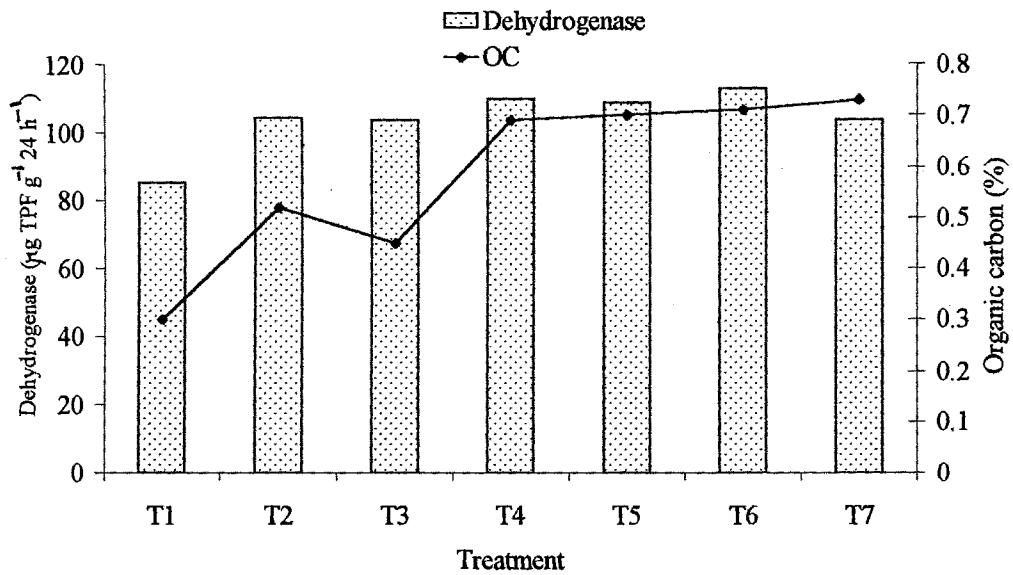


Fig.25: Relationship between organic carbon and Dehydrogenase activity due to INM treatments under Rice

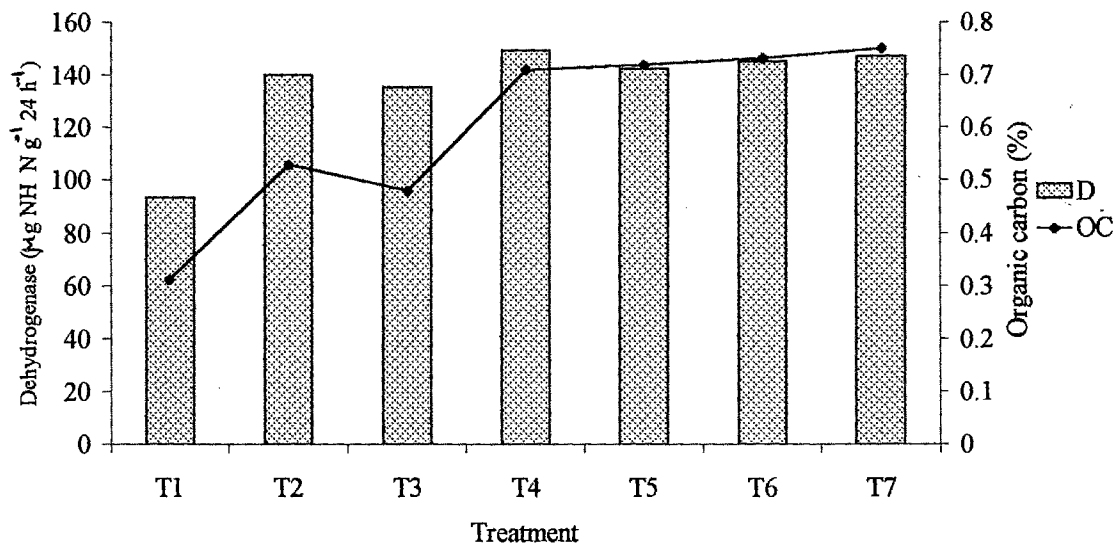


Fig.26: Relationship between organic carbon and dehydrogenase activity due to INM treatments under Cowpea

activities. In addition to this, deep root system of cowpea rhizosphere has been known to be good substrate for microbial proliferation and consequently increased the enzyme activities. This is in conformity with the findings of Chandrasekhar Rao and Saroja (2000).

5.4.4 Acid phosphatase activity

The conversion of organic P into inorganic P was mainly brought about and governed by phosphatase activity. Further, it is dependent on pH, organic matter and available P status of the soil.

The phosphatase activity was maximum again due to conjunctive use of organic and inorganic nutrients as compared with only chemical fertilizers. The control recorded lowest phosphatase activity compared to other treatments (Fig.27 & 28). These results are in conformity with the findings of Kavallappa (1989), Singaram and Kamala Kumari (1995) and Sriramachandrasekharan *et al.* (1997).

It is quite natural that the activities of enzymes would increase with the creation of favourable condition in the soil for the growth and multiplication of microorganisms. Application of organic sources have been reported to bring an ideal condition for the growth and multiplication of various kinds of microbes (Halstead and Sowden, 1986). The activity of phosphatase enzyme in the soil of present study decreased with the application of chemical NPK fertilizers. It is reported by Singaram and Kamalakumari (1995) that low activity of phosphatase was observed with

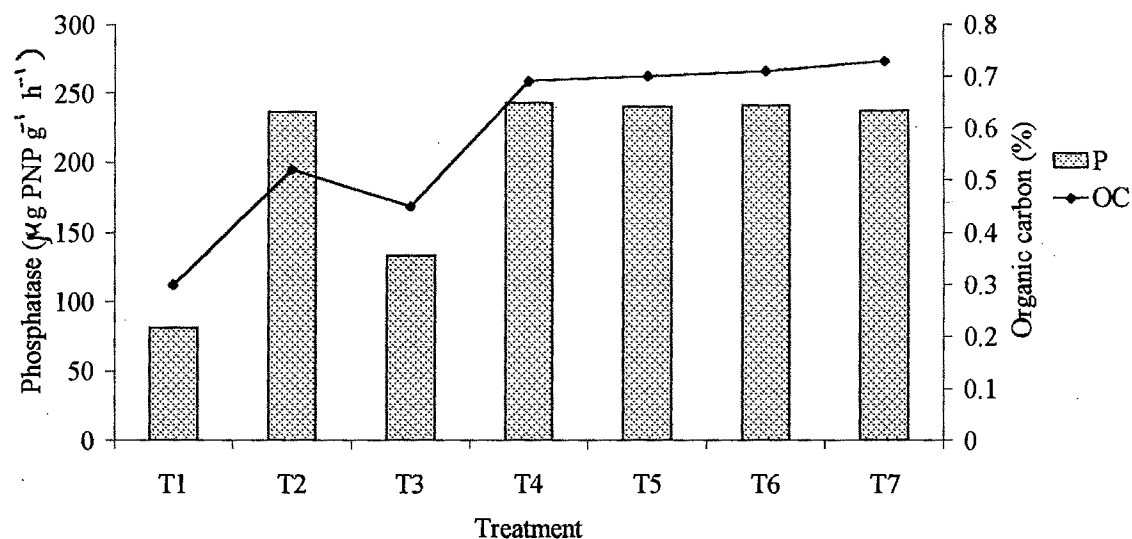


Fig.27: Relationship between organic carbon and phosphatase activity due to INM treatments under Rice

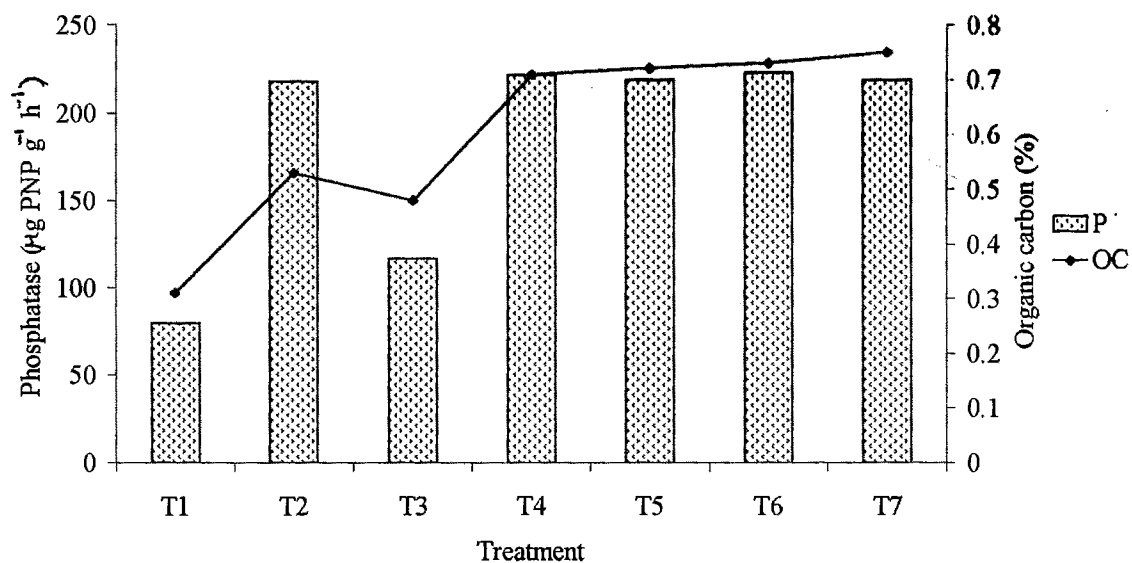


Fig.28: Relationship between organic carbon and phosphatase activity due to INM treatments under Cowpea

increased doses of NPK fertilizers. This might be due to the fact that readily available forms of phosphorus in the soil hindered the activity of microorganisms responsible for the phosphatase activity by catabolic repression (Juma and Tabatabai, 1978).

5.5 GROWTH AND YIELD ATTRIBUTES

The yield attributes viz., plant height, number of tillers per panicle, panicle per m², number of grains per panicle and 1000 grain weight recorded highest in the treatment 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM followed by 50 per cent NPK + 50 per cent N--FYM, 50 per cent NPK + 50 per cent N--GM and was superior over addition of chemical fertilizer and control which recorded lower values. This was attributed to the fact that there was a buildup of organic matter in these treatments, which might have enhanced the productivity and efficiency of nutrients for optimum plant growth (Mondal *et al.*, 1994). Incorporation of GM along with applied fertilizer nitrogen might have increased the availability of N throughout the growth period increasing the growth and yield attributes of rice crop. This is in agreement with the findings of Solaiappan and Veerabadran (1997).

In contrast to rice yield parameters, the cowpea yield parameters have recorded higher value in treatment given only with FYM @ 10 t ha⁻¹ over other treatments. The yield parameters viz., number of nodules per plant, number of pods per plant, pods weight per plant, length

of pods and 1000 grains weight of cowpea seeds were recorded at on par with organic + inorganic treatments and were significantly superior over chemical fertilizer alone. The reason for the highest being the cowpea growth parameters in FYM alone plots might be attributed to higher organic carbon content in the soil, improvement in bulk density, increase in porosity, infiltration rate, water stable segregates and increase in water holding capacity of the soil. All these had synergistic effect and enhanced productivity and efficiency of nutrients for better growth of the cowpea crop. This is in agreement with reports of Mondal *et al.* (1994), Solaiappan and Veerabadran (1997), Mastan *et al.* (1998) and Dubey and Verma (1999).

5.6 GRAIN YIELD AND NUTRIENTS UPTAKE BY RICE AND COWPEA CROPS

The 11th year of continuous cropping with combined application of organic manure and fertilizer plots had recorded higher grain and straw yield of rice compared to chemical fertilizers (Fig.29). The control recorded a lowest value among all the treatments. The reason for higher yield could be attributed to the increased contents of available forms of most of the nutrient elements in the soil as well as to the increased supply of nutrient elements from the applied sources over the years, viz., fertilizer, GM and FYM. Beneficial effect of organic matter on the soil physical, chemical, microbial and biochemical properties and in turn on the yields of crop. Jaggi (1991) and Black (1993), Bharadwaj *et al.* (1994), Chitdeswari

et al. (1997) and Jagadeeswari and Kumaraswamy (2000) also reported results similar to the present study.

Though quantity of nutrients added through 100 per cent NPK fertilizer was higher than from FYM and GM, the organic sources were superior. This was due to the complementary effects of organics in plant nutrients availability. Organics were beneficial in that they reduced fixation or precipitation with those of soil components of added or mineralized nutrients and played complementary role to boost the crop yield. This is in agreement with the findings of Deepak Kher (1993), Kabeerthuma *et al.* (1993), Rajeev Kumar *et al.* (1993), Bharadwaj and Omanwar (1994), Gill *et al.* (1994), Bagavathiammal (1997) and Chitdeswari *et al.* (1997). Combined application of fertilizer and GM indicated that GM could substitute 50 per cent urea-N. Combination of GM with urea was of the added advantage due to continuous supply of nitrogen initially from GM and thereafter from applied urea-N. Combined application of FYM with urea on an equivalent basis also proved superior with application of NPK fertilizers. These are in conformity with the reports of (Chitra *et al.*, 1999), Singh *et al.* (1999) and Milka *et al.* (2000).

Continuous growing of cowpea crop on residues of organic manure and fertilizers had shown that the treatment which received only FYM @ 10 t ha⁻¹ recorded the highest grain and stover yield followed by 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM, 50 per cent

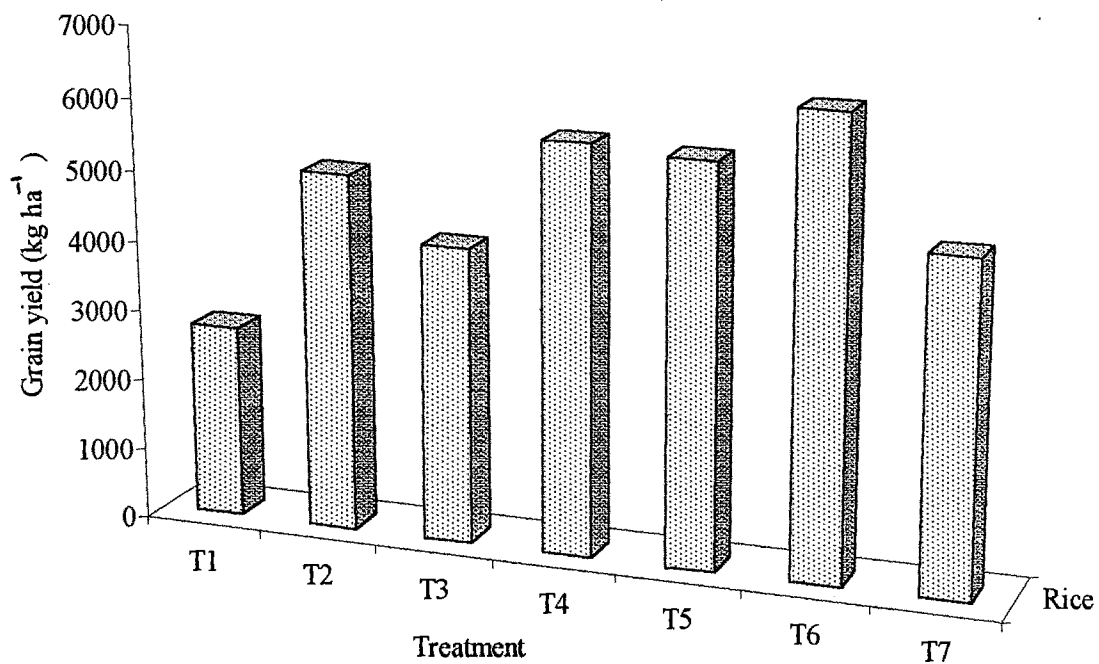


Fig.29: Grain yield of rice as influenced by organic manure and fertilizers in Rice based cropping system

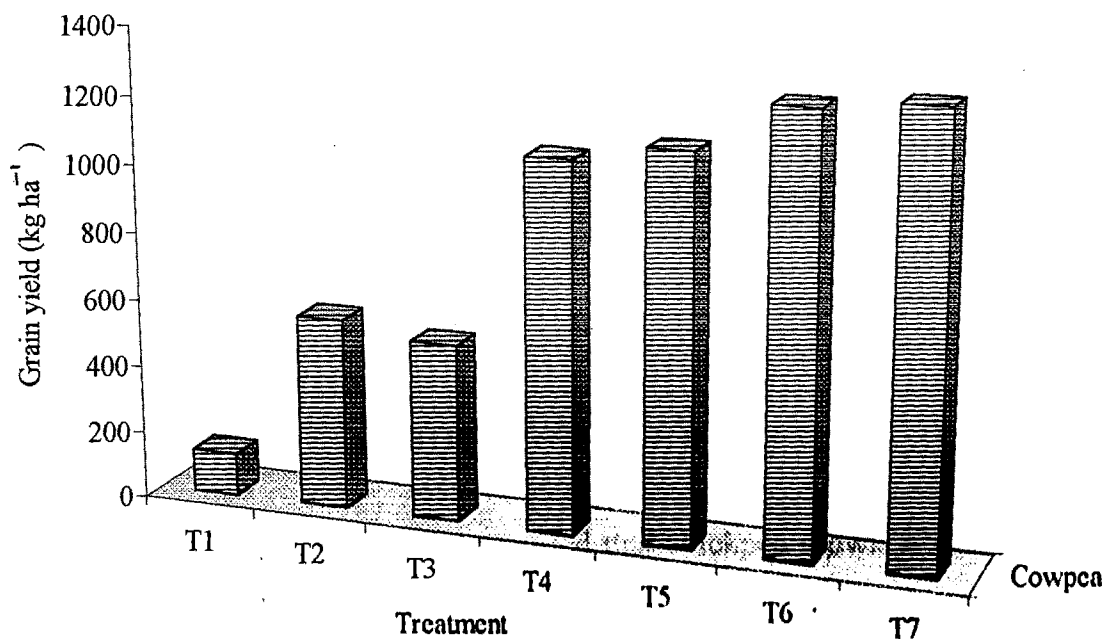


Fig.30: Grain yield of cowpea as influenced by organic manure and fertilizers in Rice based cropping system

NPK + 50 per cent N--FYM and 50 per cent NPK + 50 per cent N--GM.

The plots treated with only chemical fertilizers have recorded non significant values over organic manure and NPK fertilizers. Control recorded the lowest value among all the treatments (Fig.30).

Growing cowpea as a residual crop, its N requirement was met by BNF as the crop is leguminous and nitrogen fixation process began to start within few weeks after germination. It was also observed that cowpea with limited root system in the early stages had to depend mainly on residual P left by rice crop. As the crop growth progressed, the root depth increased appreciably and in some cases, it was noted that it goes as deep as more than one meter. Pulse crops are known to exude citric acid in large amounts. This secreted from the roots in turn made availability of P for crop from the insoluble P sources from deeper layers of soil. From the above mechanism some of which would be left behind through its root residues in the soil. Rice crop with its shallow root system was benefited from the increased P supply brought about by pulse rotation. This is in agreement with reports of Narayana Reddy and Surekha (1998).

Singh *et al.* (1999) reported that chickpea grown after harvest of rice responded favourably to the residual effect of various treatments applied to rice. Chickpea yield was maximum due to residual effect of treatments, FYM + urea followed by rice straw + urea. This could be attributed to increased organic matter and available residual N as well as

improved soil physical condition which indicated that for realizing desired level of yield of both *kharif* and *rabi* crops, organic manuring once a year along with chemical fertilizer to both the crops was essential. Similar results were also observed in the present study. Dubey and Verma (1999) also noticed that application of FYM and poultry manure combined with 50 per cent NPK had significant residual effect on pod yield of cowpea over chemical fertilizer alone.

5.6.1 Uptake of nutrients by rice crop

Uptake of nutrients by rice grain and straw has been worked out as the product of yield of grain and straw and their composition for respective element. By and large, nutrients uptake pattern has followed the trend observed in grain and straw yield.

Plots continuously received organic manures viz., Dhaincha or FYM in combination with 50 per cent NPK fertilizers have recorded maximum uptake of N, P, K, Ca, Mg and S as compared to 100 per cent NPK fertilizers. Application of organic manure in conjunction with reduced recommended dose of N, P, K fertilizers appeared to be more remunerative than application of 100 per cent fertilizers. It might be due to the fact that organic matter increased the efficiency of applied NPK fertilizers. The results on uptake of N, P and K by grain and straw showed that a manure-fertilizer schedule with either addition of FYM or green manure with N, P, K fertilizers would maximize the uptake of nutrients than the application of

fertilizer alone. This is in accordance with the findings of Bharadwaj *et al.* (1994) and Jagadeswari and Kumaraswamy (2000).

Uptake of micronutrients (Zn, Cu, Mn and Fe) by grain and straw of rice crop was also maximum in the treatment due to continuous application of organic and inorganics combination and were superior over 100 per cent recommended NPK fertilizer treatment. Continuous cropping without manures or fertilizers (control) depleted the micronutrients to the lowest value among all the treatments. The trend in uptake of nutrients was lowest in the plots received no fertilizer or manure treatment since the initiation of the experiment. This clearly indicated that continuous cropping without fertilization caused the lowest uptake of nutrients as compared to fertilized and manured plots. The lower uptake of nutrients in control plots was because of lower yields obtained in these plots due to low soil fertility status. The plots treated with organic sources showed the higher uptake of all the nutrients, indicating thereby that addition of FYM or GM along with NPK fertilizers increased the uptake of nutrients to a greater extent. The increase in uptake of the nutrients in the FYM or GM treated plots might be attributed to the extra amount of nutrients supplied by the FYM and GM which influenced to increase the yield and ultimately showed higher uptake of nutrients. This is in agreement with the findings of Kumar and Yadav (1993) and Bharadwaj *et al.* (1994).

5.6.2 Uptake of nutrients by residual cowpea crop

Residual effect of long term application of FYM or GM along with NPK fertilizers have resulted in significantly higher uptake of nutrients compared to control. The maximum uptake of nutrients was noticed in the plot given with FYM alone followed by other combined effect of organic and inorganic fertilizer. Incorporation of organic sources annually over the years have improved soil physical properties and fertility status of the soil which inturn had enhanced the efficiency of residual nutrients. Cumulative effect of nutrient built up over the years had influenced uptake of nutrients in the combined use of organic and inorganic fertilizer plots.

It was also noticed that N contributed by legume GM crops could be from BNF and $\text{NO}_3\text{-N}$ formed in the soil during aerobic phase in summer (catch crop). $\text{NO}_3\text{-N}$ accumulated in early stages in fact served as reserve dose and it helped to increase BNF capacity in later stages and might had influenced the uptake by cowpea grain and straw. This is in agreement with findings of Narayana Reddy and Krishnaiah (1999) where they reported that one tonne of organic manure on an average supplied about 5–8 kg N and K and 2 kg of P. Further, they stated that about one third of total N, half of the total P were available to the first crop and rest of N and P are available to the succeeding crops (residual effect).

Crop residues like rice straw comprised of 0.5 per cent N, 0.1 per cent P and 1.5 per cent K and unharvested root stubbles left over after rice was roughly estimated to be 10 per cent of total biomass and one tonne

of crop residue left behind supplied about 5 kg N, 1 kg P and 15 kg K. In this pattern the nutrients were added to residual pool of the soil which might have enhanced the uptake of nutrients due to integrated application of organic manure and fertilizers (Narayana Reddy and Krishnaiah, 1999).

Significantly higher uptake of N, P, K, Fe, Mn, Cu and Zn was recorded in the plots given with organic + inorganic nutrients continuously over the years and in plots which were continuously cropped without fertilizer and manures lead to decline in yields and ultimately recorded lowest uptake of nutrients. Similar trend has been observed by Bharadwaj *et al.* (1994).

Calcium (1.42 and 0.56%), Magnesium (0.94 and 0.25%) and Sulphur (0.42 and 0.78%) were the additional source of nutrients contributed by FYM and Dhaincha incorporation into soil over the years which might have improved the uptake of Ca, Mg and S in the combined effect of organic and inorganic treatments compared to only use of chemical fertilizer treatments. Similar findings are reported by Basumantary and Talukdar (1999).

Uptake of nutrients by residual cowpea was higher in the treatments provided with a combination of organic + inorganic fertilizers compared to NPK fertilizer treatment alone. Contribution of nutrients for a second crop which is a leguminous one could be from biological nitrogen

fixation, release of acidic root exudates combined with increased root length and density influenced the absorption of nutrients by cowpea crop. Hence, higher uptake of nutrients was observed in cowpea by following integrated nutrient management practices. Similar results were obtained by Narayana Reddy and Surekha (1998).

5.6.3 Balance of nutrients due to long term application of organic and inorganic nutrients in rice based cropping system

It was significant to observe that treatments which received the combination of organics + inorganics (T_6 , T_5 and T_4) have recorded higher N balance of 121.30, 110.30 and 109.00 kg ha⁻¹, respectively compared to the treatments, which received only chemical fertilizers (T_2 – 25.3 and T_3 – 38.8 kg ha⁻¹) and organics (T_7 – 39 kg ha⁻¹) or no manure (T_1 – 30.3 kg ha⁻¹) treatments.

Among the treatments having INM practices, the treatment (T_6) which had inorganics and both the forms of organics (GM + FYM) recorded the higher value 121.30 kg ha⁻¹. This clearly indicated that INM practice gave higher yield and also left higher N at the end of rice-cowpea crop sequence.

This enhanced N balance could be due to improvement in physical, chemical and biochemical properties. Incorporation of only organics (T_7) resulted in less N balance probably due to reduced dosage of N supply. Similar trend was obtained due to addition of 50 per cent NPK (T_3) without

addition of organic matter. This suggested that mere application of only organics or inorganics would not fetch good yield and also leave adequate nutrients after the rice-cowpea cropping sequence. Hence, it is necessary to balance nutrients required through the addition of both organic and inorganic nutrients.

It was interesting to note that the treatment which received 100 per cent NPK (T_2) resulted in the lowest N balance (23.3 kg ha^{-1}) that was lower than even the control treatment (30.30 kg ha^{-1}). Addition of entire nutrients only through inorganic source continuously over years led to the deterioration of soil structure and also affected microbial activities which might have induced more leaching losses of N.

Integration of organic + inorganics (T_6 , T_7 and T_4) resulted in higher P balance compared to control (T_1) and 50 per cent NPK (T_3), while negative P balance was observed in 100 per cent NPK treatment. This higher P balance under integration of nutrients management system could be due to high organic matter content which on decomposition released the acidic and hydroxyl groups and could have helped to reduce precipitation of applied and native P from potentially active ions like Fe, Al and Ca, thereby, resulted in higher P balance. Negative P balance in the treatment having nutrients in inorganic form only could be due to the reduction of pH that led to precipitation of P with Fe, Al and Ca and reduced the concentration of soluble

P. In addition, relatively higher yield encouraged more uptake and ultimately less P was left over at the end of the crop period.

Further, addition of 50 per cent NPK also resulted in low P balance even compared to control. In this situation, addition of inorganics might have affected soil chemical and biochemical properties.

Low P balance observed in treatments 50 per cent NPK which clearly indicated the necessity of organic sources of nutrients in addition to inorganic sources to attain the sustainable crop production.

Results indicated higher balance of potassium ($234.25 \text{ kg ha}^{-1}$) under treatments which received integrated nutrient management (T_6) practices (50% NPK + addition of 25% N each from GM and FYM) followed by ($205.10 \text{ kg ha}^{-1}$) the treatment which received FYM only (T_7). Higher K balance was probably due to higher biomass, higher organic matter, low K fixation, low leaching losses due to improvement in physical, chemical and biochemical properties.

Moderate level of K balance was observed in treatments which had 50 per cent NPK + organics in the form of FYM (T_4) or GM (T_5). Variation in the quantity of biomass resulted in medium level of K balance.

Lower K balance was observed wherever inorganics were applied (T_2 and T_3). Reduction in K balance could be mainly attributed to

deterioration of soil properties as a result of application of chemical fertilizers continuously over years. further, less organic matter coupled with low CEC and also due to leaching of K, lower K balance was observed.

Lowest K balance was observed in control treatment which received neither organic matter nor fertilizers over years due to low organic matter and poor physical, chemical as well as biochemical properties.

5.7 RELATIONSHIP BETWEEN SOIL PROPERTIES AND CROP YIELD

Contribution of independent variables could be significant or non-significant. The effects of many soil factors on crop yields are some times overlooked, which, however have been shown to have positive effect by statistical studies. Under the conditions prevailing in the soil during crop growth periods, the yields of crops which is the result of the interaction of several factors is found to be controlled by either one or few factors which are limiting in supply (Black, 1993). An attempt has been made here to interpret the results obtained based on the relationship of the yield of crops with different soil properties.

5.7.1 Relationship between yield of crops and soil physical and chemical properties

Grain yield of both the crops were found to be significantly and positively correlated with soil physical properties like infiltration rate,

maximum water holding capacity, porosity, and hydraulic conductivity. The bulk density of soil was significantly and negatively correlated with yield of the crops. Favourable influence of GM and FYM had improved the structural properties of the soil and consequently the crop yields. This is in conformity with the findings of Bharadwaj and Omanwar (1994), Singh *et al.* (1999) and Despande *et al.* (2000).

Crop yields also positively correlated with organic carbon, CEC and microbial biomass carbon and enzyme activities in the soil. This relationship clearly indicated the positive role played by the soil microorganisms in the release of nutrients from organic matter and organic colloids formed also improved the CEC of the soil and subsequently enhanced the uptake of nutrients by the crop during their growth period, thus, leading to higher yields. This is in conformity with the findings of Jaggi (1991) and Black (1993). Soil pH and EC of the soil are negatively correlated with yields because a decrease in pH leads to precipitation of available nutrients in the soil and due to decrease in EC, base saturation of the soil and availability of nutrients were reduced. Consequently, yields of the crops were also reduced as noticed in case of chemical fertilizer applied continuously over the years.

5.7.2 Relationship with various soil properties

Yield of both the crops exhibited a positive relationship with all the chemical properties viz., organic carbon, available nitrogen

phosphorus, potassium, sulphur and DTPA–Zn, Cu, Mn and Fe contents of the soil. This was due to complementary effect of organics in nutrient availability. Organics were beneficial in the reduction of fixation or precipitation with those of added or mineralised nutrients, which were complementary to boost the crop yields. This is in agreement with the findings of Katyal and Sharma (1991), Deepak Kher (1993), Kabeerthuma *et al.* (1993), Bharadwaj and Omanvar (1994), Gill *et al.* (1994) and Bagavathiammal (1997) and Chitdeswari and Krishnasamy (1997).

In the present study, soil organic matter was found to be strongly correlated with CEC, N, P, K, Ca, Mg, S and micronutrients. As the pH was maintained to neutral levels due to organic sources, chelating action of organic ligand from FYM and GM treated plots helped to buildup of micronutrients in the soil, which resulted in direct relationships between pH and DTPA micronutrients. DTPA–Mn showed negative relationships with pH of the soil probably due to increased solubility of insoluble Mn in the soil. These are in agreement with the reports of Lal and Mathur (1989), Brady (1990) and Katyal and Sharma (1991).

Positive correlation of organic carbon with available N is also a well known fact and the determination of organic carbon to indicate the available N status of the soil is widely followed. Similarly a better correlation of organic carbon with available P indicated its significant role

in mineralisation of native P. These findings are in conformity with the results obtained by Bharadwaj and Omanwar (1994).

Organic carbon content of the soil showed significant positive relationships with microbial biomass carbon, urease, dehydrogenase and phosphatase activities (Fig.21 to 28). The promotive effects of GM and FYM towards microbial growth and enzyme activities during crop growth period have also been reported by Singaram and Kamala Kumari (1995), Manna *et al.* (1996) and Sriramachandrasekharan *et al.* (1997).

5.8 SUSTAINABLE YIELD INDEX (SYI)

In traditional agricultural practises, the productivity of crops grown were not only low but almost stagnant. In these practices the minimum use of chemical fertilizers through adoption of organic manures would rejuvenate the soil fertility. Adopting appropriate crop rotations, which include legumes, is yet another means to maintain soil fertility. For resource – poor farmers' INM practises are sustainable in as much as they guarantee an harvest besides improving soil health.

Maximum SYI recorded with conjunctive use of organic and inorganic plots were mainly due to concomitant improvement in soil fertility by organic matter which might had supported the full potential of soil to sustain the crop yield. These observations are in conformity with the work reported by Singh *et al.* (1990) and Dubey and Verma (1999).

Incorporation of organic sources like GM or FYM along with fertilizers or application of FYM alone continuously over 11 years had demonstrated a maximum sustainable yield index value over application of only NPK fertilizers. The control recorded the lowest SYI value over rest of the treatments in both rice as well as residual cowpea crops.

5.9 ECONOMIC RETURNS

Treatments which received 50 per cent NPK + 50 per cent N through organic sources have recorded maximum net return over 100 per cent and 50 per cent NPK fertilizers and control due to rice and cowpea production. Combined application of organic manures along with reduced dose of NPK fertilizers had improved the soil fertility. Consequently, yield of rice and cowpea crops were increased, which ultimately helped in gaining the high net returns compared to use of only chemical fertilizers.

SUMMARY

VI. SUMMARY

A field trial was carried out to study the impact of long-term application of organic and inorganic fertilizers on changes in physical, chemical, microbial and biochemical properties of soils of Cauvery Command Area of Karnataka at the Regional Research Station, V.C.Farm, Mandya during 1999-2000. Rice-cowpea rotation is the cropping system, where rice was grown as the main crop during *kharif* which received various combinations of organic and inorganic fertilizers and cowpea crop was raised as residual summer crop with no incorporation of fertilizers and manure for over 11 years.

I. MONOCROPPING ON SOIL FERTILITY AND PRODUCTIVITY

Practise of monocropping like rice followed by rice continuously for many years' causes many adverse effects in the submerged rice eco-system. There are reports that due to monocropping, scope for growing *in situ* green manuring becomes a rare practice and external application of organic manures into the soil also become minimum, thereby causes low organic matter buildup in the soil. High dosage of chemical fertilizers into the soil also forms antagonistic effect on many soil nutrient reserves and emerges nutrient deficiencies in the soil. Further, continuous puddling of soil season after the season deteriorates the soil structure and

also reduces the microbial and biochemical activities in the soil, ultimately decline the rice yield.

With the background of alarming situation prevailed in the Cauvery Command Area, the present study was undertaken to study the impact of long-term practice of INM approach with rice–cowpea cropping rotation cropping system. The salient findings of different combinations of treatments and practises of the investigations are summarized as follows:

II. CEREAL-LEGUME CROP ROTATION ON SOIL FERTILITY AND PRODUCTIVITY

Crop rotation of rice followed by cowpea played an important role in improving physical, chemical, microbial and biochemical properties of the soil. They were as follows:

1. Bulk density of the soil was reduced after the harvest of cowpea compared to rice crop, which inturn improved the water stable aggregates, porosity, infiltration rate, maximum water holding capacity and hydraulic conductivity of the soil as they were significant and positively correlated over the other.
2. Organic carbon and cation exchange capacity of the soil exhibited a positive and significant correlation over each other. The values recorded were higher during summer cowpea as compared to *kharif* rice crop.

3. Available nitrogen observed was higher after harvest of cowpea as compared to rice crop, possibly due to BNF and extra addition of about 0.4 to 0.5 tonnes of biomass into the soil. In addition to these, cowpea is a deep rooted leguminous crop which is known to absorb the nitrate that was leached into the deeper layer of the soil during submerged rice season and thereby, minimize the further leaching of nitrate in to the ground water. Available phosphorus and micronutrients status of the soil noticed lesser value after harvest of cowpea compared to rice crop indicating phosphorus and micronutrients were efficiently utilised by cowpea. This was a very useful process, which reduced the continuous buildup of phosphorus and minimizes the possible antagonistic effect on other soil nutrients. It was also observed that K, Ca, Mg content of the soil were higher after cowpea compared to rice crop because of recycling of nutrients from deeper layer of soil by cowpea crop.
4. There was an improvement in microbial biomass carbon and biochemical properties viz., urease, dehydrogenase and phosphatase activities after growing cowpea as compared to rice crop and they were positive and significantly correlated with each other.

III. ORGANIC MANURE AND CHEMICAL FERTILIZERS ON SOIL FERTILITY AND PRODUCTIVITY

1. Bulk density was lower and water stable aggregates, porosity, maximum water holding capacity, infiltration rate and hydraulic conductivity of the

soil were recorded higher in the plot supplied with FYM @ 10 t ha⁻¹ as compared to 100 per cent NPK fertilizers plots under both rice and cowpea crops.

2. Organic carbon and cation exchange capacity of the soil was significant and positively correlated with each other. The values were significantly higher in treatment given with only FYM as compared to 100 per cent NPK fertilizers.
3. Significantly higher values of nutrients viz., N, K, Ca, Mg, S, Zn, Cu, Mn and Fe in the soil were recorded in case of FYM treated plots as compared to chemical fertilizers plots under both rice and cowpea crops. However, available 'P' recorded lesser value than 100 per cent NPK fertilizers and significantly more than 50 per cent NPK fertilizers.
4. Microbial biomass carbon recorded significantly higher value in case of FYM treated plots over chemical fertilizers under both rice as well as cowpea crops. Biochemical activities recorded were on par with chemical fertilizer and values were higher after cowpea than rice crop.
5. FYM applied @ 10 t ha⁻¹ recorded lower yield of rice than 100 per cent NPK fertilizers and significantly higher yield than under 50 per cent NPK fertilizers. On the other hand, cowpea yield were significantly higher under FYM treated plots compared to 100 per cent NPK fertilizers.

IV. COMBINATION OF BOTH ORGANIC AND INORGANIC FERTILIZERS ON SOIL FERTILITY AND PRODUCTIVITY

1. Bulk density, water stable aggregates, porosity, maximum water holding capacity, infiltration rate and hydraulic conductivity were higher in the treatment which received 50 per cent NPK + 50 per cent N through organic sources as compared to chemical fertilizers under both rice and cowpea crops.
2. Organic carbon and cation exchange capacity of soil were significantly higher in the treatments supplied with 50 per cent NPK + 50 per cent N-GM and FYM over 100 per cent NPK fertilizers under both rice and cowpea crops.
3. Buildup of major and micronutrients were significantly superior in the treatments given with 50 per cent NPK + 50 per cent N through Dhaincha or FYM while compared to 100 per cent inorganic fertilizers under both rice and cowpea crops.
4. Microbial biomass carbon was significantly superior and biochemical activities in the soil was on par with 50 per cent NPK + 50 per cent N-GM or FYM as compared to 100 per cent NPK fertilizers under both rice and cowpea crops.
5. The treatments supplied with 50 per cent NPK + 25 per cent N-GM + 25 per cent N-FYM recorded significantly maximum rice yield, while in cowpea the plot supplied FYM @ 10 t ha⁻¹ recorded significantly higher value compared to chemical fertilizers.

6. Sustainable yield index and net returns obtained were higher at 50 per cent NPK + 50 per cent N through organic sources as compared to 100 per cent chemical fertilizers application.

CONCLUSION

Adoption of integrated nutrient management approach comprising 50 per cent NPK + 25 per cent N--GM + 25 per cent N--FYM application into the soil in rice-cowpea crop rotation for 11 years was beneficial in improving physical, chemical, microbial as well as biochemical properties of the soil, which ultimately improved the yield of rice and cowpea crops as compared to NPK fertilizer treatments.

RECOMMENDATIONS

1. Use of 50 per cent NPK fertilizers and remaining nutrients supplemented through organic sources was an added advantage in saving remaining 50 per cent NPK fertilizers in rice crop.
2. Adopting cowpea as a residual summer crop instead of rice will give a great relief to the farmers as it saves about 100 per cent NPK fertilizers and thereby, also saves millions of rupees for the State exchequer from the command area. Further, it encourages farmers to practice judicious use of chemical fertilizers and gives scope for efficient utilization of local resources to maintain the soil health and protect environment.

PLATE-1: RICE – Control (No manure and fertilizers)

PLATE-2: RICE – 100% recommended NPK fertilizers

PLATE-3: RICE – 50% NPK + 25% N-GM + 25% N-FYM



PLATE-4: COWPEA – Control (No manure and fertilizers)

PLATE-5: COWPEA – 100% recommended NPK fertilizers

PLATE-6: COWPEA – FYM @ 10 t ha⁻¹



REFERENCES

VII. REFERENCES

- Acharya,C.L., Bishnoi,S.K. and Yaduvanshi,H.S., 1988. Effect of long-term application of fertilizers and organic and inorganic amendments under continuous cropping on soil physical and chemical properties in an Alfisol. *Indian J. Agric. Soc.*, **58** : 509-516.
- Agarwal,S., Singh,T.A. and Bharadwaj,V., 1993. Soil potassium as affected by long-term fertilizers and cropping with rice-wheat-cowpea rotation on a mollisol. *J. Indian Soc. Soil Sci.*, **41** (2) : 387-388.
- Anonymous, 1984. National Agricultural Research Project, Directorate of Rice Research, UAS, Bangalore, p.34.
- Anonymous, 1989. Progress report of All India Coordinated Research Project on Long-term Experiments (1985-86) Centre, Pantnagar.
- Aulakh,M.S., Tejinder S.Khera, John W.Doran, Kuldip Singh and Bijay Singh, 2000. Yields and nitrogen dynamics in rice-wheat system using green manure and inorganic fertilizer. *Soil Sci. Soc. Am. J.*, **64** : 1867-1876.
- *Azam,F. and Yousaf,M., 1991. Response of *Sesbania aculeata* L. Pers. to compost application and its long term value for improvement of soil fertility. *Sarhad J. Agriculture.*, **7** (2) : 153-160.

- Badanur, V.P., Poleshi, C.M. and Naik, B.K., 1990. Effect of organic matter on crop yield and physical and chemical properties of a vertisol. *J. Indian Soc. Soil Sci.*, **38** : 426–429.
- Bagavathiammal, U. and Muthaiah, N.D., 1996. Influence of organic manures and graded doses of potassium on soil K forms and yield of rice at different growth phases. *J. Potassium Res.*, **12** (3) : 263–267.
- Bagavathiammal, U., 1997. Effect of organic manures and graded doses of potassium on yield, K content and K uptake by rice. *Madras Agric. J.*, **84** (5) : 287–290.
- Basumantary, A. and Talukdar, M.C., 1998. Long-term effect of integrated nutrient supply on soil properties in an inceptisol of Assam. *Oryza.*, **35** (1) : 43–46.
- Basumantary, A. and Talukdar, M.C., 1999. Long-term effect of integrated nutrient supply system on secondary nutrients of soil *Oryza*, **36** (3) : 266–267.
- Bharadwaj, V.P.K. and Omanwar, P.K., 1992. Impact of long-term fertility treatments on bulk density water contents and microbial population of soil. *J. Indian Soc. Soil Sci.*, **40** : 553–555.
- Bharadwaj, V.P.K. and Omanwar, R.A., 1994. Long-term effects of continuous rotational cropping and fertilization on crop yields and soil properties–II. Effects on EC, pH, organic matter and available nutrients of soil. *J. Indian Soc. Soil Sci.*, **42** (3) : 387–392.
- Bharadwaj, V.P.K. and Tyagi, V.V., 1994. Impact of continuous manuring on crop yields and uptake of nitrogen, phosphorus and potassium. *J. Potassium Res.*, **10** (3) : 290–293.

- Bharadwaj, V.P.K., Omanwar, R.A., Sharma, R.A. and Vishwanath, 1994. Long-term effects of continuous rotational cropping and fertilization on crop yields and soil properties—I, effects on crop yields and nutrient uptake. *J. Indian Soc. Soil Sci.*, **42** (2) : 247–253.
- Bhatia, K.S. and Shukla, K.K., 1982. Effect of continuous application of fertilizers and manures on some physical properties of eroded alluvial soils. *J. Indian Soc. Soil Sci.*, **30** : 33–36.
- Bharguvanshi, S.R., 1988. Long-term effect of higher doses of farm yard manure on soil properties and crop yield. *J. Indian Soc. Soil Sci.*, **36** : 784–786.
- Biederbeck, V.O., Campbell, C.A., Bowren, K.E., Schnitzer, M. and Mciver, R.N., 1984. Effect of burning cereal straw on soil properties and grain yields in Saskatchewan. *Soil Sci. Soc. Am. J.*, **44** : 103–111.
- Black, C.A., 1965. Methods of soil analysis, Part I Physical and mineralogical properties. *Am. Soc. Agron. Inc.*, Madison, USA, p.770.
- Black, C.A., 1965. Methods of soil analysis, Part II Chemical and Microbiological property. *Am. Soc. Agron. Inc.*, Madison, Wisconsin, USA.
- Black, C.A., 1993. Soil fertility evaluation and control. Lewis Publishers, London.
- Boltan, Jr. H., Elliott, L.F., Papendick, R.I. and Bezdicek, D.F., 1985. Soil microbial biomass and selected soil enzymes activities effect of fertilization and cropping practises. *Soil Biol. Biochem.*, **17** : 297–302.

- Bopari, B.S., Yadvinder Singh and Sarma, B.D., 1992. Effect of green manure (*Sesbania aculeata*) on physical properties of soil and growth of wheat in rice–wheat and maize–wheat cropping systems. *Int. Agro physics.*, **6** (1–2) : 95–101.
- Bradsley, C.E. and Lancaster, J.D., 1965, Sulphur, method of soil analysis, **2** : 1102.
- Brady, N.C., 1990. Nature and properties of soils. The MacMillan Company, New York.
- Carter, M.R., 1991. Ninhydrin reactive–N released by the fumigation extraction method as a measure of microbial biomass under field conditions. *Soil Biol. Biochem.*, **23** : 139–143.
- Casida, L.E.Jr., Klein, D.A. and Santaro, T., 1964. Soil dehydrogenase activity. *Soil Sci.*, **96** : 371–376.
- Chahal, L.S., Singh, J.P. and Khera, A.P., 1984. Cumulative, direct and residual effect of phosphorus, potassium and FYM on crop yield and soil characteristics. *J. Indian Soc. Soil Sci.*, **32** : 92–96.
- Chandra Shekar Rao, P. and Saroja Raman, 2000. Soil urease activity under flooded transplanted rice. *J. Indian Soc. Soil Sci.*, **48** (4) : 831–833.
- Chaphale, S.D., Chaphale, B.S., Yerpe, Y.Z. and Lanjewar, A.D., 2000. Effect of green manuring on soil properties and yield performance of rice (*Oryza sativa* L.). *J. soils and crops.*, **10** (1) : 136–140.

- Chauhan, B.S., Stewart, J.W.B. and Paul, E.A., 1981. Effect of labile inorganic phosphate status and organic carbon additions on the microbial uptake of phosphorus in soils. *J. Indian Soc. Soil Sci.*, **61** : 375–385.
- Chawla, K.L. and Chhabra, 1991. Physical properties of a gypsum amended sodic soils as influenced by long-term use of fertilizer. *J. Indian Soc. Soil Sci.*, **39** : 40–45.
- Chitdeswari, T. and Krishnasamy, R., 1996. Effect of zinc enriched organic manures on some chemical properties of two different soils. *Madras Agric. J.*, **83** (8) : 526–528.
- Chitdeswari, T. and Krishnasamy, R., 1996. Nutrient ratio in plant as influenced by the addition of zinc enriched organic manures under submergence. *Madras Agric. J.*, **83** (8) : 542–544.
- Chitdeswari, T. and Krishnasamy, R., 1997. Dynamics of zinc and zinc-enriched organic manures in soils of Tamil Nadu. *J. Indian Soc. Soil Sci.*, **45** (4) : 774–778.
- Chitdeswari, T., Sheik Dawood, M., Subramanian, V and Krishnadoss, D., 1997. Effect of long-term manurial addition on the yield of crops and nutrient availability under rainfed vertisol. *Madras Agric. J.*, **84** (7) : 364–366.
- Chitra, L., Velu, V., Vennila, R.K and Janaki, P., 1999. Direct and residual value of several organic wastes for rice-rice cropping system. *Oryza*, **36** (1) : 53–56.
- Collins, H.P., Ragmussen, P.E. and Douglas, C.L. Jr., 1992. Crop rotation and residue management-effects on soil carbon and microbial dynamics. *Soil Sci. Soc. Am. J.*, **56** : 783–788.

- Datta, N. and Bhardwaj, K.K.R., 1995. Nitrogen contribution and soil improvement by legume green manuring in rice-wheat cropping on an acid clay loam soil. *J. Indian Soc. Soil Sci.*, **43** (4) : 603–607.
- Deepak Kher, 1993. Effect of continuous liming, manuring and cropping on DTPA-Extractable micronutrients in an alfisol. *J. Indian Soil Sci.*, **41** (2) : 366–367.
- Despande, A.N., Pawar, R.B. and Kale, S.P., 2000. Effect of different crop sequences on physical properties of inceptisols under dryland conditions. *J. Soils and Crops.*, **10** (1) : 46–49.
- Dixit, K.G. and Gupta, B.R., 2000. Effect of farm yard manure, chemical and biofertilizers on yield and quality of rice (*Oryza sativa* L.) and soil properties, *J. Indian Soc. Soil Sci.*, **48** (4) : 773–780.
- Dubey, R.P. and Verma, B.S., 1999. Integrated nutrient management in rice (*Oryza sativa*)–rice–cowpea (*Vigna unguiculata*) sequence under humid tropical Andaman Islands. *Indian J. Agron.*, **44** (1) : 73–76.
- Ganapathi, T., 1991. Effect of NPK, gypsum and coir pith on nutrient availability in soil, uptake and yield of rice. *M. Sc. (Ag) thesis*, Tamil Nadu Agricultural University, Coimbatore.
- Gill, M.S., Tarlok Singh and Rana, D.S., 1994. Integrated nutrient management in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping sequence in semi-arid tropic. *Indian J. Agron.*, **39** (4) : 606–608.
- Halstead, R.L. and Sowden, F.J., 1986. Effect of long-term additions of organic matter on crop yields and soil properties in a clay and sand. *Con. J. Soil. Sci.*, **48** : 341–348.

- Hanumantharayappa, 1994. Effect of continuous application of manures and fertilizers on some properties of *Alfisols* and yield and nutritive quality of maize grain (*Zea maize* L.), *M.Sc. (Ag) thesis*, UAS, Bangalore.
- Hoffmann, G. and Teicher, K., 1961. Z.Pflanzeenernahr. Dung.Bodenk, **95** : 55.
- Hundal, H.S. and Thind, S.S., 1993. Release of phosphorus in flooded soil ammended with green manures. *J. Indian Soc. Soil Sci.*, **41** (4) : 782–783.
- Indulkar, B.S. and Malewar, G.U., 1990. Transformation of N, P and Zn as influenced by various inorganic and organic sources of zinc in rice–gram cropping system. *Fert. News.*, 39–41.
- Jackson, M.L., 1958. Soil Chemical analysis, Prentice Hall India, Pvt.Ltd., New Delhi.
- Jackson, M.L., 1973. Soil Chemical analysis, Prentice Hall, India, Pvt.Ltd., New Delhi.
- Jagadeeswari, P.V. and Kumaraswamy, K., 2000. Long-term effects of manure–fertilizer schedules on the yield and nutrient uptake by rice crop in a permanent manurial experiment, *J. Indian Soc. Soil Sci.*, **48** (4) : 833–836.
- Jagannathan, S., Mayalagu, K. and Peer Mohamed, M., 1987. Effect of amendmets on soil physical properties. *J. Indian Soc. Soil Sci.*, **35** : 726–27.
- Jaggi, R.C., 1991. Inorganic phosphate fractions as related to soil properties in some representative soils of Himachal Pradesh, *J. Indian Soc. Soil Sci.*, **39** : 567–568.

- *John,P.S., Suresh,R.J., Pandey,R.K., Prasad,R. and Chua,T.T., 1989. Nitrogen-15 balanced for urea and neem coated urea applied to low land rice following two cowpea cropping systems. *Plant and Soil (Netherlands)*, **120** (2) : 233–241.
- *Juma,N.G. and Tabatabai,M.A., 1978. Distribution of phosphomonoesterases in soils. *Soil Sci.*, **126** : 101–108.
- Kabeerthuma,S., Mohankumar,C.R., Nair,G.M. and Nair,P.G., 1993. Effect of continuous cropping of cassava (tapioca) with organic and inorganics on the secondary and micronutrient elements status of an ultisol. *J. Indian Soc. Soil Sci.*, **41** : 710–713.
- *Kahle,P., Leinweber,P. and Menning,P., 1992. Influence of soil organic matter on physical properties of soils. *Agri. Bio. Res.*, **45** (1) : 18–28.
- Kalane,R.L., Belekar,D.U., Padole,V.R. and Kharche,S.G., 1995. Effect of fertilizers and manures on physical properties of Entisol under sorghum–wheat crop sequence. *National Seminar on Soil Development*, 60th Annual Convention.
- Kamalesh Kukreja,M.M., Mishra,S.S., Dhanakur,K.K., Kapur and Gupta,A.P., 1991. Effect of long-term manurial application on microbial biomass. *J. Indian Soc. Soil Sci.*, **39** : 685–687.
- Kapur,M.L., Talukdar,N.C. and Reena,D.S., 1986, Influence of continuous application of inorganic fertilizers in a fixed maize–wheat rotation in some soil chemical properties. *J. Indian Soc. Soil Sci.*, **34** : 198–199.
- Katyal,J.C. and Sharma,B.D., 1991. DTPA-Extractable and total Zn, Cu, Mn and Fe in Indian soils and their association with some soil properties. *Geoderma*, **49** : 165–179.

- Kavallappa,B.N., 1989. Intensive manuring and cropping programme on soil properties, crop yield, nutrient uptake and nutritive quality of finger millet [*Eleusine coracana* (L.) Gaertn.] in an *Alfisol* of Bangalore. *Ph. D. Thesis*, UAS, Bangalore.
- *Khera,T.S., Aulakh,M.S. and Doran,J.W., 1999. Significance of soil depth on nitrogen transformations in flooded and non-flooded systems under laboratory conditions. *Nutr. Cycl. Agroecosyst.*, **54** : 209-213.
- Kumar,A. and Yadav,D.S., 1993. Effect of long-term fertilization on soil fertility and yield under rice-wheat cropping system. *J. Indian Soc. Soil Sci.*, **41** (1) : 178-180.
- Ladha,J.K.,Kundu,D.K., Angelo-Van Coppenolle,M.G., Peoples,M.B., Carangal,N.K. and Dart,P.J., 1996. Legume productivity and soil nitrogen dynamics in low land rice-based cropping system. *Soil Sci. Soc. Am. J.*, **60** : 183-192.
- Lal,S. and Mathur,B.S., and Sinha,K., 1990. Effect of long-term fertilization, manuring and liming of an alfisol on forms of potassium. *J. Indian Soc. Soil Sci.*, **38** (1) : 121-26.
- Lal,S. and Mathur,B.S., 1989. Effect of long-term application of manure and fertilizer on the DTPA extractable micronutrients in the soil. *J. Indian Soc. Soil Sci.*, **37** : 588-590.
- Lal,S. and Mathur,B.S., 1992. Effect of long-term application of fertilizers,manure and lime on cationic and anionic status of red loam soils of Ranchi. *National Seminar on Development of Soil Science Abstract*, 57th Convention, Nov.26-29, pp 78-79.

Lindsay, W.L. and Norwell, W.A., 1978. Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Sci. Amer. J.*, **42** : 421–428.

*Liu, J.R. and Shen, K.P., 1992. The effect of fertilization on the properties and role of soil organic matter. In : Proceedings : International symposium on paddy soils, Nanjing, China, 15–19.

Lokeswarappa, C., 1997. Distribution of major plants in an *Alfisol* subjected to long-term fertilizer schedule and crop sequence. *M. Sc. (Ag.) thesis*, UAS, Bangalore.

Mahimairaja, S., Helkiash, J. and Gopalswamy, A., 1986. Long-term effect of graded doses of fertilizers and manures on soil physical conditions. *Madras Agric. J.*, **73** : 340–347.

Manna, M.C., Kundu, M., Singh, M. and Takkar, P.N., 1996. Influence of FYM on dynamics of microbial biomass and its turnover and activity of enzymes under soybean–wheat system on a typic Haplustalf. *J. Indian Soc. Soil Sci.*, **44** : 409–412.

Masthan, S.C., Reddy, S.N. and Shaik Mohammad, 1998. Direct residual and cumulative effects of phosphorus in rice–rape seed–green gram cropping system. *Oryza*, **35** (2) : 140–144.

McNeal, B.L. and Reeve, R.C., 1974. Elimination of boundary flow errors in laboratory hydraulic conductivity measurements. *Soil Sci. Soc. Am. Proc.*, **28** : 513–514.

Mishra, V.K. and Sharma, R.B., 1997. Influence of integrated nutrient management on soil health and energy requirement of rice–based cropping systems. *Oryza*, **34** : 165–170.

- Mondal,S.S., Mondal,T.K., Dandapat,S. and Sarkar,S., 1994. Effect of sulphur bearing fertilizer in conjunction with Farm Yard Manure on growth, productivity and nutrient uptake of rice (*Oryza sativa*), *Indian J. Agron.*, **39** (1) : 116–118.
- More,S.D., 1994. Effect of farm wastes and organic manures on soil properties, nutrient availability and yield of rice–wheat grown on sodic vertisol. *J. Indian Soc. Soil Sci.*, **42** (2) : 253–256.
- Mulvaney,R.L., 1996. Nitrogen-inorganic forms. In. D.L.Sparks (Ed.) methods of soil analysis. Part-3, SSA Book Ser. 5. SSSA and ASA, Madison, W.I., pp.1123-1184.
- Nair,K.P.P., 1997. Proc.Fert.Seminar on “Fertilizer use efficiency through package of practises”. Ludhiana p 115.
- *Nand–Ram and Ram,N., 1996. Amelioration of zinc stress by farm yard manure in a rice–wheat–cowpea system, *Acta Agronomica–Hungaria.*, **44** (1) : 35–39.
- Narayana Reddy,M and Surekha,K., 1998. Direct and residual effects of applied phosphorus on yield and nutrient uptake in chickpea–upland rice system. *Oryza.*, **35** (1) : 47–52.
- Narayana Reddy,M. and Krishnaiah,K., 1999. Integrated nutrient management for sustainable rice production. *Tech. Bull.*, Directorate of Rice Research (ICAR), Hyderabad–30 (AP)
- *Oliveira,L.A.de., Smyth,T.J., Bonneti,R. and De–Oliveira,L.A., 1992. Effect of previous fertilizr application on nodulation and yield of soybeans and cowpeas on a yellow Latosol in Amazonia, *Rivista–Brassileira–de–ceincia–do–solo*, **16** (2) : 195–201.

- Panda,N. and Sahoo,D., 1989. Long-term effects of manure and fertilizers in rice-based cropping systems in sub-humid lateritic soils. *Fert. News*,39-44.
- Panse,V.G. and Sukhatme,PO.V., 1985. Statistical methods for Agricultural Worker. Publication and Information Division, ICAR, New Delhi.
- Parashuram,C., 1998. Studies on physical, chemical and microbiological properties of an alfisol subjected to permanent manuring and cropping schedule, *M. Sc. (Ag.) thesis*, UAS, Bangalore.
- Parvathappa,H.C., Kantharaju,M.L. and Hegde,B.R., 1988. Fertilizer requirement of crops under dryland conditions in the semi arid tropics. *Proc. Intl. Conf. on Dryland Farming.*, America Tenas, USA Part VI., 461-463.
- Pathak,A.K. and Ghose,T.J., 1996. Nutrient management in rice-rice cropping system, **41** (8) : 55-58.
- Pillai,G.K., Suseeladevi,L., Sholapurkar,M.V. and Jaganath,M.K., 1987. Effect of continuous cropping and manuring in selected cropping systems. *Fert. News.*, **32** (6) : 31-36.
- Piper,C.S., 1956. Soil and Plant analysis, Hans Publishers, Bombay.
- Piper,C.S., 1966. Soil and Plant analysis, *Inter Science Publishers, Inc.*, New York.
- Prasad,B., Prasad,J and Prasad,R., 1995. Nutrient management for sustainable rice and wheat production in calcareous soil amended with green manures, organic manures and zinc. *Fert. News.*, **40** (2) : 39-41.

- Prasad,J., Srivastava,N.C. and Mathur,B.S., 1996. Available nutrients status of continuously fertilized and cropped acid soil. *J. Indian Soc. Soil Sci.*, **44** : 171–173.
- Rabindra,B. and Honnegowda, 1986. Long-range effect of fertilizers, lime and manure on soil fertility and sugarcane yield on a red sandy loam soil (udic haplustalf). *J. Indian Soc. Soil Sci.*, **33** : 704–706.
- Rajeev Kumar, Singh,K.P. and Sarkar,A.K., 1993, Cumulative effects of cropping and fertrtilizer use on the status of micronutrients in soil and crop. *Fert. News.*, **38** (11) : 13–17.
- Ram–Newaj and Yadav,D.S., 1994. Changes in physico–chemical properties of soil under intensive cropping systems. *Indian J. Agron.*, **39** (3) : 373–378.
- Rawat,M.S., Tripathi,R.P. and Nand–Ram, 1996. Long-term effect of puddling and fertilizer use in rice–wheat–cowpea sequence on structural properties of soil. *J. Indian Soc. Soil Sci.*, **44** (3) : 364–368.
- Richards,L.A., 1954. Diagnosis and improvement of a saline and alkali soils. U.S.Govt.Printing Office, Washington,D.C.
- Sarma,P,K. and Das,M., 1996. Effect of aggregating agents on synthesis of microaggregate and physical properties of an alfisol. *J. Indian Soc. Soil Sci.*, **44** (1) : 12–15.
- Saud,R.K. and Thakuria,K., 1994. Biological efficiency and economics of upland direct–seed rice (*Oryza sativa*) + fodder cowpea (*Vigna unguiculata*) intercropping, *Indian J. Agron.*, **38** (3) : 453–455.

- avich, V. and Verme, K.R., 1991. Regulation of the status of Fe, Mn, Cu and Zn compounds in soils of India. *Mazhduna rodnnyl Agropromyshlennyy Zhurnal.*, **4** : 77–79.
- arif, K., 1984. Effect of long-term application of manures and fertilizers on soil fertility and yield of finger millet in *Alfisol* of Bangalore. *M. Sc. (Ag) thesis*, UAS, Bangalore.
- ngaram, P. and Kamala Kumari, K., 1995. Long-term effect of FYM and fertilizers on enzyme dynamics of soil. *J. Indian Soc. Soil Sci.*, **43** (3) : 378–381.
- ingh, A.P., Mitra, B.N. and Tripathi, R.S., 1999. Effect of soil enrichment in conjunction with organics and chemical fertilizer on rice (*Oryza sativa*)– chickpea (*Cicer arietinum*) cropping system. *Indian J. Agron.*, **44** (2) : 223–227.
- ingh, B., Singh, Y., Maskina, M.S. and Meelu, O.P., 1988. Green manure as N source for flooded rice. *Int. Rice Res. Newsletter*, **13** (4) : 25–26.
- ingh, R.P., Dass, S.K., Bhaskara Rao, U.M. and Narayana Reddy, M., 1990. Towards sustainable dryland agricultural practises. *Central Res. Inst. Dryland Agriculture* (ICAR), Santoshnagar, Hyderabad–59.
- inha, B.K., Sakar, A.K. and Srivastava, B.P., 1983. Effect of continuous application of manure and fertilizers on different forms of aluminium in an acid soil. *J. Indian Soc. Soil Sci.*, **31** : 632–634.
- inha, N.P., Prasad, B. and Ghosh, A.B., 1980. Soil physical properties as influenced by long-term use of chemical fertilizers under intensive cropping. *J. Indian Soc. Soil Sci.*, **28** : 516–518.

- *Sisworo, W.H., Mitrosuhardjo, M.M., Rasjid, H. and Myers, R.J.K., 1992. Transfer of nitrogen from food legume stover of upland cereal crops in an acid upland soil. *Indonesian J. Trop. Agric.*, **4** (1) : 11–17.
- Solaiappan, U. and Veerabadran, V., 1997. Effect of green manure inter cropping on rice. *Madras Agric. J.*, **84** (7) : 369–370.
- Sriramachandrasekharan, M.V., Ramanathan, G. and Ravichandran, M., 1997. Effect of different organic manures on enzyme activities in a flooded rice soil. *Oryza.*, **34** : 39–42.
- Stalin, P., Thiyagarajan, T.M., Ragurajan, R., 1999. Nitrogen application strategy and use efficiency in rice. *Oryza.*, **36** (4) : 322–326.
- Subbaiah, B.V. and Asija, G.L., 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.*, **25** : 259–260.
- Subramanian, K.S. and Kumaraswamy, 1989. Fertilization on chemical properties of soil. *J. Indian Soc. Soil Sci.*, **37** : 171–173.
- Sudhir, K. and Siddaramappa, R., 1995. Role of organic manure in the maintenance of soil health and productivity. An experience from long-term fertilizer experiments at Bangalore Centre. **In:** Alternatives to fertilizers in sustainable agriculture (ed.), Shivashankar, K., UAS, Bangalore–65.
- Sudhir, K., Siddaramappa, R. and Mariswamy Gowda, S.M., 1996. Long-term fertilizer experiments—a decades experience, UAS, Bangalore–65.
- Tabatabai, M.A. and Bremner, J.M., 1969. Use of P-nitrophenyl phosphatase for assay of soil phosphatase activity. *Soil Biol. Biochem.*, **1** : 301–307.

- Tandon, H.L.S., 1988. Potassium research and agricultural production in India, FDC, New Delhi.
- Tiwari, H.C., Gangawar, M.S. and Nand-Ram, 1995. Effect of continuous cropping and fertilization on the total, organic and available sulphur in a Hapludoll. *Trop. Agric.*, **72** (4) : 274–276.
- Tripathi, B.N. and Chaubey, C.N., 1996. Effect of organic sources of plant nutrients in conjunction with chemical fertilizers on the bulk density, yield and uptake of nutrients by rice. *Oryza.*, **65** : 200–207.
- Vageesh, T.S., Jaganath, V.J., Veeranna, V.S., Naik, H.H. and Panchaksharaiah, S., 1990. Integrated nutrient supply in rice-rice sequence and its influence on soil properties. *Curr. Res.*, **19** (6) : 96–98.
- Verma, R.K. and Nand-Ram, 1994. Effect of continuous cropping and fertilizer application on different forms of potassium in a Mollisol, *J. Pot. Res.*, **10** (2) : 149–154.
- Walkley, A. and Black, C.A., 1934. An examination of degtareff method of determining soil organic matter and proposed modification of chromic and titration method. *Soil Sci.*, **37** : 29–38.
- Yadav, D.S., Kumar, A., Singh, R.M. and Ram, 1992. A proceeding on resource management for sustained crop production. *Indian Soc. Agron.*, R.A.U. Bikaner (India). P 30.
- Yaduvanshi, H.S., Tripathi, B.R. and Anif Kanwar, B.S., 1985. Effect of continuous manuring on some soil properties of an Alfisol. *J. Indian Soc. Soil Sci.*, **33** : 700–703.

Yadvinder-Singh, Bijay-Singh, Maskina,M.S. and Meelu,O.P., 1988.
Effect of organic manures, crop residues and green manure
(*Sesbania aculeata*) on nitrogen and phosphorus
transformation in a sandy loam soil at field capacity and under
water logged conditions. *Biol. Fertil. Soils.*, 6 : 183-187.

**Original not seen*

APPENDIX

APPENDIX – 1a

Meteorological data of the Regional Research Station, V.C.Farm, Mandya (Standard week-wise) during the Rice crop growth period

Standard week (Kharif 1999)	Rainfall (mm)	Temperature (°C)		Relative humidity (%)	Evapo- ration (mm)
		Maximum	Minimum		
01-07 to 07-07	-	29.92	19.93	68.72	3.84
08-07 to 14-07	2.4	29.07	19.79	70.84	3.82
15-07 to 21-07	8.6	27.93	20.00	75.14	4.00
22-07 to 28-07	14.60	26.74	19.86	80.36	4.05
29-07 to 04-08	6.20	26.79	19.86	75.76	3.60
05-08 to 11-08	0.60	26.86	19.93	79.36	3.60
12-08 to 18-08	90.20	28.43	20.36	72.14	4.63
19-08 to 25-08	86.20	29.00	20.86	73.36	5.10
26-08 to 01-09	15.00	26.43	20.21	78.56	4.62
02-09 to 08-09	-	27.81	20.29	74.57	4.85
10-09 to 15-09	1.60	28.97	20.21	67.79	3.67
16-09 to 22-09	-	29.29	19.86	67.57	3.66
23-09 to 29-09	62.40	29.43	20.71	70.57	4.16
30-09 to 06-10	61.60	28.14	20.92	78.43	3.98
07-10 to 13-10	37.20	27.86	21.21	76.28	3.73
14-10 to 20-10	49.80	28.29	20.57	79.93	4.10
21-10 to 27-10	84.80	27.36	20.04	79.79	3.90
28-10 to 03-11	59.40	28.21	18.17	77.10	3.85
04-11 to 10-11	-	28.50	18.36	71.78	3.60
11-11 to 17-11	-	28.86	18.76	75.14	3.60
18-11 to 24-11	98.00	26.57	19.14	73.42	3.61
25-11 to 30-11	4.40	27.00	17.42	76.50	3.66

APPENDIX – 1b

**Meteorological data of the Regional Research Station, V.C.Farm,
Mandya (Standard week-wise) during the Cowpea crop growth period**

Standard week (Kharif 1999)	Rainfall (mm)	Temperature (°C)		Relative humidity (%)	Evapo- ration (mm)
		Maximum	Minimum		
01-02 to 07-02	-	28.31	16.10	65.64	4.32
08-02 to 14-02	-	29.81	18.43	67.00	4.53
15-02 to 21-02	-	29.71	17.57	62.00	4.44
22-02 to 28-02	29.60	28.43	20.00	72.00	4.67
29-02 to 06-03	-	30.43	15.79	58.76	4.90
07-03 to 13-03	-	31.29	19.86	64.86	4.96
14-03 to 20-03	-	32.00	20.00	56.28	4.66
21-03 to 27-03	-	31.57	17.86	57.26	4.43
28-03 to 03-04	-	32.43	19.76	61.29	4.96
04-04 to 10-04	8.40	31.17	20.57	67.93	4.90
11-04 to 17-04	46.80	32.90	21.10	64.64	3.40
17-04 to 24-04	8.00	31.21	19.93	66.10	3.42
25-04 to 01-05	4.00	33.30	20.43	64.43	3.44
02-05 to 08-05	40.00	31.57	20.21	68.28	3.30
09-05 to 15-05	29.20	31.79	20.43	64.05	3.50
16-05 to 22-05	4.60	31.29	20.36	64.10	3.22
23-05 to 29-05	-	31.50	20.36	67.79	3.98
30-05 to 31-05	49.90	32.25	19.75	67.25	3.98