INTEGRATED NUTRIENT MANAGEMENT FOR RICE BASED CROPPING SYSTEMS OF ONATTUKARA TRACT

BY

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DECLARATION

I hereby declare that this thesis entitled "**Integrated nutrient management for rice based cropping systems of Onattukara tract**" is a bonafide record of research work done by me during the course of research and that the thesis has not formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Integrated nutrient management for rice based cropping systems of Onattukara tract"** is a record of research work done independently by **Ms. Shalini Pillai, P.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

India needs about 225 to 240 million tonnes of food grains to feed an expected population of about 1 billion by 2000 A.D. as against the current production of about 191 million tonnes. The targeted output of rice alone amounts to 94 million tonnes (Siddiq, 1996). The most disquietening feature of food grain production, particularly rice, in India is that during the decade that ended in the year 1990, the rate of food grain production could not cope up with the population growth.

In the current model of exploitative agriculture, maximisation of crop yields, per unit area per unit time is a matter of national compulsion. To enhance the production level per unit area, a number of intensive rice based cropping systems have been identified and practised all over India. Appreciable quantities of nutrients are being removed by these intensive cropping systems. Optimisation of profits and adoption of integrated crop and input management practices is the key for maintaining rice production sustainability. Research work on integrated nutrient management (INM) in rice based cropping systems has gained momentum in the last decade.

Experiments conducted under the All India Co-ordinated Agronomic Research Project and other programmes have clearly indicated that sustaining the productivity at high level without impairing the soil environment is beyond the capacity of a single type of nutrient source (Hegde and Dwivedi, 1993). As early as 1974, the need for INM has been elucidated by Dr. M.S. Swaminathan. INM has an untapped food grain potential of about 10 to 15 million tonnes. The INM philosophy combines economic and efficient traditional and frontier technologies to gain from the symbiosis and synergy of crop-soil environment bio-interactions. The approach is flexible and minimises use of chemicals but maximises use efficiency and farmers' profit. Here the soil is treated as a living system for promoting all the functions - supportive, buffering and store house of nutrients and water (Sankaram, 1996).

INM involves the intelligent use of organic, chemical and microbial sources so as to sustain optimum yields and to improve or sustain the soil health, to provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe. As INM comprises use of nutrients representing diverse sources, the optimum combinations for deriving the maximum benefit have to be determined for the different agro-ecological zones and categories of farms.

Onattukkara is an agro-ecological situation in Kerala which is designated as a problem area. The Onattukara tract consists of a cultivated area of 68340 ha, of which 28340 ha is under rice. The soil of the tract is typical sandy loam in texture and belongs to the order Entisol. These soils occur in flat to gently sloping areas and are highly porous with poor organic matter status and limited capacity for retaining water and nutrients. Water table is high in most of the locations and drainage is a problem. Water table reaches near surface during the rainy season and recedes 2 to 3 metres during summer. As such nutrient management is difficult especially in the rice based cropping systems. The rice based cropping systems practised in this tract involves the cultivation of rice during the first two seasons, while different crops like pulses, oilseeds and vegetables are grown during the summer (third crop) season. The summer crops are generally cultivated indiscriminately without giving due consideration to their impact on the succeeding rice crop and soil health. Some of these crops are soil exhausters while some are soil enrichers. The selection of the most suitable rice based cropping system should be based on the biological possibility, economic desirability and practical feasibility.

At present an efficient integrated nutrient management practice is lacking in this tract. Being a sandy loam soil, addition of organic matter assumes paramount importance in maintaining soil productivity. The role of organic matter as nitrogen source is only one of the factors favourably influencing the combined use of organic manures and chemical fertilisers. Other advantages of organic matter like stimulation of microbial growth in the rhizosphere, improvement in physico-chemical and electrical conditions of soil, adequate supply of micronutrients, etc. deserve importance (Johnkutty and Anilakumaran, 1991).

In the context of search for alternate sources of soil fertility build up through renewable sources, harnessing of bacteria and other microorganisms for fixing nitrogen assumes great importance. *Azospirillum* is a bacteria which colonises and fixes nitrogen in loose association with roots of cereals and other crops. It has shown positive interaction with applied nitrogen in several field crops with an average response equivalent to 15 to 20 kg per hectare of applied nitrogen. In the present study *Azospirillum* is the biological component of the integrated nutrient management system tried.

Research data on integrated nutrient management in rice based cropping systems are meagre. Hence the present study entitled "Integrated nutrient management for rice based cropping systems of Onattukara tract" was undertaken with the following objectives:

(i) to find out the most suitable rice based cropping system for Onattukara tract.,

(ii) to find out the most efficient nutrient management practice.,

(iii) to study the impact of integrated nutrient management on the physico-chemical properties of the soil.,

(iv) to work out the nutrient balance sheet of the soil., and

(v) to work out the economics of the different treatments.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Nutrient management gains importance in cropping systems in which many crops of varied nutrient requirements are involved. The basic concept underlying the principle of integrated nutrient management is the maintenance and possible improvement of soil fertility for sustaining crop productivity on long-term basis, which may be achieved through combined use of all possible sources of nutrients and their scientific management for optimum growth, yield and quality of different crops and cropping systems in specific agro-ecological situations (Hegde and Dwivedi, 1993). In the present study, attempts were made to identify the most suitable rice based cropping system for the Onattukara tract and to evolve a suitable and economically viable integrated nutrient management practice for the system. The available state of knowledge on the various aspects considered in the study are reviewed in this chapter. Research information on other crops and cropping systems are also reviewed wherever pertinent literature is lacking.

2.1 Production potential of rice based cropping systems

Intensive agriculture has enabled the country to keep pace with the increasing food demands. Research investigations carried out in different agro-climatic regions on viable rice based cropping systems have evidently elucidated that stabilised yield at higher levels of productivity with 200 to 400 per cent cropping intensity are possible only under balanced nutrient application, which has proved beneficial for getting higher crop yields alongwith maintaining the soil health in terms of the physical and chemical properties of the soil.

Sadanandan and Mahapatra (1972c) reported that the production was doubled by growing potato-rice-rice instead of the normal practice of growing only two crops in a year.

Experiments conducted at IRRI, Philippines with three to four crops in a sequence resulted in a total production ranging from 10 to 12 t ha^{-1} (IRRI, 1972).

A multiple cropping system involving two crops of rice and one crop of sweet potato was found to be more feasible and remunerative (Singh *et al.*, 1974).

Rice-wheat-green gram rotation was observed to be the best sequence under the agro-climatic conditions of Nizamabad district of Andra Pradesh. This crop sequence produced a yield of 9.5 t ha^{-1} per year (Raghavulu and Sreeramamoorthy, 1975).

At Coimbatore, three crop sequences with IR-8 variety of rice produced 12 to 13 t ha^{-1} grain (Subbiah, 1976).

Palaniappan *et al*. (1978) recorded the maximum grain production of 13.9 t ha^{-1} under the rice-rice-rice rotation.

Purushothaman (1979) reported that rice-rice-finger millet+green gram sequence gave the highest productivity with the most intensive land use.

Mahapatra *et al*. (1981), while reviewing the results of the Model Agronomic Experiments, have reported that the most productive rice based cropping system for Varanasi and Kalyani centres is rice-wheat-rice, for Maruteru centre is rice-finger millet-rice and for Bhubaneswar, Karamana and Mangalore centres is rice-rice-rice.

Soni and Kaur (1984) reported that in addition to two principal crops a third crop of legume in summer season was more productive.

Morita (1986) observed that three crops of rice in kharif, rabi and summer recorded 20.5 t ha^{-1} of grains as against the conventional rice-rice system of Gujarat.

Selvaraj *et al*. (1988) obtained the highest economic yield of 25 t ha^{-1} in a rice based cropping system involving rice-sesamum-pearl millet-turmeric-cotton in a two year sequence at Bhavanisagar.

Mazumdar *et al*. (1989) obtained a higher production potential for the rice-safflower rotation followed rice-gram and rice-black gram sequences.

Kumar and Reddy (1991) reported the highest total grain yield and benefit-cost ratio in rice-maize sequence followed by the rice-groundnut sequence.

The field trials conducted by Yadav *et al*. (1991) on a silty-loam soil at the Crop Research Station, Masodha (Faizabad) revealed an yield of 10.7 t ha^{-1} of cereals for the traditional rice-wheat system. The rice equivalent yields of different systems showed that rice-potato+Indian mustard system gave maximum yield (18.8 t ha^{-1}) followed by rice-wheat+Indian mustard-green gram (14.8 t ha^{-1}).

A total grain productivity of 25.73 q ha^{-1} which was the highest in the study conducted by Patil *et al*. (1992) has been obtained from the crop sequence of rice (variety, Kalinga) followed by safflower.

Kumar *et al*. (1993) reported that the crop sequence of rice-rice-bhindi was highly productive, and produced a grain yield of 6.1 t ha^{-1}.

Reddy *et al*. (1993) reported that green gram-semidry rice gave more rice grain equivalent (3.8 t ha^{-1}) which was significantly higher by 73 per cent than fallow-semidry rice.

Singha *et al.* (1993) recorded the highest average rice-equivalent yield in rice-green gram-rapeseed sequence (8.19 t ha^{-1}).

In a field experiment conducted during 1986-88 at Madurai by Jayapaul *et al.* (1993), it was observed that groundnut+blackgram-rice-sesame cropping system recorded higher rice-yield equivalent of 18.04 and 18.58 t ha^{-1} during first and second year respectively. The least rice-yield equivalent was 9.71 and 9.78 t ha^{-1} in first and second year respectively in rice-rice-fallow system.

Padhi (1993), in a study conducted at Ghumusar, Udayagiri on sandy loam soil, observed that there was no significant difference in the average yield of rice obtained from different cropping sequences in all the years. Maximum yield of rice was secured in rice-garden pea-cowpea sequence and the minimum in rice-garden pea-okra sequence.

Long term experiments with selected cropping systems in AICARP revealed that rice-rice, a dominant cropping system in Southern India, the total productivity in research trials varied from 7.4 to 9.4 t ha per annum (Kolar and Gill, 1994).

Gowda (1994), in a field experiment conducted in the wetlands of University of Agricultural Sciences, Bangalore, observed the highest mean yield for the rice-soybean sequence followed by rice-fingermillet and rice-niger sequences.

Cropping systems are highly location specific. While monoculture of rice recorded the highest production potential in certain locations, inclusion of legumes improved the production potential of cropping systems in yet other locations.

2.2 Effect of rice based cropping systems on the physico-chemical properties of the soil

2.2.1 Soil physical properties

Soil aggregation or structure is a reflection of continued effect of physical, chemical and biological agencies. The relative contribution of these agencies in the formation and degradation of soil structure varies with the different cropping systems. Harris *et al*. (1966) observed an adequate state of soil aggregation to be maintained most effectively by grain and root crops. Bulk density of a soil is very closely related to its structure. A negative correlation is observed between the bulk density and soil structure. In general, continuous cultivation results in a reduction in pore space and consequently the weight per unit volume of soil increases.

Mohant and Singh (1969) studied the effect of paddy monoculture on the water stable aggregates status of an acidic soil and observed a detrimental effect on the same.

Continuous cultivation of rice or rice in rotation with vegetable crops like tomato and chillies had a deteriorating effect on soil aggregation (Padmaraju and Deb, 1969). On the contrary, cultivation of groundnut was found to bring about a slight increase in the water stable aggregates (Mohant and Singh, 1969).

Continuous cropping of rice increased the bulk density by 0.5 gcc^{-1} (Sadanandan and Mahapatra, 1970). However they observed that the inclusion of groundnut in the cropping pattern improved the soil structure slightly (Sadanandan and Mahapatra, 1974a).

Paeth and Azizi (1974) studied the effect of inclusion of legume crops in cropping sequences and observed an improvement in soil aggregation, bulk density and water holding capacity in the case of crop rotations including alfalfa and perennial forages.

Biswas *et al.* (1975) from their work done at I.A.R.I., New Delhi, reported that the cropping systems involving legumes in the sequence increased the water holding capacity of the soil at all tensions.

Reports from IARI (1976) suggested the beneficial effect of the presence of crop throughout the year for maintaining good soil structure. The presence of a legume in the cropping system was found to improve the soil structure probably through the associated microbial activity in the rhizosphere.

Sasidhar (1978) reported that the continuous cultivation of rice had a deteriorating effect on soil structure. However, inclusion of cowpea, sesamum and groundnut crops in rotation improved the soil structure. A slight decrease in bulk density was observed after cowpea and groundnut. In rice-rice-rice system the bulk density increased by 0.004 g cc^{-1} and 0.002 g cc^{-1} during the first year and second year respectively.

Studies conducted at C.R.R.I., Cuttack by Mahapatra and Yaduraju (1981) showed that the cropping patterns, groundnut-jute-rice and rice-rice resulted in a decrease in water stable aggregates and an increase in bulk density of the soil.

Soils under rice-wheat rotation had a higher overall mean of fine aggregates (less than 1 mm), whereas soils under maize-wheat rotation showed a higher overall mean of coarse aggregates. Further the soil under rice-wheat rotation developed higher bulk density and lower infiltration capacity (Sawhney and Sehgal, 1989). Similar results have been reported by Chenkual and Acharya (1990).

Studies conducted by Arrigo *et al*. (1993) in a silty loam soil revealed a statistically significant increase in aggregate stability and bulk density in crop rotations with cereals than with monoculture of legumes.

Newaj and Yadav (1994) observed a lower bulk density in all the crop sequences tried.

Long term cultivation of soil resulted in a decrease in the energy of required to disperse aggregates. Cultivation of soils resulted in aggregates more susceptible to disperson (Fuller *et al*., 1995).

In general continuous cropping with cereals increased the bulk density and decreased the aggregate stability of the soil. However inclusion of legumes in the cropping system have the ability to counteract this effect and in the long run and even improve the soil physically.

2.2.2 Soil chemical properties

2.2.2.1 Soil nitrogen/Nitrogen balance

Experiments conducted over 37 years in Kansas, USA indicated that fertilizer treatment and cropping systems had no effect on the trend of nitrogen, but influenced the speed with which equilibrium is reached at its ultimate level (Dodge and Jones, 1947).

Haas *et al*. (1957) conducted a study on the effect of cropping patterns on the nitrogen content at 14 locations in the Great Plains of USA. The nitrogen loss varied from 24 to 60 per cent, with an average loss of 39 per cent over a period of 36 years.

Sharma and Saxena (1970) studied the balance of nitrogen in the soil under four cropping sequences and found that under double cropped sequences a positive balance of nitrogen was maintained.

Clark and Mack (1974) observed an increase in soil nitrogen under continuous cropping for four years, without the addition of fertilizers.

Paeth and Azizi (1974) reported that soil nitrogen increased under rotations including the perennial forage, alfalfa.

Nair *et al*. (1975) conducted a field experiment consisting of five rice based cropping systems. They observed that the available nitrogen of the soil improved slightly after leguminous crops were grown. They also found that the changes in the soil nutrient status were temporary and the soil reverted to near initial status after the subsequent crops.

In an experiment conducted in the wet lands of Vellayani (Kerala) by Sasidhar (1978) it was seen that the rice crops in all the cropping sequences tried, reduced the nitrogen content of the soil. The nitrogen content of the soil was found to increase after cowpea and groundnut crops. The cropping sequence, rice-rice-sesamum exibited a continuous reduction in the nitrogen content of the soil.

Crop removal of nitrogen in intensive cropping sequences (3 crops per year) can exceed 500 kg nitrogen per hectare (Tandon, 1978).

In a rice based multiple cropping study at Coimbatore, the nutrient balance was very much affected by fertilizer nitrogen levels. There was a positive balance when full dose of recommended level of nitrogen was applied to each rice crop and the balance tended to be negative when only half the nitrogen was applied to either of the rice crops (Purushothaman, 1979).

The field experiment conducted by Deka and Singh (1984) on the effect of crop rotations on fertility status of soil, revealed that the soil nitrogen content increased under all crop rotations except rice-wheat, maximum being under rice-berseem rotation.

Mahapatra *et al*. (1985) reported that the nitrogen balance in rice-rice systems were observed to be negative even when 100 per cent of recommended level of nitrogen was applied to each of the rice crops.

Experiments using ^{15}N tagged fertilisers have shown that, although a considerable portion of added nitrogen may be immobilised by the soil, its availability to the succeeding crops is less than 2 per cent (Chatterjee *et al.*, 1989).

Yadav *et al.* (1991) observed that the apparent nitrogen balance was negative in the case of the cropping system, rice-maize-maize + cowpea (fodder).

Singha *et al.* (1993) reported that the total nitrogen content of the soil was not affected significantly by the different cropping systems. The initial nitrogen status was found to be maintained even after one year of cropping, possibly owing to the fixation of nitrogen by the legumes.

Inclusion of legume crops like grain cowpea in rice based cropping systems resulted in a positive balance for soil nitrogen (Singh *et al.*, 1996b).

Thus the nitrogen status of the soil is not affected by certain cropping systems and in some cases even severe reduction in soil nitrogen is seen. In general, inclusion of legumes in cropping systems improved the nitrogen content of the soil.

2.2.2.2 Soil phosphorus/Phosphorus balance

Sharma and Singh (1970) reported that the available phosphorus content of the soil increased with crop sequences including legumes.

Sadanandan and Mahapatra (1973) from their studies at C.R.R.I., Cuttack, reported that there was no noticeable gain or loss of total phosphorus from all the cropping patterns during both the years. However, the balance sheet of available phosphorus in the soil showed a loss in all the treatments.

Nair *et al.* (1975) reported that the available phosphorus content of soil was higher in rotations involving legumes.

Biswas *et al.* (1977) studied the accumulation and decline of phosphorus in the soil after two cycles of crop rotation. The initial low status of available phosphorus improved to medium or high levels commensurate with the rates of fertilizer phosphorus application. The status of available phosphorus declined when phosphorus was not applied.

Sasidhar (1978) reported a reduction in available phosphorus content of the soil after rice crop. Available phosphorus content of soil was found to increase after sweet potato, cowpea, sesamum and groundnut, the maximum being after cowpea. However, the balance sheet of available phosphorus showed a loss in all the treatments studied.

The phosphorus content of the soil had been found to increase after each rotation, by Singh and Sandhu (1980).

Studies on rice based multiple crop sequences conducted by Deka and Singh (1984) at Pantnagar revealed a higher available phosphorus content of soil during both the years under rice-berseem rotation as compared to others. The balance of phosphorus was found to be always positive ranging from 5.7 ppm in rice-wheat to 9.4 ppm in rice-berseem rotation.

In a three year study at Ludhiana, there was a positive balance of phosphorus in the rice-wheat-greengram cropping sequence (Sharma *et al*., 1985).

Singh and Nambiar (1986) reported a depletion of soil - available phosphorus under rice-wheat-jute rotation at moderate dose of fertilizer.

Yadav *et al*. (1991) observed a positive balance for soil phosphorus in all the crop sequences tried.

Studies conducted by Singha *et al*. (1993) in the sandy clay-loam soils of Diphu (Assam) revealed that the available phosphorus status of the soil was not affected significantly by the different cropping sequences studied. However, the available phosphorus status of the soil declined from the initial status after three years of cropping. This was attributed to the leaching of fertilizer below the top soil, high fixation of phosphorus and lowering of soil pH.

In general, plant species differ in their capacity to use native and added phosphorus and the residual effect of applied phosphorus will also differ with the crop components of the system. Further the phosphorus content of the soil depends on several factors like the nature and content of clay, soil reaction and the adsorption and fixation of the soil.

2.2.2.3 Soil potassium/Potassium balance

Potassium removal by many crops is equal to or sometimes even greater than the removal of nitrogen. For the same quantity of grain production, potassium depletion is more in traditional farming due to removal of potassium-rich rice straw than in mechanised farming.

Ghosh and Kanzaria (1964) reported there was no change in the potassium content of the soil by continuous cultivation with the addition of potassic fertilizers.

Sadanandan and Mahapatra (1972a) observed that after completion of each rotation cycle the total potassium content of the soil decreased, the maximum decrease being observed in continuous cultivation of rice.

Lal (1973) reported that the available potash decreased when cropping intensity increased from 130 per cent to 300 per cent. The decrease was found to be maximum under 400 per cent cropping intensity.

In the rice-rice cropping pattern there was a slight gain in the available potassium (Sadanandan and Mahapatra, 1974b).

Clark and Mack (1974) found that the exchangeable potassium decreased under continuous cropping for four years without fertilizers.

Studies conducted by Raghavulu and Sreeramamoorthy (1975) revealed that rotations involving cereals and pulses resulted in a decrease in available potassium status at the end of three years.

Studies on rice based cropping systems conducted by Sasidhar (1978) showed that the exchangeable potassium status of the soil increased after sweet potato, cowpea, sesamum and groundnut, whereas after the rice crops it decreased. The maximum increase was brought about after cowpea crop.

Purushothaman (1979) reported that there was a slight decrease in available potassium in the rice based cropping systems studied (rice-rice-rice, rice-rice-sorghum + cowpea, rice-rice-maize-soybean and rice-rice-fingermillet-greengram). The uptake of potassium by the crops in all the systems was higher than the quantity applied through fertilizers and so the deficit was met from the soil reserves.

In a field experiment conducted at the Crop Research Centre, Pantnagar, it was observed that the available potassium decreased considerably in the rice-berseem crop rotation. On the contrary it increased in all three rotations of

300 per cent intensity (rice-wheat-greengram, rice-wheat-maize + cowpea and rice-mustard-green gram). The available potassium content was highest under rice-mustard-green gram followed by rice-wheat-green gram rotation. The balance of potassium was also positive in all rotations except rice-berseem (Deka and Singh, 1984).

Several workers have reported the depletion of soil available potassium under different rice based cropping sequences (Singh and Nambiar, 1986; Soni *et al*., 1988; Thakur and Sharma, 1988).

Yadav *et al*. (1991) reported a negative balance for soil potassium in all the rice based cropping sequences tried.

Results of the studies conducted by Singha *et al*. (1993) revealed that the available potassium content of the soil was the lowest under rice-green gram - rape seed rotation. They opined that this might be due to the addition of the lowest quantity of potassium in that sequence. Higher quantity of available potassium found under rice-sesame-lentil and rice-soybean-rape seed sequences was attributed to the lower total yield and the consequent lower exhaustion of soil available potassium.

Pillai (1993) observed that with regard to potassium, all the cropping systems studied had a negative balance except rice-rice-groundnut system. He attributed this to the absorption of potassium from the deeper layers and to litter fall.

2.2.2.4 Organic carbon

Prabhakara (1970) observed that the organic carbon content was higher throughout the year in the crop rotations involving four crops.

Continuous cultivation of rice was found to reduce the organic carbon content of the soil (Prasad and Jha, 1973).

Sadanandan and Mahapatra (1975) reported a decrease in the organic carbon content of the soil with a maximum decrease under the continuous cultivation of rice.

Cropping sequences involving legumes like cowpea and pigeon pea recorded a higher organic carbon content in the soil (Rao and Sharma, 1976).

In a field experiment conducted by Deka and Singh (1984) in the sandy loam soils of Pantnagar, it was seen that the organic carbon content of the soil increased after rice-berseem, rice-lentil and rice-mustard-green gram rotations. Organic carbon content of the soil was lowest after the rice-wheat rotation.

Gill *et al*. (1984) reported that cropping sequences decreased the organic carbon content of the soils.

Mandal *et al.* (1984) observed a marked decrease in the per cent organic carbon content of the soil, as a result of continuous cropping.

Organic carbon content of the soil has been reported to decrease after continuous cropping for eight years, the maximum loss being in the rice-wheat rotation (Deka *et al.*, 1984).

Sanchez and Lopez (1986) reported a decline in the organic carbon content of the soil, due to continuous cultivation. However, the rate of fall was slower in plots which received green manure or organic manure.

Sahu *et al.* (1988) reported that while the organic carbon content of the soil decreased with continuous cultivation of cereals, it increased with cropping patterns like rice-cowpea, rice-green gram and rice-groundnut.

The experiment conducted by Singha *et al.* (1993) revealed the highest organic carbon content under rice-green gram-rapeseed followed by rice-soybean-rapeseed and rice-blackgram-wheat. They attributed this to the greater leaf production and shedding of leaves in the legumes.

In a study conducted on the sustainability of rice based cropping systems, introduction of legume crops like grain cowpea was observed to have a positive influence on the organic carbon content of the soil (Singh *et al.*, 1996b).

2.2.2.5 Soil reaction

In five (potato-rice-rice; maize-rice-rice; groundnut-rice-rice; rice-jute-rice; rice-rice) of the cropping patterns studied by Sadanandan and Mahapatra (1972b) it was observed that there was a decrease in soil pH in all cropping patterns after each cycle. The maximum decrease in soil pH was noticed in rice-jute-rice and rice-rice cropping patterns which received inorganic fertilizers alone. They opined that the fall in pH was more because of the sandy loam textured soil of the experimental site in which leaching was high.

Lal (1973) observed that the soil pH decreased with increase in crop intensity from 100 to 400 per cent.

A slight reduction in pH at the end of three years of experimentation was noted by Raghavulu and Sreeramamoorthy (1975), in all crop rotations involving rice, wheat, maize, greengram, bengalgram, barley and blackgram.

Juo and Lal (1975) reported that the continuous cropping for more than three years resulted in a decrease in the soil pH.

Sasidhar (1978) reported a decrease in soil pH in all the five cropping patterns (rice-rice-sweet potato; rice-rice-cowpea; rice-rice-sesamum; rice-rice-groundnut; rice-rice-rice) after each cycle.

Thakur and Sharma (1988) observed that the soil pH did not change significantly even after three years of cropping, although the initial pH decreased slightly.

Singha *et al.* (1993) could not observe any significant difference in soil pH due to the different rice based cropping sequences.

Studies on the changes in soil properties under intensive cropping conducted by Newaj and Yadav (1994) showed a decrease in soil pH from the initial soil pH value of 7.8 to a lower pH value ranging from 7.5 to 7.6 under all the crop sequences, after two years.

2.3 Effect of preceding crops on the performance of succeeding crops in rice based cropping systems

Various crops when grown on soils leave certain after effects which exert a marked influence on the growth of the subsequent crops. In some cases the effect is beneficial, while it is injurious in some other cases.

Grist (1965) reported a decline in rice yields, when the crop was grown continuously. However, Morachan and Subbiah (1972) could not observe any reduction in yield of rice under continuous monocropping of rice.

Rice based cropping systems involving lowland rice and upland crops are of some contradiction. In lowlands, due to puddling the physical properties of soil may be unfavourable to the succeeding upland crops (Melhuish *et al.*, 1976). The conditions in low land rice fields are such that nitrogen and probably phosphorus could be limiting nutrients for the upland crops that follow rice in a sequence (Griffin and Brandon, 1983). Nodulation of legumes grown after wetland rice is profuse even without rhizobial inoculation (Rerkasem and Rerkasem, 1984). Prasad (1985) and Sreekantan (1987) did not observe any depressing effect of the preceding rice crop on the succeeding legume.

Legume crops are known to fix nitrogen, improve soil productivity and benefit the succeeding crop yield compared to non-legume crops in rotation, thus affecting considerable economy in plant nutrients.

According to Sardor (1975) preceding leguminous crop increased the yield of rice by 12.8 to 13.7 per cent.

Misra and Misra (1975) reported that cowpea benefited the following cereal crop of rice in sequence and the yield of rice crop increased by 2-4 q ha^{-1}.

Singh and Singh (1975), Mahapatra *et al.* (1981), De *et al.* (1983), Rekhi and Meelu (1983), Deka and Singh (1984), Mahapatra *et al.* (1985), Pandey *et al.* (1985), Prasad (1985), Sreekantan (1987), all have reported the beneficial effect of inclusion of legumes in rice based cropping systems.

In a five year field study conducted by Tajudeen *et al.* (1989) to study the effect of summer crops on the long term productivity of rice, it was observed that the residual effect of summer crops like green manure green gram, groundnut and cowpea on the subsequent wet season and dry season rice were more or less the same. But the long term effect of summer cropping on paddy was considerable. At end of the fifth year, the plots cultivated with groundnut in summer registered the highest yield increase (63 per cent) in dry season rice.

John *et al.* (1989) reported that a preceding crop of cowpea, significantly increased the grain yield of the succeeding rice crop.

Hegde and Dwivedi (1993) evaluated a number of leguminous crops for the contribution they make in meeting the nitrogen requirement of the succeeding rice crop and it was found that as much as 50 to 60 kg nitrogen per hectare might be made available.

Grain yield of rice was observed to be significantly higher under green gram-semidry rice system, than under fallow-semidry rice system (Reddy *et al.*, 1993). They opined that the biological efficiency of legumes was due to its contribution to soil organic matter and nitrogen.

Ali (1993) studied the effect of summer legumes on productivity of succeeding rice in sequential cropping. He observed a mean yield increase of 429 and 159 kg of grain per hectare due to preceding fodder cowpea and green gram respectively.

Studies conducted at the Cropping Systems Research Centre, Karamana for investigating the performance of different summer crops raised in rice fallows and their influence on the succeeding rice crop, revealed that rice after cowpea recorded the highest yield (5.3 t ha^{-1}) followed by rice after groundnut and rice after bhindi. The lowest yield was recorded by rice grown after sesamum (Kumar *et al.*, 1993).

Padhi (1993) reported that maximum yield of rice was secured in rice-garden pea-cowpea sequence and the minimum in rice-garden pea-okra sequence.

Sinsinwar (1995) observed that the grain and straw yields of rice in Egyptian clover-rice sequence were maximum and lowest when the preceding crop was wheat.

Quayyum and Maniruzzaman (1996) conducted a field experiment at Joydebpur, Gazipur (Bangladesh), to study the effect of preceding crops on the succeeding crop of rice. The yield attributes and grain yield of rice were significantly higher when the crop was grown after sole blackgram.

Continuous growing of cereal crops like rice may impoverish the soil of its nutrients and deteriorate its biological productivity. Inclusion of legumes, which are considered as soil fertility restorers may therefore prove beneficial for sustainable production.

2.4 Effect of integrated use of organic, inorganic and/or biological fertilisers on the growth, yield and nutrient uptake of rice/rice based cropping systems

The basic principle behind the "integrated nutrient supply" concept is to use both chemical and organic fertilizers in the most efficient manner because of their limited availability and high prices. The complementary use of chemical fertilizers and organic manures will augment the efficiency of chemical fertilizers as well as that of organic manures in order to maintain a higher level of crop productivity (Gaur and Singh, 1982). The key to successful culture of rice is to supply large quantity of nitrogen at a low level of intensity. This is very easily possible and economically feasible when inorganic fertilisers are applied in conjunction with organic substances (Chatterjee and Maiti, 1988). The integrated approach sustains soil health and productivity in the long run (Mohanty *et al.*, 1992) besides meeting the nutritional deficiencies which are likely to occur due to continuous and intensive cultivation (Nambiar and Abrol, 1989; Patnaik *et al.*, 1989; Suzuki *et al.*, 1990; Prasad and Power, 1991).

Pandalia (1980) reported that the application of inorganic fertilizers in conjunction with farmyard manure or compost gave significantly higher grain yield over no compost. The plots which received inorganic nitrogen alone gave slightly lower grain yields in the following year.

The combined use of 12 t of farmyard manure and 80 kg ha^{-1} of nitrogen not only gave as much rice yield as that obtained by the application of 120 kg ha^{-1} of nitrogen but also gave a residual effect equivalent to 30 kg each of nitrogen and phosphorus in the succeeding wheat crop (Meelu, 1981; Meelu *et al*. 1981).

Gaur and Singh (1982) reported that the response of rice to nitrogen as chemical fertiliser increased when it was used in combination with farmyard manure and a saving on fertiliser nitrogen could be effected.

Ghose (1984) observed that in direct seeded rice-wheat crop sequence, application of farmyard manure in conjunction with chemical fertilisers gave better results than inorganic fertilisers alone.

Cattle manure was found to have cumulative beneficial effect on rice. Only 25 to 30 per cent of nitrogen from cattle manure is absorbed by the rice plant during the current growing season. Continuous application helps to accumulate nitrogen and other nutrients in the soil. These accumulated nutrients are gradually mineralized and utilized by the successive rice crop (Inodo, 1984).

Meelu and Morris (1984) observed that in an alluvial soil, integrated use of 12 t ha^{-1} of farmyard manure and 60 kg ha^{-1} of nitrogen as chemical fertiliser gave as much rice yield as 120 kg ha^{-1} of nitrogen. Farmyard manure also gave a residual effect equivalent to 30 kg each of nitrogen and phosphorus per hectare in the succeeding wheat crop.

Several multilocation on-farm trials conducted to study the management of fertilisers in a fixed single year rice-rice cropping system revealed that the total productivity, net returns and cost-benefit ratio of the system as a whole were in favour of combined use of organic manures and/or biofertilizers with reduced dose of mineral fertilizers (Mahapatra *et al*., 1985).

Roger and Watanabe (1986) reported that the carry-over effect of biofertilizers applied to rice on the succeeding crops is scarce and debatable.

Fertilizer nitrogen source applied in conjunction with bio-organic sources was better utilized than the inorganic source alone (Saravanan *et al*., 1987).

Gopalaswamy *et al*. (1989 b) reported a significant increase in rice grain yield due to *Azospirillum lipoferum* inoculation to soil, fertilized with 75 kg nitrogen per hectare.

Panda and Sahoo (1989) advocated the application of 5 to 10 t ha^{-1} of farmyard manure in addition to fertilisers for sustained rice production in rice based cropping systems.

Data for seven years (1978-'79 to 1985-'86) from the permanent manurial trial at the Rice Research Station, Kayamkulam revealed that highest yield was recorded by treatments that received either full quantity of nitrogen (80 kg ha^{-1}) as cattle manure or three-fourth the nitrogen requirement (60 kg ha^{-1}) as ammonium sulphate and one-fourth (20 kg ha^{-1}) as cattle manure along with 40 kg ha^{-1} each of phosphorus and potassium (Sushamakumari *et al.*, 1989).

Sharma and Mitra (1990) reported that application of organic materials increases grain and straw yields of rice and succeeding wheat and uptake of nitrogen and other nutrients in wheat.

When a part of the nitrogen requirement of rice (50 per cent) was substituted by farmyard manure or green leaves the yields were significantly superior to that of chemical fertilizers alone (Johnkutty and Anilakumaran, 1991).

In a field experiment conducted by Arumugam *et al.* (1992) to study the effect of integrated nutrient management on rice yield in lowland conditions, rice yields obtained with 100 per cent nitrogen (soil test lab recommendation) was on par with 75 per cent nitrogen combined with farmyard manure (5 t ha^{-1}) and *Azospirillum*.

Chakravorti and Chalam (1992) observed that the combined application of farmyard manure and urea (1:1) was not good in alluvial and laterite soils, but gave good yield in sandy soils.

In long term fertilizer experiments, annual incorporation of 10-15 t ha^{-1} of well decomposed farmyard manure contributed 23 to 27 per cent of the total grain yield response in rice based cropping systems like rice-rice and rice-wheat (Kundu and Pillai, 1992).

Tanveer *et al*. (1993) reported that the application of farmyard manure at the rate of 12 t ha^{-1} exerted significant influence on yield and yield attributing characters of rice compared with no farmyard manure.

Malik and Jaiswal (1993) obtained significantly equal grain yield of rice under 58 kg N ha^{-1} applied through prilled urea and half dose of prilled urea + half as farmyard manure. Further, it was concluded that half to two-thirds of chemical nitrogen can be substituted by organic nitrogen (farmyard manure) without any yield loss depending upon the rate of nitrogen applied to rice crop.

Hegde and Dwivedi (1993) observed that it was possible to substitute a part of fertiliser nitrogen needs of kharif crop by farmyard manure without any adverse effect on the total productivity of the system in major rice based cropping systems such as rice-rice, rice-wheat and rice-maize. Further, the fertiliser needs of rabi crop could be reduced by 25 per cent by substituting 25 per cent nitrogen needs of kharif crop through farmyard manure in a rice-rice system.

Mathew *et al*. (1993) attempted an integration of organic, bio and mineral fertilisers in a study at the Agronomic Research Station, Chalakudy as a means to reduce production cost and improve the productivity of rice in poorly fertile sandy loam soils. A reduction in the mineral fertilizer requirement to the extent of one-third dose of nitrogen and potassium and two-third dose of phosphorus from a recommended fertilizer dose of 70:35:35 kg ha^{-1} of N, P_2O_5 and K_2O was found to be feasible when farmyard manure was regularly applied in all seasons at the rate of 5 t ha^{-1}.

A thorough scrutiny of yield data (of tall as well as dwarf indica varieties in both the seasons) of permanent manurial experiments, conducted at the Regional Agricultural Research Station, Pattambi clearly indicated the beneficial influence of farmyard manure, alone or in combination with inorganic fertilizers to supply half the quantity of nitrogen and full dose of phosphorus and potassium in rice based cropping systems (Padmaja *et al*., 1993).

Varghese (1993) reported that chemical farming without organics showed a steady decline in yield as years passed by, whereas organic farming gave stable yields and even a marginal increase during the wet second crop season, in the sandy loam soils of the Onattukara tract. A least response of 300 kg rice was noticed to applied nitrogen over no nitrogen (1300 kg ha^{-1}) which was 60 per cent of the maximum yield of 2300 kg ha^{-1} in organic farming.

Farmyard manure at the rate of 5 t ha^{-1} + 50 per cent recommended inorganic fertilisers gave significantly more yield than the 100 per cent recommended inorganic fertilisers (Gill *et al.*, 1994).

Prasad (1994) reported that the integrated use of farmyard manure at the rate of 12 t ha^{-1} + 80 kg ha^{-1} of nitrogen gave as much rice yield as with 120 kg ha^{-1} of nitrogen as mineral fertilizer.

Rathore *et al.* (1995) reported significantly higher (16-17 per cent) rice grain yield under treatments of farmyard manure at the rate of 5 t ha^{-1} combined with 60 kg N + 37.5 kg P_2O_5 + 22.5 kg K_2O per hectare. The residual effect of organic manure with inorganic fertiliser was significant on the grain yield and nutrient uptake of succeeding wheat crop.

A field experiment was conducted by Rajput (1995) at Faizabad to study the direct effect of different sources of organic matter, alone and in combination with different rates of NPK in rice and their residual effect on subsequent crop of wheat. Addition of organic matter in conjunction with 50 per cent or more of NPK gave higher rice grain yield than the addition of organic matter alone. This treatment also showed a significantly high residual effect on wheat.

A study carried out at four locations in coastal area for 4 to 10 years in rice-rice system indicated that 25 to 50 per cent nitrogen need of rice in rainy season could be substituted by organic sources like farmyard manure (Hegde, 1996).

Jana and Ghosh (1996) conducted a field experiment to study the integrated nutrient management through organic and inorganic sources of fertilizer in a rice-rice crop sequence. Grain yield of rainy season rice was higher under 100 per cent recommended dose of NPK fertilizer supplied through either inorganic source alone or 75 per cent through inorganic and 25 per cent through organic source. In winter season maximum yield and nutrient uptake was recorded when 100 per cent of NPK was applied as inorganic source.

In a field experiment conducted by Singh *et al.* (1996a), to study the influence of nitrogen economisation in rice-wheat crop sequence, it was observed that the application of 60 kg N ha^{-1} + 10 t ha^{-1} of farmyard manure recorded the highest grain and straw yields both for rice and wheat.

A study on rice made during 1987 to 1990 at Cuttack under shallow, submerged situation in an alluvial sandy-loam soil revealed that integrated nitrogen management system involving farmyard manure and inorganics, the organic source meeting 37.5 kg N ha^{-1} gave comparable yields to the application of 75 kg N ha^{-1} as inorganic nitrogen alone (Rao *et al.*, 1996).

Application of 75 per cent of the recommended doses of NPK in conjunction with 10 t of farmyard manure per hectare produced highest and significant number of panicles per square metre, number of grains per panicle, per cent of filled grain, test weight, grain yield and straw yield of rainfed transplanted rice (Puste *et al.*, 1996).

2.5 Effect of integrated application of organic manure and inorganic fertilisers on the physico-chemical properties of the soil

Continuous use of chemical fertilisers alone have been reported to exert an adverse effect on the physical, chemical and biological characteristics of the soil, which in turn affect the soil health and crop productivity. Integration of organic matter with chemical fertilisers keep up the productive capacity of soils or rather enhance the yield.

Biswas *et al.*, (1969) studied the changes in soil physical and chemical properties in the permanent manurial trial on red silty clay loam soil of Ranchi being carried out since 1956. Significant increase in the organic carbon content was observed due to the combined application of farmyard manure and inorganic fertilisers. The soil pH was hardly modified by the integration of organics and inorganics. However, a lowering of soil pH was observed due to the application of inorganic fertilisers alone. Farmyard manure alone or in combination markedly improved the structural status of the soil through better soil aggregation. It also improved the water holding capacity of the soil.

Manickam and Venkitaramanan (1972) observed that in the new permanent manurial trial at Coimbatore, plots which received NPK as inorganic fertilisers or cattle manure recorded a favourable increase in pore space, volume expansion and water holding capacity.

Continuous application of farmyard manure in combination with chemical fertilisers proved to be beneficial in improving the water holding capacity of soil (Prasad and Singh, 1980).

Sinha *et al.* (1980) observed a decrease in bulk density by the application of farmyard manure in combination with chemical fertilisers, whereas the continuous use of chemical fertilisers alone caused an increase in bulk density.

Muthuvel *et al*. (1981) could not find any significant change in the water holding capacity of soil by the continuous application of farmyard manure. However, the bulk density of the soil decreased with increase in organic matter.

Laddha *et al*. (1984) observed that hydraulic conductivity, water stable aggregates and water holding capacity of the soil increased with increasing doses of farmyard manure.

Organic matter accumulation in soils from long term application of organic materials decreased the bulk density, crushing strength, solid ratio and specific gravity and increased the porosity and water stable aggregates (Nakaya and Motomura, 1984).

Saravanan *et al*. (1987) observed that the in situ pH of soil was not influenced by the combined application of bio-organic and chemical fertilisers, but a decreasing trend towards neutrality was noted upto 45 days after transplanting.

A six year field study showed that the application of farmyard manure in conjunction with nitrogenous fertilisers lowered the bulk density of soil and thus increased the cumulative infiltration of water. Total nitrogen, available phosphorus and organic carbon contents increased significantly due to farmyard manure, while the C:N ratio remained unaffected due to use of organics (Sharma *et al*., 1987). They also reported that the application of farmyard manure resulted in a significant increase in the soil pH.

Bulk density in long term application of organic manure was found to be lower in surface soil of non-application than nitrogen application. Aggregates of size bigger than 2 mm increased by long term application of organic manure. Soil pH decreased and organic carbon, total nitrogen, available phosphate and available potassium contents increased with long term application of organic manure (Yoo *et al*., 1988a; Yoo *et al*., 1988b).

Lal and Mathur (1989) observed a decrease in bulk density with organics either alone or in conjunction with inorganics whereas inorganics alone increased it. Maximum reduction in bulk density (9 per cent) was observed only after 28 years. Soil aggregation and water holding capacity was found to be significantly higher in soils receiving organics than inorganics.

Udayasoorian *et al*. (1989) reported that the continuous application of organic manure over a period of seven years in an intensive cropping system significantly increased the total and available nitrogen contents of the soil.

Combined application of farmyard manure and chemical fertilisers increased nitrogen, phosphorus and potassium contents of the soil (Biswas and Benbi, 1989).

Nambiar and Abrol (1989) reported a moderating effect of organic manure in combination with inorganic fertilisers on soil reaction particularly under acid soils. They also observed an improvement in the sustained availability of N, P and K.

Badanur *et al.* (1990) reported a significant increase in the infiltration rate, bulk density, water holding capacity, organic carbon, available nitrogen and available phosphorus contents of the soil as a result of addition of organic matter.

Jo (1990) observed that while the soil bulk density, strength and dispersion ratio decreased, the porosity and percentage of water stable aggregates of paddy soil increased significantly after annual applications of compost at the rate 7.5 t ha^{-1} over twenty years.

The growth promoting substances and soil structure developing materials released during the decomposition of organic manure helps in providing the soil with a better structure, water holding capacity, bulk density, etc. Integration of farmyard manure with chemical fertilisers helps to maintain the soil pH, through the buffering action of farmyard manure (Johnkutty and Anilakumaran, 1991).

Brar (1991) observed that bulk density of the soil was significantly and negatively correlated to the organic carbon content.

Sharma and Mittra (1991) reported that the application of farmyard manure improved the soil fertility appreciably over the initial content. It improved the organic carbon, available nitrogen and available phosphorus contents of the soil.

Kumar *et al*. (1992) evaluated the physical properties of the soil (sandy loam) as influenced by continuous application of farmyard manure in a rice-wheat cropping system. Application of farmyard manure did not affect the bulk density and infiltration rate of the soil. Water stable aggregates larger than 2 mm were significantly more in farmyard manure treatment.

Kundu and Pillai (1992) opined that bulky organic manures like farmyard manure, besides serving as source of plant nutrients, help to improve soil aeration, permeability, aggregation, water holding capacity, nutrient holding capacity and biological properties of soils, thereby enhancing the fertiliser use efficiency when applied in conjunction with mineral fertilisers.

Varghese (1993) reported that eventhough the organic carbon content of soil was not improved by organic farming with cattle manure, it improved the soil structure and water holding capacity and maintained soil acidity at levels favourable for rice growth.

Results of the permanent manurial trial being conducted at the Regional Agricultural Research Station, Pattambi, since 1961 showed that the soil physical parameters like bulk density, particle density, porosity and moisture retention capacity were not affected significantly by the various treatments. All treatments which included cattle manure revealed significantly higher values for organic carbon, available phosphorus and available potassium contents (Padmaja *et al*. 1993).

Sharpley and Smith (1995) observed that manure application increased the amounts of organic nitrogen, but had little influence on the distribution or availability of nitrogen forms measured. In the contrast with nitrogen, manure increased available inorganic phosphorus fractions.

Soil CEC, total organic carbon content and total nitrogen increased with increasing rates of manure (Gao and Chang, 1996).

Madhu *et al*. (1996) observed that the integrated use of recommended dose of fertiliser plus farmyard manure at the rate of 5 t ha^{-} did not produce any appreciable change among the various soil physical properties. However, the bulk density was observed decreasing after five years of cropping. The total and available N, available P and availble K were found to increase. Continuous application of inorganic fertilisers was found to have a depressing effect on the soil pH.

Sheeba and Chellamuthu (1996a) reported a decrease in bulk density and particle density and an increase in water holding capacity as the result of application of 100 per cent NPK + farmyard manure.

Application of farmyard manure conjointly with 100 per cent NPK registered the highest organic carbon, total nitrogen, total phosphorus and total potassium contents in the soil (Sheeba and Chellamuthu, 1996b).

In general, the integrated use of organic manures and chemical fertilisers help in maintaining stability in crop production on certain soils through supply of macronutrients and correction of marginal deficiencies of secondary and micronutrient elements in course of mineralisation of organic manures on one hand and providing favourable soil physical and ecological condition on the other.

2.6 Role of *Azospirillum* in nutrient management of rice

Work on biological nitrogen fixation in rice soils have been extensively reviewed by Buresh *et al*. (1980), Watanabe and Brotonegoro (1981) and the results have been summarised by Lowendorf (1982) and Watanabe and Roger (1984).

2.6.1 Nitrogen fixation in association with rice

A saving of upto 35 per cent nitrogen in rice by the application of *Azospirillum* has been reported from TNAU (1980).

Kumar and Balasubramanian (1986) observed that *Azospirillum* treatments in rice saved 25 to 50 kg nitrogen per hectare.

Azospirillum treatments in the nursery and mainfield helped to save 25 to 50 per cent nitrogen without reducing the grain and straw yields in IR-20 variety of rice (Kumar and Balasubramanian, 1989). Similar results have been reported by Ramakrishnan *et al*. (1992) and Resmi (1993).

Azospirillum was found to fix about 20 to 30kg nitrogen per hectare and increased yield by 5 to 15 per cent. However, the crop response to inoculation was not always positive and was found to be highly variable (Singh and Kapoor, 1996).

2.6.2 Effect on growth characters, yield and yield attributes of rice

Azospirillum inoculation increased the root biomass of rice seedlings, thus providing maximum surface area for absorption of nutrients (Dewan and Subba Rao, 1979).

Subba Rao *et al*. (1979) found that inoculation of rice (Pusa 2-21) with *Azospirillum* increased the grain yield at 0, 40 and 60 kg nitrogen per hectare.

Natarajan *et al*. (1980) observed an increase in grain yield of rice (variety TNAU 4372) due to inoculation with *Azospirillum*.

Subba Rao *et al*. (1980) reported a 8.6 per cent increase in grain yield of rice (var. Triveni) by inoculation with *Azospirillum* in the presence of 35 kg nitrogen per hectare.

Karthikeyan (1981) reported that the dry matter accumulation in rice increased as a result of inoculation with *Azospirillum*.

Shivaradj (1981) observed a positive influence of *Azospirillum* inoculation on the number of tillers per hill leaf area index, dry matter production and thousand grain weight in the rice, variety IR-20.

Root inoculation with *Azospirillum* resulted in significant increase in grain and straw yields of rice especially at low levels of nitrogen (30 and 45 kg nitrogen per hectare) than at an application rate of 60 kg nitrogen per hectare (Rao *et al*., 1983).

Bacterisation of rice seedlings with *Azospirillum* alongwith an application of 90 kg nitrogen per hectare resulted in increase in the number of tillers per plant. It also increased the panicle weight, number of grains per panicle and the nutrient uptake by the grains. Combined effect of

Azospirillum and nitrogen at the rate of 30 kg ha^{-1} was more pronounced in increasing the yield (Prasad and Singh, 1984).

Somachoudhary (1984) observed a significant increase in plant height, fresh weight and dry weight of rice due to the application of *Azospirillum*.

Watanabe and Lin (1984) reported that root dipping and soil application of *Azospirillum* promoted early tillering and reproductive growth of wetland rice. But the total dry weight did not increase. A significant increase in the filling rate of grains and grain yield per plant was observed.

Jayaraman and Ramaiah (1986) reported that the growth characters such as plant height and total number of tillers per hill were found to be maximum in treatments which received nitrogen at the rate of 75 kg ha^{-1} alongwith root dipping of *Azospirillum*. This treatment also recorded a significantly higher grain yield.

Nayak *et al*. (1986) reported that *Azospirillum* inoculation on two rice varieties significantly increased the plant height, tiller number and dry weight of root and shoot. The grain yield of the varieties was also significantly increased by the treatment.

Balasubramanian and Kumar (1987) revealed that the combined application of *Azospirillum* markedly increased the grain and straw yields of rice at all nitrogen levels.

Gopalaswamy and Vidhyasekharan (1987a) in a field experiment with rice (ADT-36) found that split application of *Azospirillum* (through seed, seedling and soil) increased the plant height, number of productive tillers, grain yield and straw yield.

In a study conducted at Coimbatore, Murali and Purushothaman (1987) observed that *Azospirillum* inoculation increased the root surface area, number of productive tillers per square metre, grain yield and straw yield. Grain yield obtained with *Azospirillum* alongwith 75 kg nitrogen per hectare was higher than that with 100 kg nitrogen per hectare alone.

A pot culture experiment conducted revealed an improved root mass for rice as a result of *Azospirillum* inoculation. It also increased the grain yield and nitrogen uptake. It was concluded that the nitrogen fixation and production of growth promoting substances by *Azospirillum* might have contributed to this improvement (Prasad and Singh, 1987).

Subramanian (1987) reported a marked influence of *Azospirillum* inoculation on the productive tillers, panicle number, panicle length and panicle weight. Significant increase in the number of field grains per panicle and thousand grain weight was noticed due to *Azospirillum* inoculation, while the sterility percentage was considerably reduced. *Azospirillum* inoculation recorded maximum grain yield, while the straw yield and harvest index were not influenced by the treatment.

TNAU (1987a) reported a maximum grain yield of 3 t ha^{-1} with 100 per cent recommended nitrogen plus seed and soil application of *Azospirillum*. Straw yield also showed a significant increase.

Reports from TNAU (1987b) have shown that the application of *Azospirillum* in three equal splits, through seed, root and soil resulted in higher grain yield.

Alice and Subramanian (1987) evaluated the effect of *Azospirillum* on the grain yield of the rice variety, ASD-16. It was observed that the yield difference due to *Azospirillum* treatment as well as the interaction between *Azospirillum* and nitrogen levels were not significant.

Azospirillum inoculation increased the number of productive tillers, grain yield and straw yield of all the tested varieties namely, TKM-9, ADT-36, IR-50 and ADT-37 (Gopalaswamy and Vidhyasekharan, 1988).

In a field experiment conducted by Jayaraman and Purushothaman (1988), inoculation of *Azospirillum* biofertiliser (root-dipping) alongwith 75 kg ha^{-1} of nitrogen gave a significant yield increase both in the wet and dry seasons.

Mahapatra and Sharma (1988) observed that root dipping of seedlings in 2 per cent solution of *Azospirillum* increased grain yield only slightly (2 quintals/ha) over control.

Purushothaman (1988) found that the combined application of *Azospirillum* (seed plus soil) increased the grain and straw yields of the rice variety, TKM-9. Response was more at 75 kg and 80 kg nitrogen per hectare than at 100 kg. He opined that the beneficial effect of *Azospirillum* application is due to nitrogen fixation and enhanced root proliferation.

Kumar and Balasubramanian (1989) reported that both the methods of *Azospirillum* application (nursery plus main field, main field alone) markedly increased the number of tillers and plant dry weight.

Studies conducted at TNAU (1989a) revealed that application of *Azospirillum* at 1 kg with seed, 2 kg in nursery and 2 kg in main field resulted in 7 per cent increase in the grain yield.

On-farm trials conducted in the Tanjavur district of Tamil Nadu, gave a 10.7 to 13.6 per cent increase in grain yield, as a result of *Azospirillum* inoculation (TNAU, 1989b).

At lower nitrogen levels, *Azospirillum* did not give significant increase in yield but at higher levels of 75 kg nitrogen per hectare, it increased the grain yield and straw yield significantly (Gopalaswamy *et al.*, 1989a).

Azospirillum applied through both seed and soil increased the productive tillers, grain yield and straw yield of rice (Gopalaswamy *et al.*, 1989b).

Kumar and Balasubramanian (1989) observed that *Azospirillum* inoculation markedly increased the grain yield, straw yield and the total nitrogen uptake. Grain yield obtained with 50 per cent nitrogen and *Azospirillum* inoculation in the nursery and main field were on a par with 100 per cent nitrogen alone.

Reports from TNAU (1990) showed an yield increase of 22.6 per cent over the farmers' practice, as a result of *Azospirillum* inoculation.

Jayaraman (1990) reported that the application of *Azospirillum* alongwith suboptimal doses of either 75 kg or 50 kg nitrogen per hectare showed an increasing trend in the number of productive tillers, panicle length, number of filled grains and thousand grain weight.

Combined application of *Azospirillum* (seed, seedling root dip and soil application) increased the grain yield significantly, but the straw yield showed no significant difference (Subramanian and Rangarajan, 1990).

An augmentative effect of *Azospirillum* inoculation on the grain yield and straw yield of rice was reported by Govindasamy *et al*. (1992).

In a study conducted by Muthukrishnan and Purushothaman (1992) it was seen that *Azospirillum* inoculation exerted considerable influence on the nutrient uptake, number of panicles per square metre and yield of rice.

Ramakrishnan *et al*. (1992) observed that the combined application of *Azospirillum* through seed, nursery and main field increased the grain yield and straw yield of the tested varieties, ASD-16 and IR-20.

Resmi (1993) obtained significant increase in productive tillers per square metre, panicle weight, grain yield and straw yield as a result of inoculation with *Azospirillum*. However the number of grains per panicle, percentage of filled and unfilled grains and thousand grain weight were not influenced significantly by the treatment.

Vasudevan and Rangasamy (1995) reported that *Azospirillum* could increase grain yield, plant biomass, nutrient uptake, grain and tissue nitrogen and promote uniform flowering, tillering and panicle production.

Azospirillum inoculation along with 75 kg nitrogen per hectare significantly increased the grain yield of rice, being 18 per cent higher than that with 75 kg nitrogen per hectare alone. The bacterium promoted early tillering and reproductive growth of rice and significantly increased filling rate of grain and grain weight per plant (Gopalaswamy *et al.*, 1997).

Azospirillum colonise rice roots and fix atmospheric nitrogen. Inoculation with the bacterium increases the yield of rice and promotes plant growth by mechanisms other than nitrogen fixation.

2.7 Vermicompost as a component of integrated nutrient management

Vermicompost is an important component of organic farming. Rural and urban foul smelling biowastes can be converted into nutrient rich organic manures by vermicomposting, without much financial involvement. Vermiculture is the nature's own way to provide balanced nutrition to plants.

2.7.1 Crop response to vermicompost application

Kale and Bano (1983) reported the possibility of replacing chemical fertilisers with vermicompost in preliminary field trials conducted with paddy variety IR-20.

Altavinyte and Zimkuviene (1985) observed improved growth and yield of barley crop through the application of vermicompost.

Senapathi *et al*. (1985) reported that the application of vermicompost resulted in higher grain yield (95 per cent) and straw yield (128 per cent) in paddy.

Zao Shi-Wei and Huong Fu-Zhan (1988) observed an increase in the nutrient uptake and net production of wheat and sugarcane by the application of vermicompost in conjunction with chemical fertilisers.

Application of vermicompost was found to produce a 30 to 50 per cent increase in plant growth and nitrogen uptake and a 10 per cent increase in height, effective tillering and diameter of sugarcane (Shuxin *et al*., 1991). Kale *et al*. (1992) also observed an increased uptake of nitrogen and phosphorus in rice treated with vermicompost.

Perreira and Cruz (1992) opined that while vermicompost was not a substitute for fertiliser or lime, it was advantageous to use it in combination with one or both.

Bhawalkar and Bhawalkar (1993) have advocated the application of vermicompost at a basal dose of 2.5 t ha^{-1} so as to trigger the soil biology. They also observed that the transition from chemical nutrition to bionutrition was quick without any significant loss of yield.

Syres and Springett (1994) reported that vermicompost application enhanced the phosphatase activity in soil, which in turn improved the phosphorus availability.

Zachariah (1995) observed an increased potassium uptake in vermicompost applied plants. She attributed this to the increase in potassium availability by shifting the quilibrium among the forms of potassium, relatively unavailable forms to more available forms in the soil.

Application of 25 t ha^{-1} of vermicompost + full dose of inorganic fertilisers resulted in the highest uptake values for nitrogen, phosphorus and potassium in tomato (Pushpa, 1996).

Angadi and Radder (1996) reported that, in sorghum, recommended fertilisers along with 2.5 t ha^{-1} vermicompost and 10 kg ha^{-1} *Azospirillum* increased production and helped in sustaining soil nutrition status.

In the field experiments conducted at the Agriculture College and Research Institute, Madurai by Vasanthi and Kumaraswamy (1996) grain yields of rice, variety ADT-36, were significantly higher in treatments which received vermicompost at the rate of 5 t ha^{-1} along with recommended levels of N, P and K than in the treatment that received N, P and K alone.

2.7.2 Effect of vermicompost on the physico-chemical properties of the soil

Kale and Bano (1983) opined that by using vermicompost at the rate of 2.5 t ha^{-1} as fertiliser, it is possible to bring down the usage of chemical fertilisers to an extent of 50 per cent and found that it was not only economical but also helped in improving the physico-chemical properties of the soil.

Kale (1992) observed that vermicompost application enhanced the activity of nitrogen fixers which in turn led to the increase in total nitrogen content of the soil.

Soil physical properties such as porosity, aggregation, conductivity and dispersive power of wormcast fertilized soil were improved when compared with no wormcast amended soil in a pot culture experiment in paddy (Vijayalakshmi, 1993).

Kale (1994) observed that application of vermicompost improved the water holding capacity of the soil.

Pushpa (1996) reported a significant increase in the pH and organic carbon content of the soil due to vermicompost application. Availability of nitrogen, phosphorus and potassium were also significantly improved.

George (1996) reported that vermicompost application lowered the bulk density of the soil. Water holding capacity, porosity and mean weight diameter of the soil increased as a result of vermicompost application. Treatments which received vermicompost were reported to have higher content of available nitrogen, phosphorus and potassium in the soil.

Organic carbon content and fertility status as reflected by the available status of N, P and K were found to be higher in treatments that received vermicompost plus N, P and K than in the treatment with N, P and K alone (Vasanthi and Kumaraswamy, 1996).

In general, vermicompost not only improves the growth and productivity of crops, but also helps in the maintaining the physical, chemical and biological properties of the soil.

2.8 Nutrient removal by crops in the systems

2.8.1 Rice

Grist (1965) observed a removal of 16.3 kg N, 8.6 kg P_2O_5 and 18.3 kg K_2O for the production of one ton of rice.

Rice crop yielding 50 q of grain removed 80 kg N, 18 kg P and 100 kg K ha^{-1} (Sharma and Prasad, 1980).

De Datta (1981) has reported that under tropical conditions, for the production of every ton of rice the crop removes 16.2 kg N, 2.8 kg P_2O_5 and 16.7 kg K_2O.

Narang *et al*. (1990) observed that to produce 9.5 t ha^{-1} of unhusked rice, it removed 198 kg N, 31 kg P and 230 kg K ha^{-1} $annum^{-1}$.

Pathak and Ghose (1996) opined that rice being a heavy feeder removed on an average 18.9 kg N, 3.9 kg P_2O_5 and 26.4 kg K_2O per hectare to produce 1 t of grain.

2.8.2 Sesamum

Gopalakrishna *et al.* (1971) opined that the mineral nutrition of sesamum is rather complex considering the extraordinary uptake of nutrients.

Sasidhar (1978) reported that sesamum removed 12.09 kg N, 4.99 kg P and 15.4 kg K per ton of dry matter produced.

Regy (1996) observed a removal of 2.64 kg N, 5.04 kg P and 10.15 kg K for the production of about 450 kg of seeds per hectare.

2.8.3 Groundnut

Puhtamkar and Batkal (1967) observed that groundnut crop removed a maximum of 51.09 kg N and 14.24 kg of P from one hectare.

Groundnut removed on an average 21.26 kg N, 2.04 kg P and 7.83 kg K per hectare, per ton of dry matter produced (Sasidhar, 1978).

Aulak *et al.* (1985) have recorded a crop removal of 170 kg N, 30 kg P_2O_5 and 100 kg K_2O per hectare to produce a yield of 19 q ha^{-1}.

A crop of groundnut producing on economic yield of 2 t ha^{-1} removed on an average 170 kg N, 30 kg P and 110 kg K (Tandon, 1993).

2.8.4 Cowpea

Jacquinot (1967) reported that about 40 kg N is removed by each tonne of cowpea seed harvested from one hectare of land.

According to Richie and Robert (1974) each tonne of cowpea seed removed 40 kg N, 17 kg P and 48 kg K from the soil.

In a study conducted by Sasidhar (1978) it was observed that cowpea, on an average removed 22.29 kg N, 3.07 kg P and 13.25 kg K per ton of drymatter produced.

On an average cowpea crop absorbed 1.87 kg N per quintal of grain yield (Godsase and Dougale, 1984).

2.8.5 Bhindi

Maurya *et al*. (1987) observed a removal of 87.81 kg N, 20.57 kg P_2O_5 and 103.91 kg K_2O per hectare by a bhindi crop with an yield of 67.39 q ha^{-1}.

Kalarani (1995) reported that, to produce a fruit yield of 100.38 qha^{-1}, bhindi crop removed 25.61 kg N, 13.17 kg P and 44.43 kg K per hectare.

2.9 Economics of rice based cropping systems

Multiple cropping systems are dynamic and result in judicious utilization of land and other resources. The adoption of a cropping system by the farmers depend on the net profit and labour cost. At the same time, crops in a sequence should be grown with the aim of maintaining soil fertility and productivity because large quantities of fertiliser nutrients are required and removed by intensive cropping systems.

Panda *et al*. (1973) studied ten high intensity single year crop rotations, and found that the rotation rice-tomato-rice-mung to be most productive and profitable with a net profit of Rs.11025 per hectare.

Rice-soybean system was the most profitable sequence among the various rice based cropping sequences studied (Patro *et al*., 1988; Wesley *et al*., 1988).

Kumar and Reddy (1991) observed that although the crop sequence rice-sunflower recorded the highest net income, it recorded the lowest benefit cost ratio. The benefit cost ratio was found to be higher in the rice-maize sequence.

In a study conducted in the irrigation canal command areas in Rajasthan, among the different sequences tried rice-berseem gave the highest benefit cost ratio. Its net return was observed to be 42 per cent higher than that from the dominant rice-wheat rotation (Sharma and Tomar, 1991).

Yadav *et al*. (1991) observed that the maximum net profit (Rs.12178 ha^{-1} $year^{-1}$) was obtained from rice-wheat+Indian mustard-green gram sequence. The benefit cost ratio was the highest from rice-wheat-fallow followed by rice-wheat + Indian mustard-green gram sequence.

Hegde (1992) conducted economic analysis of various rice based cropping systems and concluded that there was scope for curtailment in fertiliser use in some crop sequences at selected locations without any adverse effect on the profitability.

In a study conducted at the Cropping Systems Research Centre, Karamana, on the performance of different summer crops raised in rice fallows, rice-rice-bhindi crop sequence emerged as the most profitable one giving a net profit of Rs.11329 per hectare followed by rice-rice-cowpea (Rs.10336 ha^{-1}) and rice-rice-groundnut (Rs.9457 ha^{-1}) (Kumar *et al*., 1993).

Gowda (1994) recorded the highest net returns from rice-soybean sequence (Rs.16522 ha^{-1}) followed by rice-fingermillet (Rs.10417 ha^{-1}) and rice-niger (Rs.7995 ha^{-1}) sequences.

The adoption of a cropping system by the farmers depend on the net profit and labour cost. Generally the high cost of labour makes rice farming unattractive. Thus it is imperative to increase the productivity of rice based cropping systems but without increasing the cost of production.

2.10 Energetics of rice based cropping systems

Energetics approach in cropping system focusses acceleration of the pace of crop production on one hand and efficient energy utilization particularly in intensive cropping systems on the other. Energy relationship in cropping system vary and constitute a dependent function of crops knitted in a sequence, yield level, nature of power use, soil type, energy input and agro-climate.

It has been studied and observed in rice production (Freedman, 1980) that traditional production practices involves minimum input of energy. Increasing modernization in general involves larger input of energy in crop production. Energy ratio in his studies showed that traditional rice production technology was most efficient energy user (energy ratio, 13.8) and the least efficeint was Green Revolution technology (2.9).

Rice based cropping systems involving crops producing vegetative material as the main product postulated better energy ratios (Pal *et al*., 1985). Legumes fix nitrogen symbiotically and are thus capable of economizing fertilizer nitrogen energy input equal to 1800 to 4800 MJ ha^{-1}. They offer an effective means of saving non-renewable energy. Besides this use of non-obligatory associative relationship in cereals call for in-depth studies in various agro-ecological and soil conditions.

Dazhong (1988) reported that the consumption of total energy for a rice based cropping system was 2.76 x 10^3 Kcal ha^{-1}.

Baishya and Sharma (1990) observed that the integrated use of organic (azolla) and inorganic nitrogenous fertilizers in rice resulted in higher energy use efficiency in rice-wheat cropping system.

Pillai (1993) evaluated rice based cropping systems in terms of energy values of edible produces obtained. He observed that rice-rice-cassava ranked first with a total energy production of 18303 KJ ha^{-1} followed by rice-rice groundnut (16767 KJ ha^{-1}) and rice-rice-rice (15070 KJ ha^{-1}) systems.

Jayapaul *et al*. (1993) observed that the highest total energy output was generated by the cropping of groundnut + blackgram-rice-sesame and the least by the cropping of rice-rice-fallow.

Energetics approach, in agricultural systems though new, is expected to assume added dimensions and to open up new bright horizons in near future.

MATERIALS AND METHODS

MATERIALS AND METHODS

An investigation was carried out with the objective of assessing the most suitable rice based cropping system for the Onattukara tract, under an integrated nutrient management system, in terms of its impact on the physico-chemical properties of the soil, nutrient utilisation efficiency and economics.

The experiment was carried out during the period extending from April 1994 to May 1996. The details regarding the materials used and methods adopted for the study are presented in this chapter.

3.1 Materials

3.1.1 Experimental site

The experiment was conducted in the wet lands of the Rice Research Station, Kayamkulam. The research station is located at 9.8°N latitude and 76.8°E longitude, at an altitude of 3.05 metres above mean sea level.

3.1.2 Soil

The soil of the experimental site was sandy loam (Entisol) and was acidic in reaction. Soil analysed low content of nitrogen, medium content of available phosphorus and

Table 1c Chemical properties of the soil of the experimental site

Constituent	Content	Rating	Method used
Available nitrogen (kg ha^{-1})	172.31	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (P) (kg ha^{-1})	17.57	Medium	Bray colorimetric method (Jackson, 1973)
Available potassium (K) (kg ha^{-1})	62.14	Low	Ammonium acetate method (Jackson, 1973)
Total nitrogen (%)	0.036	Low	Microkjeldahl method (Jackson, 1973)
Organic carbon (%)	0.413	Low	Walkley and Black rapid titration method (Jackson, 1973)
pH	5.2	Moderately acidic	Potentiometry (Jackson, 1973)

3.1.3 Cropping history of the field

The experimental site selected was lying fallow for three months before the experiment and prior to that it was under a bulk crop of rice.

3.1.4 Season

The experiment was conducted during the period extending from April 1994 to May 1996.

very low content of available potassium. The data regarding the mechanical composition and chemical nature of the soil of the experimental site are given below.

Table 1a Mechanical analysis of the soil of the experimental site

Constituent	Content in soil (%)	Method used
Coarse sand	66.6	International Pipette Method (Piper, 1950)
Fine sand	18.2	
Silt	3.4	
Clay	10.4	
Textural Class:- Sandy loam		

Table 1b Physical properties of the soil of the experimental site

Physical property	Value	Method used
Bulk density ($g\ cc^{-1}$)	1.591	Core Method (Gupta and Dakshinamoorthy, (1980)
Particle density ($g\ cc^{-1}$)	2.596	-do-
Water holding capacity (%)	18.35	-do-
Water stable aggregates (%)		Yoder's wet sieving technique (Yoder, 1936)
> 2 mm	9.98	
1 - 2 mm	6.41	
0.5 - 1 mm	6.98	
0.25 - 0.5 mm	11.42	
0.1 - 0.25	10.10	

3.1.5 Weather conditions

A warm humid tropical climate prevails over the Onattukara tract. The tract receives a good share of the South West monsoon and some amount of the North East monsoon.

The data on various weather paameters (rainfall, mean maximum temperature, mean minimum temperature and relative humidity) during the cropping period obtained from the meteorological unit attached to the Regional Station, Central Plantation Crops Research Institute, Kayamkulam are given in Appendix I and graphically represented in Fig.1a and 1b.

3.1.6 Seed materials

The seed materials for all the four tests crops (rice, sesamum, groundnut, cowpea and bhindi) were obtained from the Rice Research Station, Kayamkulam.

3.1.6.1 Varieties used for the experiment

Rice crop was raised during the first crop and the second crop seasons. During the third crop season four different crops were raised as per the treatments. They were sesamum, cowpea, groundnut and bhindi. The details regarding the varieties of crops used for the experiment are given in Table 2.

Fig.1a Mean meteorological data during the cropping period (1994-95)

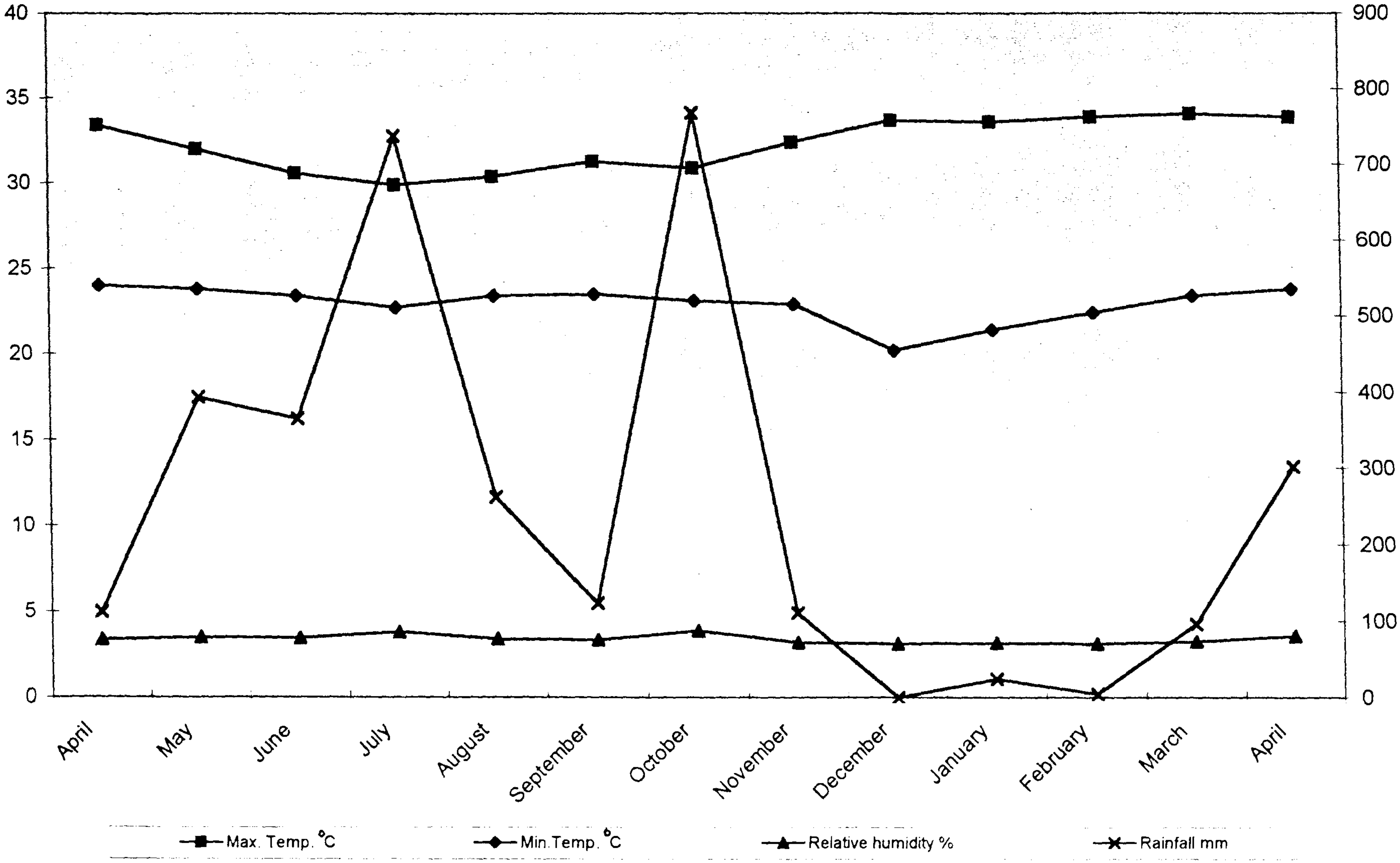


Fig.1b Mean Meteorological data during the cropping period (1995-96)

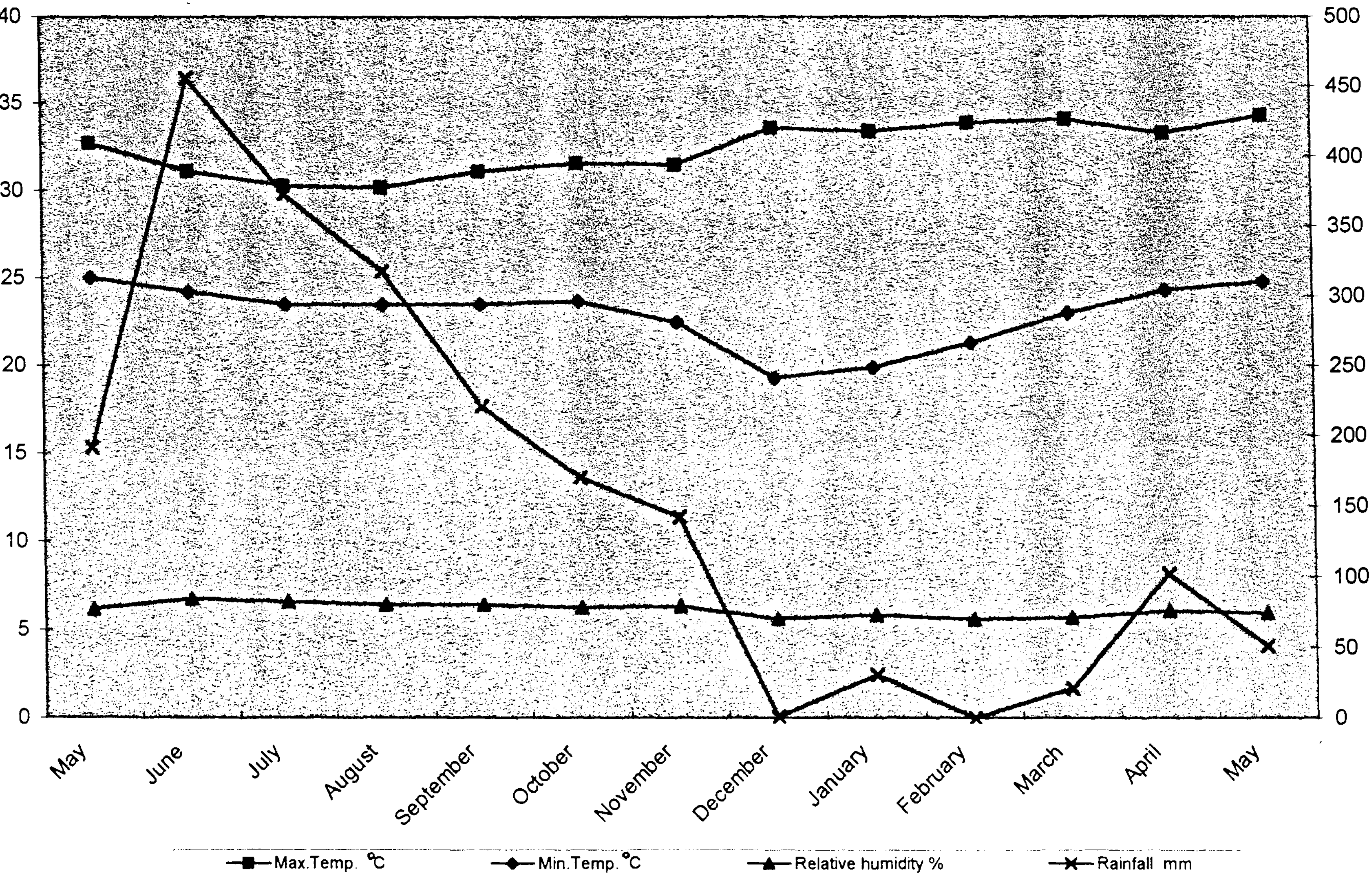


Table 2 Season and varietal details of the test crops

Crop	Season	Variety	Duration (days)
Rice	First crop (Virippu)	Red Triveni (PTB-45)	100 - 105
	Second crop (Mundakan)	Dhanya (Kayamkulam-4)	160 - 165
Sesamum	Third crop (Punja)	Thilak (ACV-3)	80 - 90
Groundnut	Third crop	TG-3	100 - 110
Cowpea	Third crop	Kanakamoni (PTB-1)	90
Bhindi	Third crop	Arka Anamika (Sel-10)	100 - 110

Table 3a Cropping programme (1994-'95)

Cropping system	Crops	Period of cropping		Field duration (days)
		From	To	
C_1	Rice	22-04-1994	30-07-1994	100
	Rice	14-08-1994	21-01-1995	126*
	Sesamum	30-01-1995	28-04-1995	89
C_2	Rice	22-04-1994	30-07-1994	100
	Rice	14-08-1994	21-01-1995	126*
	Groundnut	30-01-1995	12-05-1995	103
C_3	Rice	22-04-1994	30-07-1994	100
	Rice	14-08-1994	21-01-1995	126*
	Cowpea	30-01-1995	30-04-1995	91
C_4	Rice	22-04-1994	30-07-1994	100
	Rice	14-08-1994	21-01-1995	126*
	Bhindi	30-01-1995	12-05-1995	104

Table 3b Cropping programme (1995-'96)

Cropping system	Crops	Period of cropping		Field duration (days)
		From	To	
C_1	Rice	20-05-1995	28-08-1995	101
	Rice	08-09-1995	14-02-1996	125*
	Sesamum	21-02-1996	19-05-1996	89
C_2	Rice	20-05-1995	28-08-1995	101
	Rice	08-09-1995	14-02-1996	125*
	Groundnut	21-02-1996	31-05-1996	101
C_3	Rice	20-05-1995	28-08-1995	101
	Rice	08-09-1995	14-02-1996	125*
	Cowpea	21-02-1996	22-05-1996	90
C_4	Rice	20-05-1995	28-08-1995	101
	Rice	08-09-1995	14-02-1996	125*
	Bhindi	21-02-1996	01-06-1996	102

* The field duration of second crop rice has been given excluding the duration in nursery.

3.1.7 Fertilisers and soil amendments

The chemical nutrient sources used for the study were urea (46 per cent nitrogen), factomphos (20 per cent nitrogen and 20 per cent P_2C_5), mussoriephos (20 per cent P_2O_5), muriate of potash (60 per cent K_2O) and ammonium sulphate (20.5 per cent nitrogen). The organic manures used were farmyard manure (0.35 per cent nitrogen, 0.60 per cent P_2O_5 and 0.24 per cent K_2O), poultry manure (2.18 per cent nitrogen, 2.90 per cent P_2O_5 and 2.30 per cent K_2O) and vermicompost (1.60 per cent nitrogen, 0.76 per cent P_2O_5 and 2.71 per cent K_2O). The *Azospirillum* and *Rhizobium* cultures required for the study were obtained from the Department of Plant Pathology, College of Agriculture, Vellayani.

3.2 Methods

3.2.1 Design and layout

The experiment was laid out in 4x6 factorial Strip Plot Design with four replications. The layout plan of the experiment is given in Fig.2. The details of the layout are given below.

Number of treatment combinations	:	24
Number of replications	:	4
Plot size	:	5 x 4 m
Total number of plots	:	96
Width of bunds	:	30 cm
Width of irrigation channels	:	30 cm

3.2.2 Treatments

Treatments included four cropping systems and six nutrient management levels.

Fig. 2 PLAN OF LAYOUT

N

R-III

c_3n_3	c_3n_2	c_3n_4	c_3n_5	c_3n_6	c_3n_1
c_2n_3	c_2n_2	c_2n_4	c_2n_5	c_2n_6	c_2n_1
c_1n_3	c_1n_2	c_1n_4	c_1n_5	c_1n_6	c_1n_1
c_4n_3	c_4n_2	c_4n_4	c_4n_5	c_4n_6	c_4n_1

R-IV

c_1n_4	c_1n_5	c_1n_1	c_1n_3	c_1n_2	c_1n_6
c_4n_4	c_4n_5	c_4n_1	c_4n_3	c_4n_2	c_4n_6
c_2n_4	c_2n_5	c_2n_1	c_2n_3	c_2n_2	c_2n_6
c_3n_4	c_3n_5	c_3n_1	c_3n_3	c_3n_2	c_3n_6

R-II

c_2n_5	c_2n_6	c_2n_4	c_2n_1	c_2n_3	c_2n_2
c_1n_5	c_1n_6	c_1n_4	c_1n_1	c_1n_3	c_1n_2
c_3n_5	c_3n_6	c_3n_4	c_3n_1	c_3n_3	c_3n_2
c_4n_5	c_4n_6	c_4n_4	c_4n_1	c_4n_3	c_4n_2

R-I

c_2n_4	c_2n_3	c_2n_6	c_2n_1	c_2n_2	c_2n_5
c_4n_4	c_4n_3	c_4n_6	c_4n_1	c_4n_2	c_4n_5
c_3n_4	c_3n_3	c_3n_6	c_3n_1	c_3n_2	c_3n_5
c_1n_4	c_1n_3	c_1n_6	c_1n_1	c_1n_2	c_1n_5

Design : Strip Plot Design Plot size : 5 x 4 m.
Horizontal strip : Cropping system Vertical strip : Nutrient management.

R-I : Replication I R-II : Replication II
R-III : Replication III R-IV : Replication IV

3.2.2.1 Cropping Systems

C_1 : Rice (semi-dry) - Rice (transplanted) - Sesamum

C_2 : Rice (semi-dry) - Rice (transplanted) - Groundnut

C_3 : Rice (semi-dry) - Rice (transplanted) - Cowpea

C_4 : Rice (semi-dry) - Rice (transplanted) - Bhindi

3.2.2.2 Nutrient management

N_1 : Farmers' practice (for all the three crops)

N_2 : KAU package of practices recommendations (1993) (for all the three crops)

N_3 : 3/4 recommended nitrogen as chemical + 1/4 recommended nitrogen as organic (FYM) (for first and second crop of rice)

N_4 : 3/4 recommended nitrogen as chemical + 1/4 recommended nitrogen as organic (FYM) + *Azospirillum* (for first and second crop of rice)

N_5 : 3/4 recommended nitrogen as chemical + 1/8 recommended nitrogen as organic (FYM) + 1/8 recommended nitrogen as vermicompost (for first and second crop of rice)

N_6 : 3/4 recommended nitrogen as chemical + 1/8 recommended nitrogen as organic (FYM) + 1/8 recommended nitrogen as vermicompost + *Azospirillum* (for first and second crop of rice)

During the third crop season the treatments N_2 to N_6 were package of practices recommendations and N_1 was farmers' practice (for the respective crops).

3.2.3 Treatment combinations

The treatment combinations are as follows.

c_1n_1	c_2n_1	c_3n_1	c_4n_1
c_1n_2	c_2n_2	c_3n_2	c_4n_2
c_1n_3	c_2n_3	c_3n_3	c_4n_3
c_1n_4	c_2n_4	c_3n_4	c_4n_4
c_1n_5	c_2n_5	c_3N_5	c_4n_5
c_1n_6	c_2n_6	c_3n_6	c_4n_6

3.2.4 Field culture

3.2.4.1 Rice

The first crop of rice was direct sown and semi-dry in nature. The second crop of rice was a transplanted one.

3.2.4.1.1 First crop rice

3.2.4.1.1.1 Seed treatment

Seeds of the rice variety Red Triveni were treated with *Azospirillum* as per the treatments. Peat based *Azospirillum* inoculum at the rate of 2 kg ha^{-1} was mixed with the seeds, dried in shade for 20 minutes and sown as suggested by Gopalaswamy *et al*. (1989a). A small quantity of gruel water was added to improve the stickiness of inoculant. Further 4 kg ha^{-1} of peat based inoculum was mixed with 15 kg of sand and broadcast.

3.2.4.1.1.2 Cultural practices

The field was ploughed thoroughly two times, clods were broken and the soil was brought to a good tilth. Each plot was then levelled after trimming and repairing the bunds.

3.2.4.1.1.3 Manures and manuring

Farmyard manure @ 5t ha^{-1} was applied as basal to all the plots except those receiving farmers' practice as per the treatment. In farmers' practice, farmyard manure (@ 3 t ha^{-1}) was applied in the plots at the time of first interculture. Vermicompost and farmyard manure were applied according to the treatments. Fertilisers were applied as per the KAU package of practices recommendations (KAU, 1993) for the Onattukara tract. A fertiliser recommendation of 70:35:35 kg ha^{-1} of N, P_2O_5 and K_2O was followed. Fifty per cent of nitrogen (as urea), full dose of phosphorus (as mussoriephos) and 50 per cent of potassium (as muriate of potash) were applied as basal dressing, 25 per cent of nitrogen and 25 per cent of potassium were applied during the tillering stage and the remaining 25 per cent each of nitrogen and potassium were applied 7 days prior to panicle initiation. The farmers' practice consisted of applying fertilisers at the rate of 3 kg of factamphos and 2 kg of muriate of potash per 1 *para* (approximately 14 cents) area, a week prior to panicle initiation. Subsequently 3 kg of urea was applied per one *para* area at the flowering stage.

3.2.4.1.1.4 Sowing

Seeds of the rice variety Red Triveni were sown at a seed rate of 85 kg ha^{-1} keeping a distance of 15 cm between rows and 10 cm between plants. Planking was done after sowing so as to bring proper contact between the moist soil and seeds.

3.2.4.1.1.5 Intercultivation and weeding

Hand hocing was done 10 days after sowing. Later the plots were hand weeded twice, 20 and 40 days after sowing.

3.2.4.1.1.6 Plant protection

Prophylatic plant protection measures were taken against pests and diseases according to the KAU package of practices recommendations (KAU, 1993).

3.2.4.1.1.7 Harvesting and threshing

In the case of all the treatments, the crop in the border rows and in the net area were harvested and threshed separately. Weight of grain and straw of individual plots were recorded.

3.2.4.1.2 **Second crop rice**

3.2.4.1.2.1 **Nursery**

The nursery area was ploughed and harrowed two to three times until the soil was thoroughly puddled and levelled. Cattle manure was applied @ 1 kg m^{-2} of nursery bed and mixed well with the soil. Raised beds of 5 to 10 cm height, 1 to 1.5 m width and 4 m length were prepared. Drainage channels were provided between the beds. Pre-germinated seeds were sown at a seed rate of 70 kg ha^{-1}. The seedlings became ready for transplanting at 35 days after sowing.

3.2.4.1.2.2 **Cultural practices**

After the harvest of first crop of rice, the bunds of individual plots were trimmed, repaired and plastered. Individual plots were dug repeatedly, puddled and levelled.

3.2.4.1.2.3 **Manures and manuring**

In all the plots except those receving farmer's practice, farmyard manure was applied at the rate of 5t ha^{-1}. In the case of farmer's practice, farmyard manure was applied at the rate of 3t ha^{-1}. Furthermore, farmyard manure and vermicompost, were applied as per the treatments. Fertilisers were applied as per the KAU package of practices recommendations. The fertiliser recommendation for the rice variety Dhanya under the Onattukara conditions is 60:30:30 kg NPK per hectare. The entire dose of phosphorus was applied basally. Nitrogen and potassium were applied in five equal splits. The plots receiving farmers' practice as a treatment were supplied with N, P and K at the rate of 2.5 kg factomphos and 3 kg muriate of potash per 1 *para* (approximately 14 cents) area, at active tillering stage followed by the application of urea at the rate of 2.5 kg per 1 *para* area, at the flowering stage.

3.2.4.1.2.4 Transplanting

Seedlings were transplanted at a spacing of 20 x 10 cm. Prior to transplanting, the seedlings required for the plots receiving *Azospirillum* treatment, were treated with the inoculant of *Azospirillum*. A suspension was prepared by mixing *Azospirillum* inoculant in water. The rate of application adopted was 2 kg of inoculant + 100 litres of water for treating seedlings required for transplanting 1 hectare of area. At the time of transplantation, the roots of the seedlings were dipped in the inoculant suspension for 15 minutes and then planted (Gopalaswamy *et al*., 1989b). Furthermore, 2 kg of inoculant per hectare was mixed with 15 kg of sand per hectare and broadcasted in the field before transplanting.

3.2.4.1.2.5 Intercultivation and weeding

Gap filling was done one week after transplanting. The crop was weeded twice at 20 and 40 days after transplanting.

Irrigation and water management, plant protection and harvesting and threshing operations were done as in the case of first crop rice.

3.2.4.2 Sesamum

3.2.4.2.1 Preparatory tillage

After the harvest of second crop of rice the experimental plots were dug and stubbles removed. Clods were broken and the soil was brought to a fine tilth.

3.2.4.2.2 Manuring

Farmyard manure, nitrogen, phosphorus and potassium were applied as per the package of practices recommendations, to all the plots of sesamum except those receiving farmer's practice as the treatment. Basal application of farmyard manure at the rate of 5 t ha^{-1}, nitrogen at the rate of 22.5 kg ha^{-1} phosphorus at the rate of 15 kg ha^{-1} and potassium at the rate of 30 kg ha^{-1} followed by the foliar spraying of nitrogen at the rate of 7.5 kg ha^{-1} at 3 per cent concentration, 25 days after sowing is the package of practices recommendation. In the case of farmers' practice neither farmyard manure non fertilisers were applied.

3.2.4.2.3 Seeds and sowing

Seeds were line sown at the rate of 5 kg ha^{-1}. The seeds were mixed with sand 2-3 times its volume and sown in lines at 20 cm. apart. Later the soil was compacted with wooden plank.

3.2.4.2.4 After cultivation

Thinning was done 15 days after sowing so as to maintain a spacing of 20 x 15 cm, by working with 'kochuthoompa', a special type of implement prevalent in the Onattukara tract. A second interculture and weeding were done 25 days after sowing.

3.2.4.2.5 Irrigation

One irrigation was given at the flowering stage.

3.2.4.2.6 Plant protection

Ten per cent BHC was applied to control the leaf and pod caterpillar during the flowering period.

3.2.4.2.7 Harvesting and threshing

The crop became ready for harvest 85 days after sowing. Border row plants were harvested separately. The plants of the net area were pulled out, the root portions cut and the plants stalked in bundles for 3 to 4 days. These bundles were then spread, dried in the sun and beaten with sticks to break the capsules. Drying and threshing were repeated for three more days.

3.2.4.3 Groundnut

3.2.4.3.1 Preparatory tillage

After the harvest of second crop rice, the bunds of the experimental plots were repaired, plots were dug, stubbles were removed, clods were broken and the soil was brought to a fine tilth.

3.2.4.3.2 Seeds and sowing

Seeds of TG-3, the bunch type variety of groundnut were dibbled in plough furrows at a spacing of 15 x 15 cm, adopting a seed rate of 100 kg kernels ha^{-1}.

3.2.4.3.3 Manuring

The KAU package of practices recommendation comprising a basal application of farmyard manure at the rate of 2t ha^{-1}, nitrogen at the rate of 10 kg ha^{-1}, phosphorus at the rate of 75 kg ha^{-1} and potassium at the rate of 75 kg ha^{-1}, followed by the application of lime at the rate of 1t ha^{-1} at the flowering stage were given to all the treatments except those treated in accordance with the farmers' practice. In the case of farmers' practice farmyard manure and fertilisers were not applied.

3.2.4.3.4 Intercultivation and weeding

Gap filling was done 10 days after sowing. Hoeing and weeding operations were done 10-15 days after germination of seeds and at the time of application of lime.

3.2.4.3.5 Plant protection

At the time of seeding, BHC 10% DP was applied in soil as a control measure against ants, termites, etc.

3.2.4.3.6 Harvesting

After harvesting two border rows, the plants in the net area were harvested. The plants were pulled out alongwith the pods. The pods were then separated, dried in the sun, cleaned and weighed.

3.2.4.4 Cowpea

3.2.4.4.1 Preparatory tillage

The land, after the harvest of second crop rice was dug, stubbles removed, clods broken and the soil was brought to a fine tilth.

3.2.4.4.2 Seed and sowing

Seeds of the cowpea variety Kanakamoni were sown at a seed rate of 55 kg ha^{-1}, in small furrows at a spacing of 25 x 15 cm. Seeds were treated with *Rhizobium* (except in farmers' practice) prior to sowing.

3.2.4.4.3 Manures and manuring

The plots receiving package of practices recommendations were supplied with farmyard manure at the rate of 20t ha^{-1}, nitrogen at the rate of 20 kg ha^{-1}, phosphorus at the rate of 30 kg ha^{-1} and potassium at the rate of 10 kg ha^{-1}. Half the quantity of nitrogen, full dose of phosphorus and potassium were applied basally. The remaining nitrogen was applied 15 days after sowing. The farmers' practice received neither any farmyard manure nor any fertiliser.

3.2.4.4.4 Intercultivation and weeding

Hoeing and weeding were done at the time of application of the second dose of nitrogen.

3.2.4.4.5 Irrigation

A light irrigation was given 7 days after sowing. Subsequent irrigations were given once in two weeks.

3.2.4.4.6 Plant protection

Quinalphos at 0.03 per cent concentration was sprayed as a control measure against pea aphid.

3.2.4.4.7 Harvesting

Mature pods were harvested, weighed and shelled. The grains were dried in the sun, cleaned and weighed.

3.2.4.5 Bhindi

3.2.4.5.1 Preparatory tillage

After the harvest of second crop rice, the experimental plots were dug, stubbles were removed clods were broken and the soil was brought to a good tilth.

3.2.4.5.2 Seeds and Sowing

Seeds of the bhindi variety, Arka Anamika was sown at the rate of 8.5 kg ha^{-1}. The seeds were soaked in water for 24 hours before sowing. Seeds wer sown at a spacing of 60x30 cm.

3.2.4.5.3 Manures and manuring

Package of practices recommendations of farmyard manure at 12 t ha^{-1}, 25 kg N ha^{-1}, 8 kg P_2O_5 ha^{-1} and 25 kg K_2O ha^{-1} was adopted as per the treatments. In the case of farmers' practice, poultry manure was applied at the rate of 1t ha^{-1} and farmyard manure was applied at the rate of 6t ha^{-1}.

3.2.4.5.4 After cultivation

The crop was irrigated once in 3 to 4 days. Later as the summer advanced, irrigation was done on alternate days and at times daily. Regular weeding was done.

3.2.4.5.5 Plant protection

Quinalphos was sprayed at 0.05 per cent concentration to control jassids.

3.2.4.5.6 Harvesting

Harvesting was started 45 days after sowing. Subsequent harvests were done once in three days. The stubbles were uprooted and removed after the final harvest.

3.2.5 Observations

3.2.5.1 Rice

3.2.5.1.1 Productive tillers per square metre at harvest

Productive tillers were counted from twelve randomly selected hills at harvest and means worked out and expressed as productive tillers per square metre.

3.2.5.1.2 Spikelets per panicle

The spikelets from all the panicles of the twelve sample hills were counted and expressed as number of spikelets per panicle.

3.2.5.1.3 Percentage of filled grains

The total number of filled grains from the panicles were separately counted and the percentage of filled grains was recorded.

3.2.5.1.4 Thousand grain weight

One thousand grains were counted from the samples drawn from the cleaned produce from each plot and weights recorded in grams.

3.2.5.1.5 Grain yield

The grains harvested from each net plot was dried, cleaned and weighed and the weights expressed as kg ha^{-1}.

3.2.5.1.6 Straw yield

The straw harvested from each net plot was dried under sun, weighed and the weight expressed as kg ha^{-1}.

3.2.5.1.7 Straw : grain

The ratio between the dry weight of straw and grain was calculated.

3.2.5.1.8 Harvest index

Harvest index was calculated using the formula,

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

$$= \frac{\text{Grain yield}}{(\text{Grain yield} + \text{Straw yield})}$$

3.2.5.2 Sesamum

3.2.5.2.1 Plant height

After elimination of the border plants, ten plants were selected randomly as observational plants. The height of the plants was measured from the ground level to the growing tip of the plants and expressed as cm.

3.2.5.2.2. Number of branches per plant

Number of branches of the observational plants were counted and the average number of branches per plant was worked out.

3.2.5.2.3 Number of capsules per plant

The total number of capsules from the observational plants were counted and the average number of capsules per plant was worked out.

3.2.5.2.4 Seed yield per hectare

Crop harvested from the net plot area were dried, threshed, winnowed and cleaned. Seeds were sundried and weights were recorded. The yield of the observational plants were also added to the net plot yield. Seed yield was expressed in kg ha^{-1}.

3.2.5.2.5 Haulm yield per hectare

The haulm, after separating the seeds was dried and weighed. Haulm yield was expressed in kg ha^{-1}.

3.2.5.3 Groundnut

3.2.5.3.1 Number of mature pods per plant

The total number of mature pods were counted from the ten observatioal plants selected at random and the average number of mature pods per plant was calculated.

3.2.5.3.2 Pod yield per hectare

The mature pods were separated from the crop harvested from the net plot area, dried and weighed. Pod yield was expressed in kg ha^{-1}.

3.2.5.3.3 Haulm yield per hectare

The haulm, after separating the pods was dried and weighed and expressed in kg ha^{-1}.

3.2.5.3.4 Shelling percentage

Shelling percentage was calculated from the dry weight of seeds and dry weight of pods of the observational plants.

$$\text{Shelling percentage} = \frac{\text{Dry weight of seeds}}{\text{Dry weight of pods}} \times 100$$

3.2.5.4 Cowpea

3.2.5.4.1 Number of pods per plant

Ten plants were tagged randomly as observational plants. The total number of pods harvested from these plants were counted and the average number of pods per plant was worked out.

3.2.5.4.3 Seed yield

The yield of seeds after drying was recorded plot wise and per hectare yield was calculated from this.

3.2.5.4.4 Haulm yield

The dry weight of haulm was recorded plot wise and from this haulm yield per hectare was computed.

3.2.5.5 Bhindi

3.2.5.5.1 Number of fruits per plant

The total number of fruits obtained from five observational plants were counted and the average number of fruits per plant was worked out.

3.2.5.5.2 Length and girth of fruits

Length and girth of 20 fruits from each plot were measured and the average was worked out and expressed in cm.

Measurement of girth of fruits was done by winding a thread around the middle portion of the individual fruits.

3.2.5.5.3 Total dry matter production

Unit weight of fresh fruits and green plants were sundried till constant weights were obtained and the dry matter production was expressed in kg ha^{-1}.

3.2.5.5.4 Total fruit yield per hectare

Weight of fruits from each harvest was added together and the weight of fruits expressed as total fruit yield in kg ha^{-1} on fresh weight basis.

3.2.5.5.5 Bhusa yield

The plants from individual plots were uprooted after the final harvest and dried and the dry weight expressed as bhusa yield in kg ha^{-1}.

3.2.6 Chemical analysis

3.2.6.1 Plant analysis

The whole plants of rice, sesamum, groundnut, cowpea and bhindi were analysed for nitrogen, phosphorus and potassium contents. The seeds of rice, sesamum, cowpea and groundnut and the fruits of bhindi were analysed separately. The plant samples collected from each plot at time of harvests of the crops were dried to constant weights in an electric hot air oven at 70°C, ground and passed through a 0.5 mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in an electronic balance, subjected to acid digestion and nutrient contents were determined as percentage on dry weight basis.

3.2.6.1.1 Uptake of nitrogen

The total nitrogen content was estimated by the modified microkjeldahl method (Jackson, 1973). The uptake of nitrogen was calculated as the product of the nitrogen content in the various plant samples and the respective dry weights and the uptake expressed in kg ha^{1}.

3.2.6.1.2 Uptake of phosphorus

Total phosphorus content was estimated by the vanado-molybdo-phosphoric yellow colour method (Jackson, 1973) and read in the Klett Summerson photoelectric colorimeter. The uptake of phosphorus was calculated as the product of the phosphorus content of the various plant samples and the respective dry weights and the uptake expressed in kg ha^{-1}.

3.2.6.1.3 Uptake of potassium

Total potassium content was estimated by the atomic absorption spectrophotometry after wet digestion of the samples using di-acid mixture as suggested by Perkin-Elmer Corporation (1982). The uptake of potassium was calculated as the product of the potassium content of the various plant samples and the respective dry weights and the uptake expressed in kg ha^{-1}.

3.2.6.1.4 Crude protein content of rice

The crude protein content of rice was computed by multiplying the percentage of nitrogen content of grains by the factor 6.25 (Simpson *et al.*, 1965).

3.2.6.1.5 Nitrogen harvest index of rice (Spiretz, 1977)

$$NHI = \frac{\text{Nitrogen uptake by economic yield}}{\text{Nitrogen uptake by biological yield}} \times 100$$

3.2.6.1.6 Oil content of sesamum

Oil content of oven-dry seeds of sesamum was estimated by the cold percolation method using petroleum ether of boiling point 60-80°C (Kartha and Sethi, 1957).

3.2.6.1.7 Oil content of groundnut

Oil content of groundnut was estimated by the cold percolation method using petroleum ether of boiling point 60-80°C (Kartha and Sethi, 1957).

3.2.6.1.8 Crude fibre content of bhindi

Crude fibre content of bhindi fruits was determined by the method suggested by AOAC (AOAC, 1960).

3.2.6.2 Soil analysis

3.2.6.2.1 Physico-chemical properties of the soil

3.2.6.2.1.1 Bulk density

Core samples were collected from a depth of 0-30 cm and analysed for bulk density (Gupta and Dakshinamoorthy, 1980).

3.2.6.2.1.2 Particle density

Particle density was determined from the core samples collected from a depth of 0-30 cm (Gupta and Dakshinamoorthy, 1980).

3.2.6.2.1.3 Water holding capacity

Water holding capacity was determined from the core samples collected for determining bulk density and particle density (Gupta and Dakshinamoorthy, 1980).

3.2.6.2.1.4 Water stable aggregates

Water stable aggregate of the soil was determined using Yoder's wet sieving technique (Yoder, 1936).

3.2.6.2.1.5 Organic carbon

Organic carbon content of the soil was determined using Walkley and Black's rapid titration method (Jackson, 1973).

3.2.6.2.1.6 Total nitrogen

Total nitrogen content of the soil was estimated using the microkjeldahl method (Jackson, 1973).

3.2.6.2.1.7 Available nitrogen

Available nitrogen content of the soil was determined using the alkaline potassium permanganate method (Subbiah and Asija, 1956).

3.2.6.2.1.8 Available phosphorus

Available phosphorus content of the soil was estimated using the Bray colorimetric method (Jackson, 1973).

3.2.6.2.1.9 Available potassium

Available potassium content of the soil was estimated using ammonium acetate method (Jackson, 1973).

3.2.6.2.1.10 Soil Reaction

Soil reaction (Soil pH) was determined by potentiometry using a pH meter with glass electrode. The soil:water ratio used was 1:2.5 (Jackson, 1973).

3.2.7 Nutrient balance sheet of the soil

Nutrient balance sheet of the soil was worked out by subtracting the computed balance of nutrients from the actual balance. The computed balance was worked out by subtracting the total quantity of nutrients removed by the crops in a sequence from that added by fertilisers and soil. The actual balance of nutrients is indicated by the available nutrient status of the soil. A positive balance indicates soil storage and a negative balance depletion (Palaniappan, 1985).

3.2.8 Economics of the experiment

Economics of cultivation was worked out based on the costs of the various inputs and produce at the time of experimentation. The details regarding the costs of various inputs and produce are presented in Appendix III.

3.2.8.1 Net returns (Rs. ha^{-1})

Net returns = Gross returns - Cost of cultivation

3.2.8.2 Benefit cost ratio (BCR)

$$\text{Benefit cost ratio} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

3.2.8.3 Net returns per rupee invested on manures, fertilisers and biofertilisers for rice (Rs. ha^{-1})

$$\text{Net returns per rupee invested on manures, fertilizers and biofertilisers} = \frac{\text{Gross returns - Cost of cultivation excluding cost of manures, fertilisers and biofertilisers}}{\text{Cost of manures, fertilisers and biofertilisers}}$$

3.2.8.4 Cost and return analysis

The cost and return analysis measures the profitability of a new technology. The added cost and added returns for the new technology over and above the farmers' level was computed. The marginal benefit cost ratio (MBCR) was computed as suggested by Gomez and Gomez (1984)

$$\text{MBCR} = \frac{\text{Added returns}}{\text{Added cost}}$$

3.2.9 Land use efficiency (%) (Tomar and Tiwari, 1990)

$$\text{Land use efficiency} = \frac{\text{Total duration of crops in sequence} \times 100}{365}$$

3.2.10 Production efficiency (kg ha^{-1} day^{-1}) (Tomar and Tiwari, 1990)

$$\text{Production efficiency} = \frac{\text{Total production in a sequence}}{\text{Total duration of crops in a sequence}}$$

3.2.11 Energy budgetting of cropping systems

The direct energy input, output and net returns were calculated in terms of Mega Joules per hectare (MJ ha^{-1}) based on the energy equivalent values for the various inputs and outputs (Binning *et al.*, 1983; Baishya and Sharma, 1990; Pal *et al.*, 1985). Direct energy refers to both operational (manual, machinery, etc.) and non-operational (seeds, fertilizers, insecticides, etc.) energy. The details regarding the energy equivalents of inputs and outputs are presented as Appendix IV. Energy ratio was worked by dividing the net energy output by the total energy input as suggested by Schahezenski (1984).

3.2.12 Statistical analysis

The experimental data were analysed by applying the technique of Analysis of Variance (ANOVA) as applied to factorial experiment in strip plot design as described by Gomez and Gomez (1984). Pooled analysis was done for the grain yield of rice.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

A field experiment was conducted in the sandy loam soils of the Rice Research Station, Kayamkulam, for two consecutive years to find out the most suitable rice based cropping system for the Onattukara tract and to develop an ecofriendly and economically viable integrated nutrient management strategy for the system. The results of this experiment are presented and discussed in this chapter.

4.1 Rice-rice-sesamum system (C_1)

4.1.1 First crop rice

4.1.1.1 Number of productive tillers per square metre at harvest

The results on the number of productive tillers per square metre at harvest during the first and second year are presented in the Tables 4a and 4b respectively.

The number of productive tillers was significantly influenced by the nutrient management ranging from N_1 to N_6, both during the first year and second year. The highest number of productive tillers of 365 and 329 was recorded under N_6 during the first year and second year respectively. The increase in the number of productive tillers from N_1 to N_6 was

Table No. 4 Number of productive tillers per square metre at harvest as influenced by cropping systems and nutrient management

Table No. 4a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	200	244	231	260	312	365	269
C2	174	247	247	280	309	349	268
C3	163	242	260	308	343	376	282
C4	181	243	258	306	327	385	283
Mean	180	244	249	288	323	369	

SEm C - 7.682 N - 4.032 CN - 7.037

CD - N - 12.152 CN - 20.053

Table No. 4b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	127	207	226	257	295	329	240
C2	210	265	291	307	347	396	303
C3	168	217	267	310	346	380	281
C4	202	249	285	334	353	410	306
Mean	177	235	267	302	335	379	

SEm C - 8.033 N - 4.728 CN - 7.888

CD C - 25.699 N - 14.247 CN - 22.477

progressive and significantly superior to N_1 during both the years. All the treatments, N_2 to N_6 recorded more productive tillers than N_1 (farmers' practice). N_3 and N_4 were on a par with N_2 (package of practices) in the first year, while N_5 and N_6 showed better response in both the years. Compared to the first year a reduction in the number of productive tillers per square metre was observed during the second year.

Integrated use of bio-organic and inorganic fertilisers have been observed to improve the number of productive tillers produced by rice (Mondal *et al*., 1990). The treatment N_6 combined the beneficial effects of chemical fertilisers, farmyard manure, vermicompost and *Azospirillum*. Shuxin *et al*. (1991) have reported a 10 per cent increase in effective tillering due to vermicompost application. The positive influence of inoculation with *Azospirillum* on the number of productive tillers has been observed by Muthukrishnan and Purushothaman (1992) and Resmi (1993).

4.1.1.2 Number of spikelets per panicle

The results on the number of spikelets per panicle are presented in Tables 5a and 5b respectively.

The mean number of spikelets per panicle was 80 in 1994-'95 and 75 in 1995-'96. The highest values of 131 and 112 for the first year and second year respectively were recorded

Table No. 5 Number of spikelets per panicle as influenced by cropping systems and nutrient management

Table No. 5a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	42	58	71	89	89	131	80
C2	47	63	80	103	113	143	91
C3	49	63	82	92	105	117	85
C4	52	64	79	94	90	117	83
Mean	47	62	78	94	99	127	

SEm C - 2.595 N - 4.155 CN - 5.981

CD - N - 12.522 -

Table No. 5b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	38	57	71	84	90	112	75
C2	50	64	84	89	104	111	84
C3	55	72	82	91	104	123	88
C4	55	67	70	95	107	116	85
Mean	49	65	77	90	102	116	

SEm C - 2.153 N - 1.846 CN - 3.588

CD C - 6.888 N - 5.564 -

by the treatment N_6 and the lowest values of 42 and 38 were recorded by N_1. However, the effect of nutrient management over the cropping system was observed to be not significant during both the years.

4.1.1.3 Percentage of filled grains

The results recorded on the percentage of filled grains in 1994-'95 and 1995-'96 are presented in Tables 6a and 6b respectively.

The mean percentage of filled grains in the first year was 80.26 and in the second year it was 78.80. The lowest percentage of filled grains 76.89 (1994-'95) and 75.44 (1995-'96) was obtained under the N_1 treatment and the highest values of 82.75 (1994-'95) and 81.48 (1995-'96) was recorded under the N_4 treatment. However, the influence of the different nutrient levels over the cropping system was not significant.

4.1.1.4 Thousand grain weight (g)

The results recorded on the thousand grain weight (g) in 1994-'95 and 1995-'96 are presented in Tables 7a and 7b respectively.

The mean thousand grain weight was 25.6 g in 1994-'95 and 26.0 g in 1995-'96. N_1 recorded the lowest value for this

Table No. 6 Percentage of filled grains as influenced by cropping systems and nutrient management

Table No. 6a First crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	76.89	79.98	80.96	82.75	80.96	80.03	80.26
C2	76.67	80.02	80.86	82.67	80.84	79.04	80.02
C3	76.96	80.20	80.82	82.14	80.69	79.83	80.11
C4	76.76	79.58	81.01	82.74	81.25	79.47	80.13
Mean	76.82	79.94	80.91	82.57	80.93	79.59	

SEm C - 0.138 N - 0.126 CN - 0.242

CD - N - 0.380 -

Table No. 6b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	75.44	78.61	79.82	81.48	79.32	78.11	78.80
C2	76.29	79.34	80.66	82.70	80.38	79.42	79.80
C3	77.29	80.08	81.67	82.98	80.61	79.87	80.42
C4	76.56	80.04	80.98	82.86	80.95	79.63	80.17
Mean	76.39	79.52	80.78	82.50	80.32	79.26	

SEm C - 0.215 N - 0.198 CN - 0.347

CD C - 0.688 N - 0.598 -

Table No. 7 Thousand grain weight (g) as as influenced by cropping systems and nutrient management

Table No. a First crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	24.7	26.3	26.3	25.6	25.0	26.0	25.6
C2	25.8	26.2	25.4	25.8	25.8	25.7	25.7
C3	25.5	25.3	25.9	26.3	25.7	25.7	25.7
C4	25.2	25.8	26.4	26.0	25.9	26.3	25.9
Mean	25.2	25.9	26.0	25.9	25.6	25.9	

SEm C - 0.062 N - 0.186 CN - 0.276

CD - - -

Table No. 7b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	25.2	26.3	26.4	26.1	26.1	26.0	26.0
C2	25.3	26.1	26.1	26.1	26.2	26.1	26.0
C3	25.1	26.1	26.2	26.4	26.0	25.9	25.9
C4	25.4	26.0	26.4	26.1	26.0	26.3	26.0
Mean	25.2	26.1	26.3	26.2	26.0	26.1	

SEm C - 0.085 N - 0.087 CN - 0.195

CD - N - 0.263 -

yield attributing character during 1994-'95 (24.7) and 1995-'96 (25.2). During the first year of experimentation the treatments, N_2, N_3, N_4 and N_6 were at par. However, during the second year, significant difference was not observed among the treatments.

The low values of thousand grain weight recorded by the treatment N_1 may be due to the sub-optimal dose of nutrients applied. On the other hand in the treatments N_2 to N_6, increased uptake of nutrients with increased supply, especially at flowering and maturity stages might have paved way for greater translocation to the grains, thus increasing the grain weight. Similar results have been reported by Kiuchi and Ishizaka (1960).

4.1.1.5 Grain yield (kg ha^{-1})

The results on the grain yield of rice are presented in Tables 8a and 8b and graphically in Fig. 3a and 3b respectively.

The mean grain yield recorded under the C_1 system over the varying nutrient management levels were 2736 kg ha^{-1} during 1994-'95 and 2250 kg ha^{-1} during 1995-'96. The plots receiving farmers' practice (N_1) as a nutrient management strategy recorded an yield of 1696 kg ha^{-1} (1994-'95) and 1192 kg ha^{-1} (1995-'96). Both during 1994-'95 and 1995-'96 there

Table No. 8 Grain yield (kg ha^{-1}) of rice as influenced by cropping systems and nutrient management

Table No. 8a First crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	1696	2463	2517	2932	3202	3609	2736
C2	1737	2446	2477	2757	3041	3571	2671
C3	1545	2435	2451	2897	3226	3569	2687
C4	1719	2414	2451	2903	3108	3658	2709
Mean	1674	2439	2474	2872	3144	3608	

SEm C - 68.988 N - 77.968 CN - 65.099

CD - N - 129.843 -

Table No. 8b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1192	1933	2119	2408	2763	3083	2250
C2	1967	2481	2720	2870	3247	3705	2832
C3	1746	2155	2677	3088	3416	3752	2806
C4	1807	2222	2509	2972	3191	3714	2736
Mean	1678	2198	2506	2834	3154	3564	

SEm C - 74.456 N - 40.120 CN - 66.928

CD C - 238.181 N - 120.909 CN - 190.719

was progressive increase in yield over the treatments ranging from N_1 to N_6. The treatment N_1 produced a grain yield which was significantly lower than all the other treatments. N_2 (package of practices) and N_3 were at par. The best result was observed with N_6.

The treatment, N_6 which included both vermicompost and *Azospirillum* might have resulted in the highest grain yield by virtue of these two components. The beneficial effects of vermicompost and *Azospirillum* on the grain yield of rice have been well documented. The efficacy of *Azospirillum* in increasing grain yield of rice has been reported by Gopalaswamy and Vidhyasekharan (1987), Gopalaswamy *et al*., (1989), Ramakrishnan *et al*., (1992), Arumugam *et al*., (1992) and Resmi (1993). Senapathi *et al*. (1985) recorded an increase of 95 per cent in grain yield of paddy as result of application of vermicompost. Further the higher number of productive tillers per square metre and the higher number of spikelets per panicle recorded under N_6, might have contributed to the higher grain yield.

The grain yield of first crop rice (pooled) was observed to be maximum at N_6 (Table 37).

A reduction in grain yield was observed during the second year. The cropping system rice-rice-sesamum was observed to reduce the available nitrogen status of the soil after the first year (Table 48). This may be due to the lower grain yield of the first crop rice succeeding sesamum in the sequence. Similar results have been reported by Sasidhar (1978) and Kumar *et al*. (1993).

4.1.1.6 Straw yield (kg ha^{-1})

The results on the straw yield of rice are presented in the Tables 9a and 9b and graphically in Fig. 4a and 4b respectively.

The mean yields of straw in kg ha^{-1} during 1994-'95 was 3693 and that of 1995-'96 was 3067. The mean straw yield under N_1 was 3921 kg ha^{-1} (1994-'95) and 2731 kg ha^{-1} (1995-'96). Both during the first year and second year, the nutrient level N_6 recorded the highest straw yield. During the first year, the straw yield decreased from N_1 to N_3 and increased from N_3 to N_6. During the second year, it decreased from N_1 to N_2 and thereafter it increased.

The high straw yield recorded by N_6 may be attributed to the favourable influence of the integration of the bio-organic (*Azospirillum*, farmyard manure and vermi-compost) and inorganic sources (chemical fertilisers) at optimal dose (Kumar and Balasubramanian, 1989, Senapathy *et al*., 1985).

Table No. 9 Straw yield (kg ha^{-1}) of rice as influenced by cropping systems and nutrient management

Table No. 9a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	3921	3261	3257	3833	3827	4060	3693
C2	4504	3283	3220	3748	3633	3964	3725
C3	4030	3183	3113	3882	3871	3820	3650
C4	4530	3174	3113	3912	3639	3914	3713
Mean	4246	3225	3176	3844	3743	3939	

SEm C - 112.021 N - 77.968 CN - 121.698

CD - N - 234.970 -

Table No. 9b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2731	2684	2749	3053	3473	3715	3067
C2	4997	3227	3386	3484	3822	3927	3807
C3	4173	2730	3359	3789	4055	3977	3680
C4	4675	3048	3226	3610	3795	3907	3710
Mean	4144	2922	3180	3484	3786	3881	

SEm C - 102.822 N - 66.685 CN - 111.277

CD C - 328.924 N - 200.969 CN - 317.100

4.1.1.7 Straw:grain

The mean values for straw : grain ratio are presented in the Tables 10a and 10b.

The mean straw:grain was 1.43 during 1994-'95 and 1.45 during 1995-'96. Straw:grain was significantly influenced by nutrient management during both the years. N_1 recorded the highest value for straw:grain during the first year (2.36) and second year (2.30). N_6 recorded the lowest value for straw:grain both during the first year (1.13) and the second year (1.21). The treatments N_6 and N_5 were observed to record straw : grain values lower than N_2 (package of practices). N_3 and N_4 were on a par with N_2.

The higher straw:grain recorded by N_1 clearly indicates the fact that the nutrients applied especially nitrogen has been utilised for straw production rather than for grain production. This may be due to the poor level of nutrients applied. Similar results have been reported by Sreekumaran (1981). On the other hand, in the treatment N_6, the nutrients applied were utilised more for grain production than for straw production. One of the advantages of integrated nutrient management is its ability to supply nutrients uniformly over the entire growth phase of the crop. In the case of rice supplying adequate nutrients at middle and later stages of growth to maintain appropriate nutrient contents at

Table No. 10 Straw : Grain as influenced by cropping systems and nutrient management

Table No. 10a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2.36	1.33	1.29	1.31	1.20	1.13	1.43
C2	2.60	1.34	1.30	1.36	1.20	1.11	1.48
C3	2.61	1.31	1.27	1.34	1.20	1.07	1.47
C4	2.64	1.32	1.27	1.35	1.17	1.07	1.47
Mean	2.55	1.32	1.28	1.34	1.19	1.09	

SEm C - 0.012 N - 0.022 CN - 0.037

CD - N - 0.067 CN - 0.106

Table No. 10b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2.30	1.39	1.30	1.27	1.26	1.21	1.45
C2	2.55	1.31	1.25	1.22	1.18	1.06	1.43
C3	2.40	1.27	1.26	1.23	1.19	1.06	1.50
C4	2.59	1.37	1.29	1.22	1.19	1.05	1.45
Mean	2.46	1.33	1.27	1.23	1.20	1.09	

SEm C - 0.011 N - 0.012 CN - 0.027

CD C - 0.035 N - 0.038 CN - 0.076

the later stages has been observed to be very critical (Koyama and Chammek, 1973). The treatment N_6 might have met all these requirements for producing higher grain yield.

4.1.1.8 Harvest index

The results on the harvest index of first crop rice are presented in Tables 11a and 11b respectively.

The mean harvest index of the C_1 system during 1994-'95 and 1995-'96 were 0.422 and 0.406 respectively. The harvest index with respect to N_1 (farmers' practice) was significantly low while N_3 and N_4 were on a par with N_2 (package of practices) and was significantly low compared to N_5 and N_6 which were on a par.

A harvest index of 0.5 is believed to be ideal for high yielding rice varieties to achieve potential production (IRRI, 1994). It was observed that as the level of integration of the nutrient sources improved the harvest index also increased as is indicated by higher grain yield in N_6 (Tables 8a and 8b).

4.1.1.9 Crude protein content (per cent)

The results on the crude protein content of rice are presented in Tables 12a and 12b.

The mean crude protein content during 1994-'95 was 8.20 per cent and 1995-'96 it was 8.29 per cent. N_1 (farmers'

Table No. 11 Harvest index as influenced by cropping systems and nutrient management

Table No. 11a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.298	0.430	0.438	0.435	0.460	0.470	0.422
C2	0.278	0.430	0.433	0.420	0.453	0.470	0.414
C3	0.280	0.430	0.440	0.430	0.450	0.480	0.418
C4	0.275	0.430	0.440	0.428	0.458	0.480	0.418
Mean	0.283	0.430	0.438	0.428	0.455	0.475	

SEm C - 0.0020 N - 0.0048 CN - 0.0054

CD - N - 0.014 -

Table No. 11b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.305	0.418	0.433	0.385	0.445	0.453	0.406
C2	0.283	0.435	0.445	0.450	0.458	0.488	0.426
C3	0.298	0.440	0.447	0.448	0.455	0.488	0.428
C4	0.280	0.423	0.452	0.452	0.455	0.488	0.422
Mean	0.291	0.429	0.439	0.434	0.453	0.479	

SEm C - 0.6020 N - 0.0020 CN - 0.0041

CD C - 0.007 N - 0.006 CN - 0.012

Table No. 12 Effect of cropping systems and nutrient management on the crude protein content (%) of rice

Table No. 12a First crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	7.38	8.43	8.39	8.31	8.40	8.31	8.20
C2	7.35	8.43	8.39	8.31	8.40	8.32	8.20
C3	7.59	8.43	8.39	8.31	8.42	8.29	8.24
C4	7.46	8.43	8.38	8.32	8.41	8.32	8.22
Mean	7.44	8.43	8.38	8.31	8.41	8.31	

SEm C - 0.057 N - 0.092 CN - 0.137

CD - N - 0.278 -

Table No. 12b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	7.41	8.47	8.47	8.47	8.48	8.45	8.29
C2	7.41	8.47	8.48	8.47	8.56	8.45	8.31
C3	7.41	8.47	8.48	8.47	8.47	8.45	8.29
C4	7.41	8.46	8.46	8.47	8.59	8.46	8.31
Mean	7.41	8.47	8.47	8.47	8.52	8.45	

SEm C - 0.041 N - 0.030 CN - 0.113

CD - N - 0.091 -

practice) recorded the lowest crude protein content during 1994-'95 (7.38 per cent) and 1995-'96 (7.41 per cent). The nutrient levels ranging from N_1 to N_6 had no significant influence on the crude protein content of rice in the C_1 system.

4.1.1.10 Nitrogen harvest index (per cent)

The results on the nitrogen harvest index (NHI) of first crop rice are presented in Tables 13a and 13b.

The mean nitrogen harvest index during 1994-'95 was 51.20 per cent and 1995-'96 was 50.40 per cent. The lowest NHI values were recorded by N_1 and the highest values for NH1 was recorded by N_6. Nutrient management influenced the NHI of the C_1 system significantly during the second year. N_6, N_5 and N_4 were at par and so were N_5, N_4, N_3 and N_2. The treatment N_6 was observed to record a better NHI compared to N_2 (package of practices).

The NHI indicates that proportion of nitrogen taken up by the crop which is utilised in producing the grain. In other words, it is the efficiency of translocation. Integration of organic inorganic and/or biological sources have been observed to improve the NHI of rice (Verma and Bhagat, 1991).

Table No. 13 Effect of cropping systems and nutrient management on the nitrogen harvest index (%) of rice

Table No. 13a First crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	38.30	52.30	52.92	52.65	54.88	56.33	51.20
C2	35.83	52.02	52.80	49.50	53.65	55.25	49.80
C3	35.73	52.55	53.30	52.95	54.78	57.60	51.20
C4	35.55	52.42	53.33	53.33	55.38	57.60	51.30
Mean	36.40	52.30	53.10	52.10	54.70	56.70	

SEm C - 0.301 N - 0.394 CN - 0.720

CD C - 0.961 N - 1.188 -

Table No. 13b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	39.40	51.43	52.15	52.90	52.85	53.90	50.40
C2	36.65	51.95	53.05	54.70	54.48	57.10	51.30
C3	37.05	52.65	52.90	53.45	54.28	57.10	51.20
C4	35.28	50.68	52.30	53.70	54.23	57.30	50.60
Mean	37.10	51.70	52.60	53.70	54.00	56.30	

SEm C - 0.217 N - 0.294 CN - 0.538

CD C - 0.694 N - 0.886 CN - 1.534

4.1.1.11 Nitrogen uptake (kg ha^{-1})

The results on the total nitrogen uptake by the first crop rice are presented in Tables 14a and 14b.

In 1994-'95 the mean uptake of nitrogen was 60.72 kg ha^{-1} and in 1995-'96 it was 50.75 kg ha^{-1}. The nitrogen uptake under different nutrient management levels (N_1 to N_6) varied from 50.56 kg ha^{-1} to 73.65 kg ha^{-1} in 1994-'95 and from 35.92 kg ha^{-1} to 65.63 kg ha^{-1} in 1995-'96. During the second year the treatments N_2 and N_3 were on a par.

There was an increase in the uptake of nitrogen with the nutrient management. Increased uptake of nitrogen was the result of higher dry matter production and enhanced absorption of nitrogen at levels higher than N_1. These results are in conformity to those of Reddy (1988).

4.1.1.12 Phosphorus uptake (kg ha^{-1})

The results pertaining to the uptake of phosphorus by the first crop rice are presented in the Tables 15a and 15b.

The mean uptake of phosphorus was 13.58 kg ha^{-1} in 1994-'95 and 11.50 kg ha^{-1} in 1995-'96. The lowest uptake values were recorded by N_1 during both the years. Phosphorus uptake was found to exhibit an increasing trend, although slight, from N_1 to N_6 during the first year. During the

Table No. 14 Effect of cropping systems and nutrient management on the nitrogen uptake (kg ha^{-1}) by rice

Table No. 14a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	50.56	54.15	54.74	64.07	67.13	73.65	60.72
C2	55.64	54.13	53.99	64.26	65.24	74.45	61.28
C3	49.68	53.31	52.84	67.06	67.76	71.30	59.82
C4	55.64	52.89	52.84	64.36	64.56	73.07	60.56
Mean	52.88	53.62	53.60	64.19	66.17	73.11	

SEm	C	-	1.552	N	-	1.261	CN	-	1.756
CD		-		N	-	3.800		-	

Table No. 14b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	35.92	43.79	46.70	52.50	59.99	65.63	50.75
C2	61.62	54.75	58.78	60.30	68.39	74.50	63.06
C3	54.01	46.95	58.07	66.29	72.22	75.45	62.17
C4	58.80	50.33	55.06	63.51	67.52	74.44	61.61
Mean	52.59	48.96	54.65	60.65	67.03	72.50	

SEm	C	-	1.752	N	-	0.902	CN	-	1.663
CD	C	-	5.606	N	-	2.720	CN	-	4.740

Table No. 15 Effect of cropping systems and nutrient management on the phosphorus uptake (kg ha^{-1}) by rice

Table No. 15a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	11.07	12.18	12.26	14.34	15.08	16.58	13.58
C2	12.13	12.10	12.09	14.00	14.32	16.32	13.49
C3	10.83	11.94	11.84	14.32	15.22	16.08	13.37
C4	12.13	11.83	11.84	14.39	14.51	16.48	13.53
Mean	11.54	12.01	12.00	14.26	14.78	16.36	

SEm C - 0.366 N - 0.242 CN - 0.364

CD - N - 0.728 -

Table No. 15b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	7.98	9.98	10.61	11.83	13.64	14.95	11.50
C2	14.00	12.43	13.31	13.96	15.59	17.05	14.39
C3	11.98	10.68	13.21	15.09	16.46	17.27	14.11
C4	13.01	11.40	12.51	14.62	15.39	17.03	13.99
Mean	11.74	11.12	12.41	13.87	15.27	16.57	

SEm C - 0.385 N - 0.222 CN - 0.353

CD C - 1.233 N - 0.668 CN - 1.006

second year significant difference was observed among the nutrient management levels in the C_1 system.

The higher uptake at the nutrient management levels N_2 to N_6 compared to that at N_1 may be attributed to the better nutrition afforded by these treatments. The maximum uptake of phosphorus in N_6 may be due to higher dry matter production. Trials conducted by Iruthayaraj and Morachan (1980) revealed that uptake of phosphorus was higher with higher levels of nitrogen. In N_6, *Azospirillum* might have contributed towards a higher nitrogen level. Further the higher potassium content of vermicompost (2.71 per cent) might have favoured a better phosphorus uptake and translocation. This could be due to the increased root growth and consequently better absorption of the nutrient followed by the rapid translocation favoured by potassium (Singh *et al*., 1976).

4.1.1.13 Potassium uptake (kg ha^{-1})

The results on the uptake of potassium by the first crop rice are presented in Tables 16a and 16b.

The mean uptake of potassium over the different nutrient management levels was 78.25 kg ha^{-1} in 1994-'95 and 64.52 kg ha^{-1} in 1995-'96. During the first year, significant difference was not observed in the potassium uptake due to the various nutrient levels tried. However, the different nutrient

Table No. 16 Effect of cropping systems and nutrient management on the potassium uptake (kg ha^{-1}) by rice

Table No. 16a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	75.72	71.28	69.28	81.36	82.81	89.07	78.25
C2	85.75	69.31	68.43	78.92	78.63	87.25	78.05
C3	76.69	67.77	66.48	81.98	83.70	84.80	76.90
C4	85.89	67.29	66.47	82.51	79.11	86.90	78.03
Mean	81.01	68.91	67.66	81.19	81.06	87.00	

SEm C - 2.289 N - 1.543 CN - 2.411

CD - N - 4.651 -

Table No. 16b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	48.60	57.00	59.17	66.04	75.25	81.04	64.52
C2	96.84	69.44	73.83	76.04	83.98	88.39	81.42
C3	81.46	59.55	72.80	82.13	88.95	89.51	79.06
C4	90.41	64.89	70.69	78.79	84.08	88.10	79.49
Mean	79.33	62.72	69.12	75.75	83.06	86.76	

SEm C - 2.262 N - 1.234 CN - 2.656

CD C - 7.237 N - 3.720 CN - 7.568

management levels significantly influenced the potassium uptake during the second year. The maximum uptake of potassium was recorded by N_6 during both the years.

The *Azospirillum* component might have contributed towards a higher nitrogen level in N_6, in addition to vermicompost offering a higher level of potassium. Agarwal (1978) reported that uptake of potassium increased significantly with higher doses of nitrogen and potassium. The higher uptake of potassium can also be attributed to the vigorous root growth promoted by *Azospirillum* (Purushothaman *et al*. (1988) in addition to enhanced dry matter production.

4.1.2 Second crop rice

4.1.2.1 Number of productive tillers per square metre at harvest

The results pertaining to the number of productive tillers per square metre at harvest are presented in Tables 17a and 17b.

The mean number of productive tillers per square metre at harvest was 308 and 336 during 1994-'95 and 1995-'96 respectively. A progressive and significant increase was observed in the number of productive tillers over the nutrient levels during both the years in the C_1 system. N_1 recorded a significantly lower value for this parameter, while N_6 recorded

Table No. 17 Number of productive tillers per square metre at harvest as influenced by cropping systems and nutrient management

Table No. 17a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	189	289	310	337	359	368	308
C2	183	267	287	336	398	389	310
C3	158	236	249	328	375	373	287
C4	177	274	294	339	389	388	310
Mean	177	266	285	335	380	379	

SEm C - 5.573 N - 5.964 CN - 0.300

CD C - 17.822 N - 16.864 CN - 20.803

Table No. 17b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	201	322	326	352	406	408	336
C2	223	309	320	382	390	398	337
C3	196	251	292	372	373	383	311
C4	201	288	310	361	376	390	321
Mean	205	293	312	367	386	394	

SEm C - 5.985 N - 5.368 CN - 9.800

CD C - 19.146 N - 16.178 CN - 27.927

the highest value, during the first year and second year. N_3 and N_4 were on a par with N_2 (package of practices). N_5 and N_6 showed a better response in both the years.

The favourable influence of the integration of organic inorganic and/or biological sources of nutrients on the production of productive tillers has been well documented. Similarly the favourable effects of *Azospirillum* and vermicompost on the number of productive tillers have been discussed earlier. *Azospirillum*, by way of associative symbiosis might have supplied nitrogen to the plants under the treatment N_6. Several workers have reported the favourable influence of nitrogen on the production of effective tillers in rice (Singh and Singh, 1993; Sheela and Alexander, 1995). Vermicompost, in addition to its positive influence as a organic fertiliser, might have supplied more of potassium and thereby increased the number of productive tillers. The favourable influence of potassium on productive tiller production has been reported by Thakur (1992) and Singh *et al.* (1994).

4.1.2.2 Number of spikelets per panicle

The results data on the number of spikelets per panicle are presented in Tables 18a and 18b.

The mean number of spikelets per panicle recorded in the C_1 cropping system was 80 in 1994-'95 and 84 in 1995-'96.

Table No. 18 Number of spikelets per panicle as influenced by cropping systems and nutrient management

Table No. 18a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	64	55	66	79	97	118	80
C2	64	68	80	86	99	116	86
C3	57	66	78	83	98	119	84
C4	57	68	82	85	93	125	85
Mean	61	64	77	83	97	120	

SEm C - 2.079 N - 3.527 CN - 3.240

CD - N - 10.630 -

Table No. 18b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	66	72	78	82	89	118	84
C2	67	74	81	90	98	110	87
C3	57	59	79	85	99	117	83
C4	60	69	84	87	93	128	87
Mean	63	68	81	86	95	118	

SEm C - 1.589 N - 2.394 CN - 3.255

CD - N - 7.216 CN - 9.275

N_6 recorded the highest value for this parameter during the first year and second year. The effect of nutrient management over the cropping system was not significant during the first year. But it was observed to be significant during the second year. N_6 was found to be significantly superior to all other nutrient management levels during the second year.

The higher number of spikelets per panicle recorded by N_6 may be attributed to the better supply of nutrients, particularly nitrogen and potassium through *Azospirillum* and vermicompost respectively. Several workers have reported that nitrogen and potassium increase the number of spikelets per panicle (Kurmi and Das, 1993; Khandaand Dixit, 1996). Further, Forster (1982) justified that potassium nutrition helped in controlling the loss of grain ripening.

4.1.2.3 Percentage of filled grains

The results recorded on the percentage of filled grains are presented in Tables 19a and 19b.

The cropping system, C_1 recorded 81.13 per cent and 81.28 per cent of filled grains respectively during 1994-'95 and 1995-'96. The percentage of filled grains was observed to increase progressively upto N_4 and thereafter it was found to decrease slightly both during 1994-'95 and 1995-'96. The effect of nutrient levels over the cropping system was observed

Table No. 19 Percentage of filled grains as influenced by cropping systems and nutrient management

Table No. 19a Second crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	76.15	81.94	82.66	82.86	81.80	81.39	81.13
C2	76.59	82.14	82.69	82.84	81.75	81.24	81.21
C3	76.07	81.82	82.59	82.91	82.57	81.42	81.23
C4	76.01	81.37	82.65	82.76	81.79	81.34	80.99
Mean	76.21	81.82	82.65	82.84	81.97	81.35	

SEm C - 0.147 N - 0.117 CN - 0.153

CD - N - 0.354 CN - 0.435

Table No. 19b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	76.41	81.96	82.58	82.90	82.09	81.74	81.28
C2	76.71	82.31	83.04	83.18	82.25	81.25	81.46
C3	76.22	81.81	82.57	82.88	82.10	81.61	81.20
C4	75.96	81.11	82.57	82.83	82.96	81.54	80.99
Mean	76.32	81.80	82.69	82.95	82.10	81.54	

SEm C - 0.115 N - 0.060 CN - 0.269

CD - N - 0.182 -

to be significant only during the first year. N_4 and N_3 were observed to be on a par.

The maximum percentage of filled grain was recorded by the treatment N_4 which may be attributed to the favourable influence of the integrated nutrient management. The *Azospirillum* inoculation in N_4 might have resulted in better nitrogen status. Similar results have been reported by Watanabe and Lin (1984). The favourable influence noticed in this study may be attributed to the increased availability of potassium due to organic matter addition as reported by Ganal and Singh (1990). Increase in filled grain percentage following organic matter addition has been observed by Prakash *et al.* (1990). However, at higher levels of nitrogen the percentage of filled grains was observed to decrease (Sobhana, 1983). This may be the reason for the slight reduction observed in the filled grain percentage at N_6.

4.1.2.4 Thousand grain weight (g)

The results on the thousand grain weight are presented in Tables 20a and 20b.

The mean thousand grain weight was 26.3 g during 1994-'95 and 26.0 g during 1995-'96. The influence of the different nutrient levels ranging from N_1 to N_6 over the cropping system C_1, was non-significant.

Table No. 20 Thousand grain weight (g) as influenced by cropping systems and nutrient management

Table No. 20a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	25.3	26.2	26.3	26.3	26.5	27.1	26.3
C2	25.3	26.2	26.4	26.3	26.2	27.0	26.2
C3	25.5	26.1	26.4	26.3	26.5	26.9	26.3
C4	24.6	26.0	26.3	26.3	26.5	27.0	26.1
Mean	25.2	26.1	26.3	26.3	26.4	27.0	

SEm C - 0.088 N - 0.128 CN - 0.171

CD - N - 0.384 -

Table No. 20b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	25.1	26.2	26.2	26.1	26.3	26.3	26.0
C2	24.9	26.2	26.1	26.4	26.3	26.2	26.0
C3	25.2	26.3	26.3	26.2	26.3	26.3	26.1
C4	25.3	26.3	26.2	26.3	26.3	26.3	26.1
Mean	25.1	26.2	26.2	26.2	26.3	26.3	

SEm C - 0.052 N - 0.053 CN - 0.154

CD - N - 0.160 -

4.1.2.5 Grain yield (kg ha^{-1})

The results on the grain yield (kg ha^{-1}) of the second crop rice raised are presented in Tables 21a and 21b and graphically in 5a and 5b.

The C_1 cropping system produced a mean second crop rice grain yield of 2954 kg ha^{-1} during 1994-'95 and 3116 kg ha^{-1} during 1995-'96. Grain yield was found to be influenced significantly by the nutrient management ranging from N_1 to N_6. Grain yield showed steady progressive increase over the varying nutrient management levels. N_1 (farmers' practice) was significantly inferior to all the other treatments. While N_2 (package of practices) recorded a response more or less on a par with N_3 and N_4 , the treatment N_5 and N_6 ahowed a better response in both the years.

Pooled analysis of the grain yield of second crop rice showed that the treatment N_6 recorded the maximum grain yield (Table 38).

The low grain yield recorded by the treatment N_1 (farmers' practice) may be attributed to the application of nutrients at sub-optimal doses. Further the split schedule of application of nutrients followed in N_1 was also inferior. The longer duration of the rice variety 'Dhanya' raised during the second crop season demanded a better split application of

Table No. 21 Grain yield (kg ha^{-1}) of rice as influenced by cropping systems and nutrient management

Table No.21a Second crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	1800	2773	2961	3223	3424	3543	2954
C2	1703	2561	2646	3173	3675	3759	3920
C3	1488	2283	2348	3115	3547	3606	2731
C4	1670	2634	2761	3203	3656	3732	2942
Mean	1665	2563	2679	3178	3575	3660	

SEm C - 49.585 N - 51.316 CN - 65.586

CD C - 158.620 N - 154.651 CN - 186.896

Table No. 21b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1915	3027	3100	3293	3517	3842	3116
C2	2109	2927	3026	3607	3777	3887	3222
C3	1854	2646	2762	3514	3640	3720	3023
C4	1898	2872	2933	3410	3656	3798	3094
Mean	1944	2868	2955	3456	3647	3812	

SEm C - 52.750 N - 38.098 CN - 71.161

CD - N - 114.816 CN - 204.081

nutrients especially nitrogen and potassium, which was lacking in N_1. As far as the treatment N_6 was concerned while *Azospirillum* supplied nitrogen, vermicompost supplied potassium in addition to that applied through chemical fertilisers. Higher phosphorus availability to rice may be ascribed to the solubilising effect of carbonic acids formed during the decomposition of organic matter (Beresteskii *et al.*, 1986). The improved availability of the major nutrients may be the reason for the higher grain yield in N_6 as compared to the other treatments.

4.1.2.6 Straw yield (kg ha^{-1})

The mean straw yield recorded in 1994-'95 and 1995-'96 are presented in Tables 22a and 22b and graphically in Fig. 6a and 6b.

The mean straw yield recorded by the C_1 cropping system was 7340 kg ha^{-1} in 1994-'95 and 7936 kg ha^{-1} in 1995-'96. The different nutrient management levels tested had significant influence on the straw yield during both the years. In 1994-'95, the straw yield increased progressively from N_1 to N_4 and thereafter it decreased upto N_6. In 1995-'96, the straw yield increased over the nutrient levels ranging from N_1 to N_2 and over the levels N_3 to N_6 it decreased.

The poor straw yield recorded by the treatment N_1 can be explained with the same reasons as already explained for

Table No. 22 Straw yield (kg ha^{-1}) of rice as influenced by cropping systems and nutrient management

Table No. 22a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	5482	7423	7965	8064	7856	7247	7340
C2	5237	6767	7168	7906	8452	7722	7207
C3	4658	6152	6334	7789	8162	7527	6770
C4	5096	7090	7444	7981	8414	7695	7287
Mean	5118	6858	7228	7935	8221	7548	

SEm C - 145.848 N - 141.301 CN - 184.875

CD - N - 425.836 CN - 526.828

Table No. 22b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	6011	8466	8410	8308	8267	8152	7936
C2	6918	8443	8473	9395	9104	8637	8495
C3	6119	7973	7865	9780	9117	8459	8219
C4	5827	8148	8070	8701	8758	8183	7948
Mean	6219	8257	8205	9046	8812	8358	

SEm C - 143.307 N - 109.457 CN - 225.733

CD - N - 329.869 CN - 643.258

grain yield. However, in the case of the treatment N_6, a reduction was observed in the straw yield. This indicates that in the treatment N_6 the partitioning of assimilates was more towards the grain than straw. This is clearly evident from the data on the straw : grain (Tables 23a and 23b). Since potassium is highly essential for the translocation of carbohydrates from the source to the sink (Tanaka, 1972) the higher grain yield compared to straw yield in N_6 may be attributed to the higher availability of potassium by way of vermicompost application in N_6.

4.1.2.7 Straw : grain

The results recorded on the straw : grain are presented in Tables 23a and 23b.

The mean straw : grain recorded during 1994-'95 and 1995-'96 were 2.54 and 2.61 respectively. The effect of nutrient management over the cropping system C_1 was not significant as far as the straw : grain was concerned. However, the strar : grain decreased progressively over the nutrient management levels ranging from N_1 to N_6.

4.1.2.8 Harvest index

The results on the harvest index of the second crop rice of the cropping system, C_1 are presented in the Tables 24a and 24b.

Table No. 23 Straw : grain as influenced by cropping systems and nutrient management

Table No. 23a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	3.05	2.68	2.69	2.50	2.30	2.05	2.54
C2	3.09	2.64	2.71	2.49	2.30	2.06	2.55
C3	3.14	2.70	2.70	2.50	2.30	2.09	2.57
C4	3.05	2.69	2.70	2.49	2.30	2.06	2.55
Mean	3.08	2.68	2.70	2.50	2.30	2.06	

SEm C - 0.013 N - 0.020 CN - 0.025

CD - N - 0.059 -

Table No. 23b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	3.14	2.80	2.71	2.52	2.35	2.12	2.61
C2	3.29	2.89	2.80	2.61	2.41	2.22	2.70
C3	3.30	3.02	2.85	2.79	2.51	2.28	2.79
C4	3.07	2.84	2.75	2.55	2.40	2.16	2.63
Mean	3.20	2.88	2.78	2.62	2.42	2.19	

SEm C - 0.017 N - 0.020 CN - 0.030

CD C - 0.054 N - 0.061 -

Table No. 24 Harvest index as influenced by cropping systems and nutrient management

Table No. a Second crop rice (1994-'95)

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.248	0.265	0.270	0.288	0.303	0.328	0.283
C2	0.245	0.265	0.270	0.288	0.300	0.330	0.283
C3	0.243	0.263	0.270	0.288	0.303	0.328	0.281
C4	0.248	0.263	0.270	0.288	0.303	0.328	0.283
Mean	0.246	0.264	0.270	0.288	0.302	0.327	

SEm C - 0.0011 N - 0.0014 CN - 0.0026

CD - N - 0.004 -

Table No. 24b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.238	0.263	0.273	0.283	0.298	0.320	0.279
C2	0.235	0.260	0.260	0.281	0.290	0.310	0.273
C3	0.233	0.250	0.258	0.265	0.285	0.303	0.265
C4	0.245	0.263	0.268	0.285	0.295	0.318	0.279
Mean	0.238	0.259	0.264	0.278	0.292	0.313	

SEm C - 0.0011 N - 0.0020 CN - 0.0031

CD C - 0.005 N - 0.005 -

The mean harvest index was 0.283 in 1994-'95 and 0.279 in 1995-'96. The harvest index increased progressively over the nutrient management levels. The effect of nutrient management over the cropping system C_1 was not significant during the first year and second year.

4.1.2.9 Crude protein content (per cent)

The results on the crude protein content are presented in Tables 25a and 25b.

The mean crude protein content of C_1 was 8.68 per cent and 8.67 per cent respectively during the first year and second year. A non-significant influence was observed for the various nutrient levels over the cropping system during 1994-'95 and 1995-'96. However, N_1 recorded the lowest crude protein content during both the years.

4.1.2.10 Nitrogen harvest index (per cent)

The results on the nitrogen harvest index (NHI) are presented in Tables 26a and 26b.

The mean NHI for 1994-'95 was 37.10 per cent and 36.80 per cent in 1995-'96. NHI during 1994-'95 and 1995-'96 was not influenced significantly by nutrient management.

4.1.2.11 Nitrogen uptake (kg ha^{-1})

The results on the nitrogen uptake by the second crop rice are presented in Tables 27a and 27b.

Table No. 25 Effect of cropping systems and nutrient management on the crude protein content (%) of rice

Table No. 25a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	7.53	8.91	8.91	8.91	8.91	8.91	8.68
C2	7.54	8.91	8.91	9.01	9.01	8.91	8.71
C3	7.53	8.68	8.90	8.91	8.90	9.01	8.65
C4	7.54	8.67	8.91	8.90	8.92	8.90	8.64
Mean	7.54	8.79	8.91	8.93	8.94	8.93	

SEm C - 0.069 N - 0.093 CN - 0.160

CD - N - 0.279 -

Table No. 25b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	7.57	8.92	8.91	8.91	8.91	8.89	8.67
C2	7.58	8.94	8.90	8.92	8.91	8.79	8.67
C3	7.58	8.77	8.91	8.90	8.91	9.00	8.68
C4	7.63	8.94	8.90	8.92	8.90	8.79	8.68
Mean	7.59	8.89	8.91	8.91	8.91	8.87	

SEm C - 0.086 N - 0.065 CN - 0.187

CD - N - 0.197 -

Table No. 26 Effect of cropping systems and nutrient management on the nitrogen harvest index (%) of rice

Table No. 26a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	32.67	35.93	35.52	37.20	39.23	42.03	37.10
C2	32.40	35.05	35.35	37.28	39.17	41.90	36.90
C3	32.08	35.13	35.45	37.20	39.15	41.50	36.70
C4	32.73	35.55	35.45	37.27	39.15	41.80	37.00
Mean	32.50	35.40	35.40	37.20	39.20	41.80	

SEm C - 0.124 N - 0.169 CN - 0.254

CD - N - 0.510 -

Table No. 26b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	32.45	34.97	35.72	37.38	39.00	41.50	36.80
C2	31.45	34.30	34.98	36.65	38.40	40.38	36.00
C3	31.00	33.30	34.55	35.10	37.55	39.82	35.30
C4	32.85	34.68	35.38	37.45	38.20	41.15	36.60
Mean	32.00	34.30	35.20	36.60	38.30	40.70	

SEm C - 0.149 N - 0.175 CN - 0.311

CD C - 0.478 N - 0.529 -

Table No. 27 Effect of cropping systems and nutrient management on the nitrogen uptake (kg ha^{-1}) by rice

Table No. 27a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	67.39	95.35	102.14	106.17	106.91	103.34	96.88
C2	64.17	87.34	91.69	104.25	114.92	109.91	95.38
C3	56.75	78.85	81.14	102.57	110.94	106.42	89.44
C4	62.60	90.90	95.38	105.23	114.36	109.36	96.30
Mean	62.73	88.11	92.59	104.55	111.78	107.26	

SEm C - 1.792 N - 1.775 CN - 2.290

CD - N - 5.350 CN - 6.526

Table No. 27b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	72.75	106.51	106.96	108.50	110.93	113.98	103.27
C2	82.55	105.09	106.56	121.26	121.97	118.49	109.15
C3	72.88	97.79	98.33	123.27	119.38	114.73	104.40
C4	71.02	102.00	102.12	112.39	116.64	113.69	102.98
Mean	74.80	102.85	103.49	116.35	116.98	115.22	

SEm C - 1.814 N - 1.343 CN - 2.695

CD - N - 4.048 CN - 7.679

The mean nitrogen uptake was 96.88 kg ha^{-1} in 1994-'95 and 103.27 kg ha^{-1} in 1995-'96. The effect of nutrient management over the cropping system was significant during the first year and second year. N_6, N_5, N_4 and N_3 were on a par during 1994-'95. N_6, N_5, N_4, N_3 and N_2 were on a par during 1995-'96. N_1 recorded the lowest nitrogen uptake value during both the years.

Uptake of nutrients is a function of the nutrient concentration and the total dry matter production. Thus the higher dry matter production in the treatments N_2 to N_6 might have paved way for higher nitrogen uptake. Fagi and De Datta (1991) have reported a linear relationship between dry matter production and nutrient uptake.

4.1.2.12 Phosphorus uptake (kg ha^{-1})

The results on phosphorus uptake are presented in Tables 28a and 28b.

The mean phosphorus uptake during 1994-'95 was 19.58 kg ha^{-1} and during 1995-'96 was 21.28 kg ha^{-1}. Phosphorus uptake was influenced significantly by the different nutrient levels over the cropping system, C_1 during both the years. N_1 recorded the lowest phosphorus uptake value during 1994-'95 and 1995-'96. During the first year, N_6, N_5, N_4 and N_3 were on a par. The treatments N_6, N_5, N_4, N_3 and N_2 were on a par during the second year.

Table No. 28 Effect of cropping systems and nutrient management on the phosphorus uptake (kg ha^{-1}) by rice

Table No. 28a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	13.64	19.28	20.66	21.46	21.60	20.87	19.58
C2	12.99	17.66	18.54	21.07	23.21	22.19	19.28
C3	11.49	15.95	16.41	20.73	22.41	21.49	18.08
C4	12.67	18.38	19.24	21.27	23.10	22.07	19.46
Mean	12.70	17.82	18.72	21.13	22.58	21.65	

SEm C - 0.362 N - 0.360 CN - 0.464

CD - N - 1.084 CN - 1.321

Table No. 28b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	15.03	21.99	22.06	22.36	22.84	23.43	21.28
C2	17.68	19.81	21.99	26.04	24.91	24.30	22.45
C3	15.06	20.19	20.29	25.43	24.60	23.66	21.54
C4	14.67	21.05	21.07	23.32	24.02	23.38	21.25
Mean	15.61	20.76	21.35	24.29	24.09	23.69	

SEm C - 0.418 N - 0.316 CN - 0.666

CD - N - 0.952 CN - 1.899

The organic matter supplied through the treatments N_2 to N_6 might have improved the availability of phosphorus (Gaur, 1992) and thereby increased the phosphorus uptake. Further higher the dry matter produced higher will be the uptake.

4.1.2.13 Potassium uptake (kg ha^{-1})

The results on potassium uptake by the second crop rice of the C_1 cropping system are presented in Tables 29 a and 29b.

The mean uptake of potassium recorded in the C_1 cropping system during 1994-'95 and 1995-'96 were 140.91 kg ha^{-1} and 153.79 kg ha^{-1} respectively. The effect of the various nutrient levels ranging from N_1 to N_6 over the cropping system, C_1 was significant. N_1 recorded the lowest potassium uptake during both the years. While N_4, N_5, N_3 and N_5, N_3 and N_6 were at par in 1994-'95, N_2, N_3, N_4, N_5 and N_6 were at par during 1995-'96.

The sub-optimal dose of nutrients applied in N_1 might have led to a lower dry matter production and consequently a lower uptake of potassium. Application of organic matter improve the potassium availability. The soil organic matter because of its high adsorptive capacity usually carries substantial quantities of exchangeable potassium (Manickam, 1993). The organic matter applied through the treatments N_2 to N_6 might have favoured a better potassium uptake as compared to N_1 (farmers' practice).

Table No. 29 Effect of cropping systems and nutrient management on the potassium uptake (kg ha^{-1}) by rice

Table No. 29a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	102.95	141.30	151.53	154.69	152.30	142.68	140.91
C2	98.25	129.00	162.50	151.72	163.82	151.92	138.50
C3	87.24	117.02	120.46	149.41	158.22	147.77	130.02
C4	95.67	134.00	141.58	153.16	163.05	151.32	139.79
Mean	96.03	130.33	137.46	152.25	159.34	148.42	

SEm C - 2.703 N - 2.646 CN - 3.487

CD N - 7.975 CN - 9.938

Table No. 29b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	113.97	162.38	161.85	161.19	161.76	161.63	153.79
C2	131.71	161.42	162.50	181.62	177.59	170.20	164.17
C3	115.46	151.77	150.56	187.70	177.03	166.19	158.12
C4	110.73	156.05	155.06	165.98	170.96	161.91	153.45
Mean	117.96	157.91	157.49	174.12	171.83	164.98	

SEm C - 2.535 N - 2.005 CN - 4.171

CD C - 8.111 N - 6.042 CN - 11.886

4.1.3 Sesamum

4.1.3.1 Plant height (cm)

The results on the height of plants recorded are presented in Tables 30a and 30b.

Nutrient management of preceding crops of rice had a significant influence on plant height. N_6 recorded the highest value for this parameter and N_1 the lowest N_6, N_5, N_4 and N_3 were at par during both the years. During 1995-'96 N_3 and N_2 were also at par.

4.1.3.2 Number of branches per plant

The results pertaining to the number of branches per plant are presented in Tables 30a and 30b.

There was significant residual effect for the various nutrient management of rice, on this growth parameter of sesamum. N_6 recorded significantly higher number of branches per plant and N_1 the lowest number of branches per plant, both during 1994-'95 and 1995-'96. N_4 and N_3 were at par in the first year. N_5, N_4 and N_3 were at par in the second year.

The lower values for plant height and number of branches per plant at N_1 may be due to the poor vegetative growth supported by the sub-optimal levels of nutrients in N_1. Some residual effect has been observed for N_5 and N_6 during the first year and for N_6 during the second year.

4.1.3.4 Number of capsules per plant

The results on the number of capsules per plant are presented in Tables 30a and 30b.

Perusal of the data showed significant variation among the various nutrient management levels, with N_5 producing the highest number of capsules per plant during the first and second year.

4.1.3.5 Number of seeds per capsule

The results on the number of seeds per capsule are presented in Tables 30a and 30b.

The number of seeds per capsule was found to be affected significantly by the different nutrient management levels applied to rice, during both the years. While N_5 recorded the maximum number of capsules per plant during 1994-'95 and 1995-'96, N_1 recorded the lowest number of capsules per plant during the first and second year. Integrated nutrient management in the preceding crops of rice could be observed to have a positive influence on the succeeding crop of sesamum.

4.1.3.6 Seed yield (kg ha^{-1})

The mean seed yield in kg ha^{-1} recorded are presented in Tables 30a and 30b.

Nutrient management of rice had significant influence on the seed yield of sesamum during both the years. N_6 and N_5 recorded the highest seed yield during 1994-'95 and 1995-'96 respectively. During the first year, N_6, N_5 and N_4, N_3 and N_2 were on a par. During the second year N_6, N_5 and N_4 were on a par.

Seed yield of sesamum is a function of the number of capsules per plant and the number of seeds per capsule. Both these parameters were observed to record values (at N_2 to N_6) which were significantly higher than the values recorded at N_1. In N_1, the farmers practice neither farmyard manure nor fertilisers were applied to sesamum. Further the preceding crops of rice were also supplied with sub-optimal doses of farmyard manure and chemical fertilisers. Thus the poor nutrition of the crop offered by N_1 might have resulted in the poor seed yield. The higher yields recorded by the treatments N_2 to N_6 may be attributed to the fact that the crop was fertilised as per the package of practices recommendations in these treatments. However the higher yields in N_4, N_5 and N_6 as compared to N_2 might have been due to the residual effect of the organic matter and nutrients applied to the preceeding crops of rice. This is in accordance with the works of Nambiar and Abrol (1989) have reported that integrated use of organic manures and inorganic fertilisers enhanced the biological activities in the soil leading to better soil structure and

Table No. 30 Growth, yield attributes, yield and oil content of sesamum as influenced by nutrient management management

Table No. 30a 1994-'95

Nutrient management	Plant height (cm)	Branches $plant^{-1}$	Capsules $plant^{-1}$	Seeds $capsule^{-1}$	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Oil content (%)
N1	60.20	3.06	34.24	45.79	245.93	993.64	45.22
N2	89.01	4.30	49.68	53.13	348.44	1022.04	48.33
N3	102.01	5.12	60.40	56.67	358.60	1037.94	48.06
N4	105.98	5.29	84.88	60.14	432.49	1115.96	48.48
N5	106.31	6.27	95.04	65.31	462.50	1159.72	48.66
N6	109.78	7.83	94.99	57.89	466.86	1289.61	48.30
SEm	3.1627	0.1604	5.2749	1.5194	16.6047	22.9296	0.8708
CD (0.05)	9.5316	0.4833	15.8970	4.5791	50.0415	69.1027	2.62[illegible]

Table No. 30b 1995-'96

Nutrient management	Plant height (cm)	Branches $plant^{-1}$	Capsules $plant^{-1}$	Seeds $capsule^{-1}$	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Oil content (%)
N1	60.22	3.22	36.26	45.71	236.15	1019.21	45.13
N2	91.56	4.99	51.12	52.29	322.41	1025.19	48.33
N3	100.29	5.84	62.39	61.01	371.41	1036.32	47.99
N4	107.06	5.80	86.06	62.45	420.95	1147.34	48.37
N5	108.12	6.00	92.43	64.53	439.71	1167.82	49.01
N6	109.77	7.01	92.16	64.40	437.12	1254.99	48.60
SEm	3.5029	0.2057	3.3382	1.0962	10.7918	18.0241	0.5305
CD (0.05)	10.5568	0.6198	10.0603	3.3035	32.5231	54.3189	1.5988

nutrient availability especially micro nutrients not only to the current crop but also to the succeeding crop.

4.1.3.7 Haulm yield (kg ha^{-1})

The results on the haulm yield of sesamum are presented in Tables 30a and 30b.

The treatment N_6 exerted significant influence on the haulm yield during both the years. N_6 recorded the highest haulm yield and N_1 the lowest haulm yield during the first year and second year. During both the years the treatments N_5 and N_4 and the treatments N_3, N_2 and N_1 were on a par.

The lowest haulm yield recorded by N_1 (farmers' practice') may be related to the poor plant height and number of branches per plant recorded by the same. The poor vegetative growth recorded may be due to the poor nutrition offered to the crop by this treatment. All the other treatments (N_2 to N_6) were supplied with nutrients as per the package of practices recommendations of KAU. This may be the reason for the higher haulm yield in these treatments. However it can be seen that in the treatments like N_4, N_5 and N_6, which provided a better integrated nutrient supply to the preceeding crops of rice, haulm yield of sesamum was higher. Thus as in the case of seed yield, organics applied to rice was observed to have a positive residual influence on the haulm yield.

4.1.3.8 Oil content of sesamum (per cent)

The mean oil content of sesamum are presented in Tables 30a and 30b.

The oil content of sesamum was found to be influenced significantly by nutrient management. The treatments N_6, N_5, N_4, N_3 and N_2 were on a par. N_5 recorded the highest oil content and N_1 the lowest.

The better nutrition provided by the treatments N_2 to N_6 might have led to higher oil content. Oil content of sesamum has been observed to be influenced significantly by nitrogen (Girijadevi, 1985), phosphorus (Kostrinksy, 1989) and potassium (Dasmahapatra *et al*., 1990).

4.1.3.9 Nitrogen uptake (kg ha^{-1})

The results on the nitrogen uptake by sesamum are presented in Tables 31a and 31b.

Significant influence was observed for nutrient management on the nitrogen uptake by sesamum during 1994-'95. The treatments N_6, N_5, N_4, N_3 and N_2 were at par. N_1 recorded the lowest values and N_6 recorded the highest value for nitrogen uptake during the first year. Significant differene was not observed for the effect of nutrient management on the nitrogen uptake by sesamum during the second year.

Table No. 31 Effect of cropping systems and nutrient management on the nitrogen uptake (kg ha^{-1}) by the summer crops

Table No. 31a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	11.34	13.81	14.13	16.24	17.17	18.03	15.12
C2	66.32	74.27	76.73	76.11	100.09	100.46	82.33
C3	22.07	34.61	35.08	37.88	39.06	39.14	34.31
C4	17.22	20.40	21.17	22.62	22.98	24.30	21.45
Mean	29.24	35.27	36.77	38.21	44.82	45.48	

SEm C - 1.108 N - 0.872 CN - 1.577

CD C - 3.545 N - 2.628 CN - 4.494

Table No. 31b Third crop season (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	10.08	13.34	14.50	16.28	16.81	17.28	14.72
C2	63.12	75.34	77.56	83.38	101.83	102.00	83.87
C3	20.33	32.92	35.69	38.16	39.48	38.95	34.25
C4	16.65	19.83	20.62	20.70	20.90	21.44	20.02
Mean	27.54	35.36	37.09	39.63	44.76	44.92	

SEm C - 1.388 N - 1.269 CN - 2.817

CD C - 4.439 N - 3.826 CN - 8.028

Application of nitrogen at optimum levels has been observed to improve nitrogen uptake (Girijadevi, 1985). As the total dry matter production increases uptake also increases.

4.1.3.10 Phosphorus uptake (kg ha^{-1})

The results on the effect of the nutrient management on phosphorus uptake are presented in Tables 32a and 32b.

The effect of nutrient management on the uptake of phosphorus by sesamum was significant during the first year only. N_6 recorded the highest value for phosphorus uptake during the first year and second year and N_1 recorded the lowest value.

The higher dry matter production recorded by the treatments N_2 to N_6 may be one of the reasons for the higher phosphorus uptake recorded by the same. A better phosphorus uptake has been obtained at optimal doses of nitrogen and potassium (Regy, 1996). The residual effect of the organic sources applied to the preceding crops of rice might have also improved the phosphorus availability to sesamum.

4.1.3.11 Potassium uptake (kg ha^{-1})

The results on the effect of nutrient management on the uptake of potassium are presented in Tables 33a and 33b.

Table No. 32 Effect of cropping systems and nutrient management on the phosphorus uptake (kg ha^{-1}) by the summer crops

Table No. 32a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	5.47	6.35	6.49	7.33	7.72	8.23	6.93
C2	6.67	8.01	7.82	7.73	10.17	10.20	8.43
C3	3.15	4.71	5.07	5.47	5.65	5.65	4.95
C4	8.66	10.59	10.83	11.57	11.69	12.27	10.94
Mean	5.99	7.42	7.55	8.03	8.80	9.09	

SEm C - 0.324 N - 0.174 CN - 0.306

CD C - 1.037 N - 0.523 CN - 0.872

Table No. 32b Third crop season (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	5.50	6.19	6.60	7.38	7.60	7.90	6.86
C2	6.51	7.77	8.00	8.60	10.50	10.52	8.65
C3	2.93	4.75	5.15	5.50	5.69	5.61	4.94
C4	8.73	10.35	10.95	11.00	11.17	11.07	10.54
Mean	5.92	7.26	7.67	8.12	8.74	8.77	

SEm C - 0.320 N - 0.210 CN - 0.401

CD C - 1.023 N - 0.634 -

Table No. 33 Effect of cropping systems and nutrient management on the potassium uptake (kg ha^{-1}) by the summer crops

Table No. 33a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	20.34	21.96	22.35	24.54	24.28	28.00	23.58
C2	26.74	31.84	30.94	30.70	40.37	40.51	33.52
C3	15.36	21.50	23.15	25.00	25.77	25.82	22.77
C4	30.72	36.30	35.77	39.58	39.75	41.99	37.35
Mean	23.29	27.90	28.05	29.95	32.54	34.08	

SEm C - 1.252 N - 0.678 CN - 1.179

CD C - 4.004 N - 2.042 CN - 3.361

Table No. 33b Third crop season (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	20.67	21.72	22.44	24.95	25.52	27.04	23.72
C2	25.86	30.86	31.77	34.15	41.71	41.73	34.35
C3	13.35	21.63	23.44	25.05	25.94	25.58	22.50
C4	29.53	34.97	36.58	36.41	36.73	36.73	35.16
Mean	22.35	27.29	28.56	30.14	32.47	32.77	

SEm C - 1.098 N - 0.747 CN - 1.512

CD C - 3.511 N - 2.250 CN - 4.308

Potassium uptake was influenced significantly by nutrient management. N_6 and N_1 recorded the highest and lowest uptake values respectively during both the years.

As in the case of uptake of nitrogen and phosphorus, application of optimal dose of potassium and higher dry matter production may be the reasons for the higher uptake of potassium recorded by the treatments, N_2 to N_6 as compared to N_1. The increase in potassium uptake recorded by N_6 may also be attributed to the residual effect of the organics applied to rice.

4.2 Rice-rice-groundnut system (C_2)

4.2.1 First crop rice

4.2.1.1 Number of productive tiller per square metre at harvest

The results on the number of productive tillers per square metre at harvest as influenced by nutrient management are presented in Tables 4a and 4b.

The mean number of productive tillers per square metre at harvest recorded in the C_2 system were 268 in 1994-'95 and 303 in 1995-'96. Nutrient management exerted significant influence on the number of productive tillers per square metre at harvest during both the years. N_6 was significantly superior to all the other treatments and recorded a maximum value of 349 in 1994-'95 and 396 in 1995-'96. N_2 (package of practices), N_3 and N_4 were at par. N_1 (farmers' practice) was significantly inferior to all the other treatments during both the years, while N_6 resulted in the best response.

The beneficial effect of integration of organic, inorganic and biofertilisers in increasing the number of productive tillers in first crop rice has been discussed earlier. The number of productive tillers was observed to increase during the second year. The high fertility status especially of nitrogen maintained continuously by the additional nitrogen fixation by groundnut might be responsible for the higher number of productiive tillers in the first crop rice of the second year. Increase in ear bearing tillers due to the increase in nitrogen levels has been reported by Reddy and Reddy (1989) and Singh and Singh (1993).

4.2.1.2 Number of spikelets per panicle

The results on the number of spikelets per panicle are presented in Tables 5a and 5b.

The mean number of spikelets per panicle recorded by the first crop rice component of the C_2 cropping system was 91 in 1994-'95 and 84 in 1995-'96. The effect of the treatments on the crop was not significant during the first year and second year.

4.2.1.3 Percentage of filled grains

Tables 6a and 6b present the results on the percentage of filled grains.

The mean percentage of filled grains of the first crop rice component of the C_2 cropping system was 80.02 per cent in 1994-'95 and 79.80 per cent in 1995-'96. First year and second year showed a non-significant influence for nutrient management on the percentage of filled grains.

4.2.1.4 Thousand grain weight (g)

The results on the influence of nutrient management on the thousand grain weight of first crop rice are presented in Tables 7a and 7b

Mean thousand grain weight recorded during 1994-'95 was 25.7 g and that during 1995-'96 26.0 g. Significant difference was not observed among the different nutrient management levels in both the years.

4.2.1.5 Grain yield (kg ha^{-1})

The results on the influence of nutrient management over the first crop rice of the C_2 cropping system, on the grain yield are presented in Tables 8a and 8b and graphically in Fig. 3a and 3b.

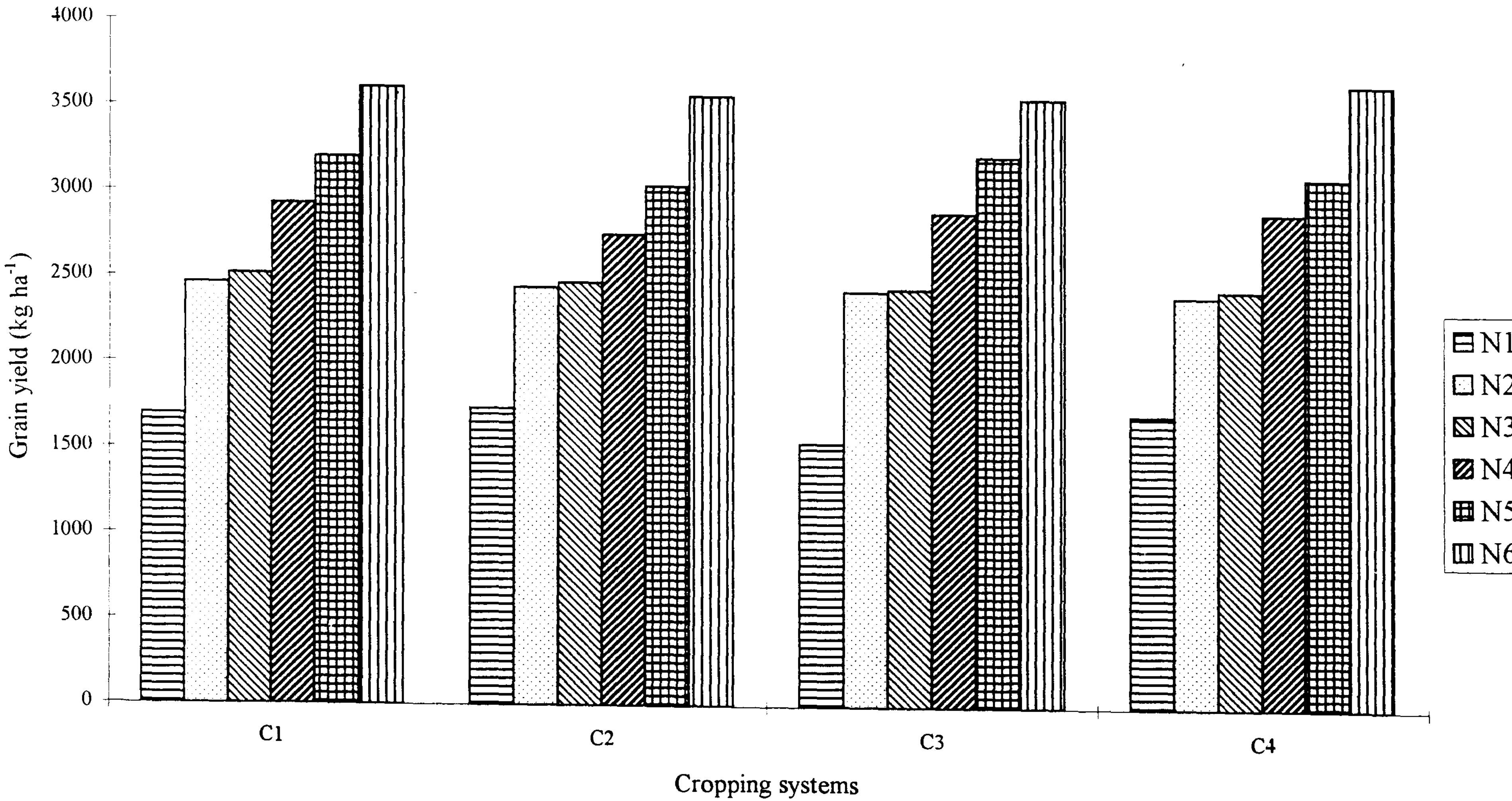


Fig.3a First crop rice (1994 - '95) - Grain yield (kg ha^{-1})

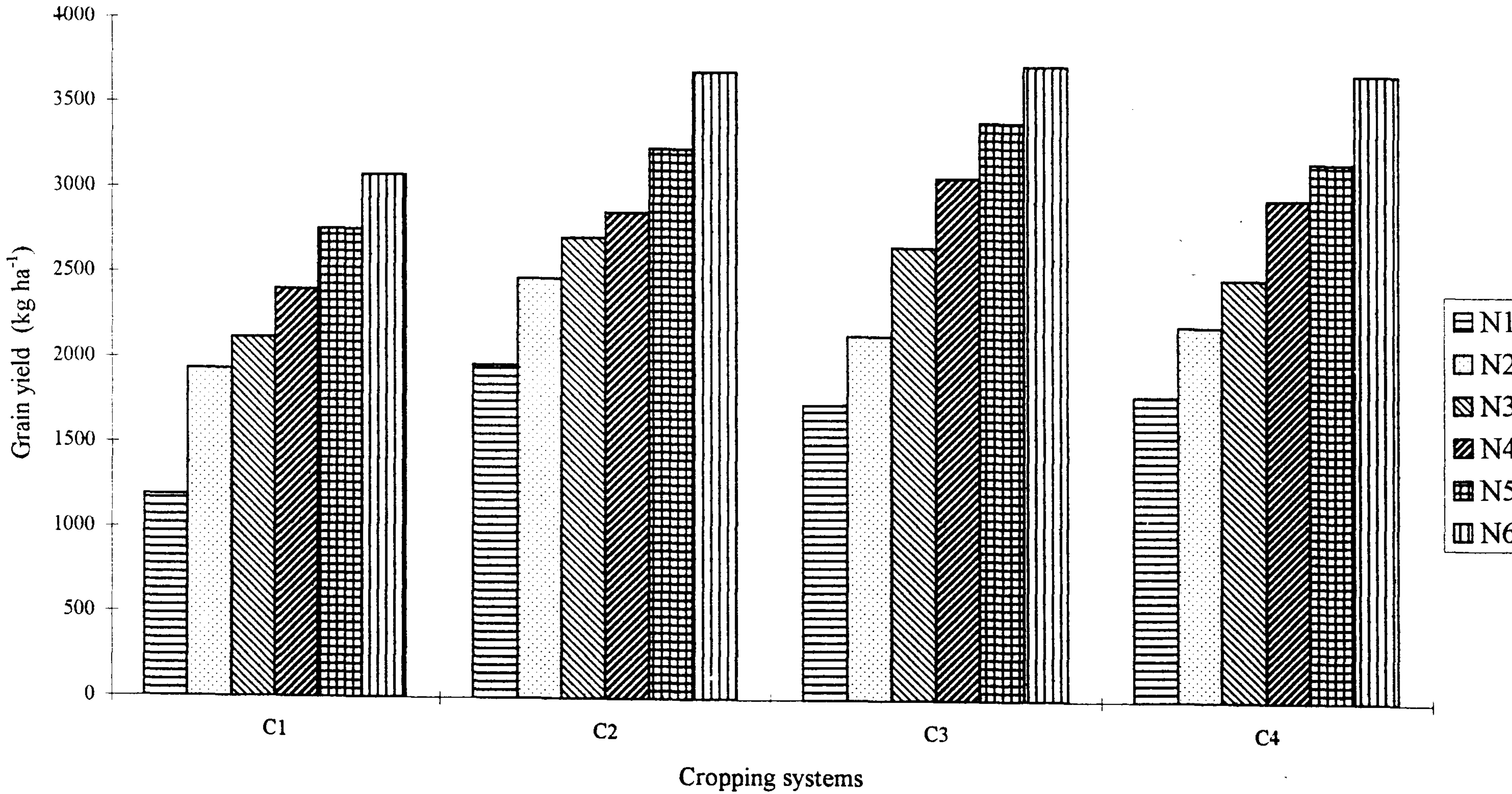


Fig.3b First crop rice (1995-96) - Grain yield (kg ha^{-1})

The mean grain yield of the first crop rice component of the C_2 cropping system were 2671 kg ha^{-1} and 2832 kg ha^{-1} during the first year and second year respectively. The effect of nutrient management on the grain yield was not significant during the first year. But it was significant during the second year. N_6 and N_5 recorded significantly higher yield in both the years and was observed to be superior to the package of practices recommendations (N_2), N_3 and N_4.

The maximum grain yield (pooled) was recorded at N_6 (Table 37).

The higher grain yield recorded by the treatments N_2 to N_6 as compared to the low yields in N_1 may be attributed to the application of optimal doses of nutrients and the effect of integrated use of organic, inorganic and biological sources of nutrients, as discussed earlier. Grain yield in general was observed to be higher during the second year. The data on the nitrogen status of the soil after the first year indicate a positive increase in the nitrogen status of soil in plots where groundnut was cultivated during the third crop season. This may be the reason for the increase in grain yield of the first crop rice during the second year in the rice-rice-groundnut cropping system. Similar results have been reported by Sasidhar (1978) and Tajudeen *et al.* (1989).

4.2.1.6 Straw yield (kg ha^{-1})

Tables 9a and 9b and Fig. 4a and 4b present the results on the effect of nutrient management on the grain yield of first crop rice in the C_2 cropping system.

The mean straw yield recorded during the first year and second year were 3725 kg ha^{-1} and 3807 kg ha^{-1} respectively. Straw yield was not affected significantly by nutrient management during the first year. However, significant differences was observed during the second year. N_1 recorded the highest straw yield of 4997 kg ha^{-1}, during the second year. N_6 and N_5 and N_4, N_3 and N_2 were on a par.

The high straw yield recorded by N_1 was accompanied by very low grain yield. Thus most of the nutrients applied have been utilised for production of vegetative matter rather than for grain production. The superiority of integrated application of organic, inorganic and biological nutrients is clearly indi-cated by the high straw yield and high grain yields at the nutrient levels N_3, N_4, N_5 and N_6. Further, in N_1 there was increase in straw yield during the second year. This may be due to the fact that the nitrogen fixed by the preceding crop of groundnut was utilised mostly for producing vegetative matter. Higher levels of nitrogen especially at sub-optimal levels of phosphorus and potassium has been reported to favour straw production. Similar results have been reported by Sreekumaran (1981) in rice.

4.2.1.7 Straw : grain

The results on the straw : grain of the first crop rice of the C_2 cropping system, during 1994-'95 and 1995-'96 are presented in Tables 10a and 10b respectively.

The effect of the nutrient levels on the straw : grain of the first crop rice of the C_2 cropping system was significant during the first year and second year. The mean straw : grain recorded was 1.48 during 1994-'95 and 1.43 during 1995-'96. N_6 and N_1 recorded the lowest and highest values respectively for straw : grain during both the years. N_6 and N_5 and N_4, N_3 and N_2 were at par during 1994-'95. N_5, N_4 and N_3 and N_3 and N_2 were at par during 1995-'96.

The reasons for the variation in the straw : grain at nutrient management levels varying from N_1 to N_6, have been discussed earlier. The straw : grain was observed to decrease slightly during the second year. This suggests that the nitrogen fixed by groundnut was utilised mainly for grain production, under integrated nutrient management.

4.2.1.8 Harvest index

Tables 11a and 11b present the results on the harvest index of first crop rice.

The mean harvest index recorded by first crop rice in the C_2 cropping system was 0.414 in 1994-'95 and 0.426 in

1995-'96. The effect of nutrient management over the crop was not significant during the first year, but significant during the second year. N_6 recorded the highest value of 0.488 during the second year, and N_1 (farmers' practice) recorded the least value of 0.283. The harvest indext at N_2 (package of practices) was significantly lower than that at N_5 and N_6.

The effect of nutrient management on the harvest index of first crop rice has been discussed earlier. The harvest index was observed to be higher during the second year. This may be due to the improvement in soil fertility through nitrogen fixation by groundnut. Similar results have been reported by Sobhana (1983).

4.2.19 Crude protein content (per cent)

The results on the crude protein content of first crop rice as influenced by nutrient management are presented in Tables 12a and 12b.

The mean crude protein content recorded during 1994-'95 was 8.20 per cent and that during 1995-'96 was 8.31 per cent. The effect of the nutrient management on the crude protein content of the crop was not significant during the first year and second year.

4.2.1.10 Nitrogen harvest index (per cent)

The results on the nitrogen harvest index (NHI) of first crop rice in the C_2 cropping system are presented in Tables 13a and 13b.

The mean NHI recorded during 1994-'95 was 49.80 per cent and that during 1995-'96 was 51.30 per cent. NHI was not affected significantly by nutrient management during the first year, whereas in the second year NHI was found to be influenced significantly by the treatments. N_6 recorded the highest NHI of 57.10 per cent and N_1 recorded the lowest NHI of 36.65 per cent. N_4 and N_5, N_6 and N_3 and N_3 and N_2 were at par during the second year.

The higher NHI in the treatments higher than N_1 may be attributed to the better utilisation of nitrogen for the production of grain rather than straw under the influence of integrated nutrient management as suggested by Rathore *et al.* (1995).

4.2.1.11 Nitrogen uptake (kg ha^{-1})

Tables 14a and 14b present the result on the nitrogen uptake by rice as influenced by nutrient management.

The mean nitrogen uptake by the first crop rice of the C_2 cropping system was 61.28 kg ha^{-1} in 1994-'95 and 63.06 kg ha^{-1} during 1995-'96. Nitrogen uptake was not affected significantly by nutrient management during the first year as compared to the second year, where significance was observed. N_6 recorded the highest nitrogen uptake of 74.50 kg ha^{-1}.

Increased nitrogen uptake due to organic sources of nitrogen have been reported by Azam (1990). Further *Azospirillum* has been observed to increase the uptake of nitrogen by way of nitrogen fixation. These may be the reasons for the higher nitrogen uptake in N_6.

4.2.1.12 Phosphorus uptake (kg ha^{-1})

The results on the influence of the nutrient management on the first crop rice in the C_2 cropping system, on the uptake of phosphorus are presented in Tables 15a and 15b.

The mean values of phosphorus uptake during 1994-'95 and 1995-'96 are 13.49 kg ha^{-1} and 14.39 kg ha^{-1} respectively. While the effect of nutrient management on the uptake of phosphorus was not significant during the first year, it was significant during the second year. N_6 recorded the maximum uptake (17.05 kg ha^{-1}) during 1995-'96.

The higher phosphorus uptake recorded by the treatments N_2 to N_6 as compared to N_1 may be attributed to the higher dry matter production recorded by the same. However the higher uptake of phosphorus recorded under the treatments N_3 to N_6 may be attributed to the beneficial effects of organics on the mobilisation of soil phosphorus as reported by Sivasamy (1982).

4.2.1.13 Potassium uptake (kg ha^{-1})

The results on the potassium uptake by first crop rice in the C_2 cropping system are presented in Table 16a and Table 16b.

The mean potassium uptake recorded was 78.05 kg ha^{-1} in 1994-'95 and 81.42 kg ha^{-1} during 1995-'96. Potassium uptake was influenced significantly by nutrient management only during the second year. N_1 recorded the highest potassium uptake of 96.84 kg ha^{-1} followed by N_6 with an uptake of 88.39 kg ha^{-1}.

The probable reasons for the higher uptake of potassium by the treatments N_2 to N_6 have been discussed earlier. Apart from these, the favourable influence of organic in enhancing the available potassium content of soils and consequently the uptake has been reported by Muthuvel *et al.* (1977). However the higher uptake of potassium recorded by N_1 is due to high straw yield recorded in this treatment. Compared to grain, straw recorded higher content of potassium.

4.2.2 Second crop rice

4.2.2.1 Number of productive tillers per square metre at harvest

The results on the number of productive tillers per square metre at harvest are presented in Tables 17a and 17b.

The mean number of productive tillers per square metre at harvest as influenced by the different nutrient management levels was 310 during 1994-'95 and 336 during 1995-'96. Nutrient management influenced the number of productive tillers per square metre at maturity significantly during both the years. N_1 was found to produce significantly lower number of productiive tillers. The treatment N_6 and N_5 were on a par and gave a better response than N_2 (package of practices).

The probable reasons for the results stated above have been discussed earlier. The increase in the number of producti ve tillers recorded during the second year as compared to the first year may be attributed due to the legume effect.

4.2.2.2 Number of spikelets per panicle

The results on the number of spikelets per panicle of the second crop rice of the C_2 cropping system as influenced by nutrient management are presented in Tables 18a and 18b.

The mean number of spikelets recorded by the second crop rice of the C_2 cropping system during the first year and second year were 86 and 87 respectively. This yield component of rice was influenced significantly by the nutrient management during the second year only. N_6 produced significantly maximum value for this parameter and N_1 the lowest value N_5 and N_4, N_4 and N_3, N_3 and N_2 and N_2 and N_1 were at par during 1995-'96.

The superiority of integration of bio-organics and inorganics with regard to the number of spikelets per panicle have been discussed earlier.

4.2.2.3 Percentage of filled grains

The results in the percentage of filled grains of the second crop rice are presented in Tables 19a and 19b.

The mean percentage of filled grains recorded by the second crop rice of the C_2 cropping system was 81.21 per cent in 1994-'95 and 81.46 per cent in 1995-'96. The effect of nutrient management C_2 on the percentage of filled grains was non-significant during the second year, but significant during the first year. N_4 recorded the highest percentage of filled grains (82.84 per cent) and N_1 the lowest percentage of filled grains (76.59 per cent). N_4 and N_3 and N_2 and N_5 were at par during the first year.

The organic matter applied, because of its high adsorptive capacity usually carries substantial quantities of exchangeable potassium. Increased availability of potassium due to the combined application of farmyard manure and NPK was reported by Aravind (1987). The role of potassium in establishing an appropriate source - sink relationship has been discussed earlier. However at higher nitrogen levels (as in N_6) the filled grain percentage has been observed to decrease.

4.2.2.4 Thousand grain weight (g)

The results on the thousand grain weight of second crop rice in C_2 cropping system as influenced by nutrient management are presented in Tables 20a and 20b.

The mean thousand grain weight recorded by the second crop rice in 1994-'95 was 26.2 g and in 1995-'96 was 26.0 g. Both the first year and second year no significant influence was seen for nutrient management on the thousand grain weight of rice.

4.2.2.5 Grain yield (kg ha^{-1})

Tables 21a and 21b and Fig. 5a and 5b present the result on the grain yield of second crop rice of the C_2 cropping system as influenced by nutrient management.

The mean grain yield recorded by the second crop rice of the C_2 cropping system over the varying nutrient management levels was 2920 kg ha^{-1} during 1994-'95 and 3222 kg ha^{-1} during 1995-'96. The effect of nutrient management on the grain yield of second crop rice was significant during both the years. N_6 and N_1 recorded the maximum and minimum values respectively for grain yield during the first year and second year. The treatments N_2 to N_6 recorded more grain yield than N_1 (farmers' practice). While N_3 and N_4 were on a par with N_2 (package of practices), N_5 and N_6 showed better response in both years.

Perusal of the data on the pooled analysis of grain yield (Table 38) showed that the treatment N_6 recorded the maximum grain yield.

The influence of the integrated use of bio-organics and inorganics in improving the grain yield of rice have been discussed earlier. The higher grain yield recorded during the second year clearly illustrates the favourable effect of legume crop on the succeeding rice crops. Similar results were reported by Sasidhar (1978) and Reddy *et al*. (1993).

4.2.2.6 Straw yield (kg ha^{-1})

The results on the straw yield of second crop rice in the C_2 cropping system are presented in Tables 22a and 22b amd graphically in Fig. 6a and 6b.

The mean straw yield recorded by second crop rice as during 1994-'95 was 7207 kg ha^{-1} and 8495 kg ha^{-1} during 1995-'96. Straw yield was influenced significantly by nutrient management during the first year and second year. N_5 and N_4 recorded the highest straw yields during 1994-'95 and 1995-'96 respectively. N_1 recorded the lowest straw yield during both the years. The treatments N_6 and N_4 and N_3 and N_2 were at par during 1994-'95. N_4 and N_5, N_5, N_6 and N_3 and N_3 and N_2 were at par during 1995-'96.

As in the case of grain yield, the probable reasons for the poor straw yield in N_1 and the higher straw yield in the other treatments have been discussed earlier. The favourable influence of groundnut was extended to the straw yield of the second crop rice of the second year also. This may be the reason for the higher straw yield recorded during the second year. Similar results have been reported by Sasidhar (1978).

4.2.2.7 Straw : grain

Tables 23a and 23b present the results on the straw : grain.

The mean straw:grain recorded by the second crop rice of C_2 cropping system over the varying nutrient management levels was 2.55 during 1994-'95 and 2.70 during 1995-'96. Significant difference was not observed in the straw : grain of the second crop rice due to the various nutrient levels, both during 1994-'95 and 1995-1996.

4.2.2.8 Harvest index

The results on harvest index of rice are presented in Tables 24a and 24b.

The mean harvest index recorded by the second crop rice component of the C_2 cropping system were 0.283 and 0.273 respectively during the first year and second year. Harvest index was not influenced significantly by nutrient management during both the years.

4.2.2.9 Crude protein content (per cent)

The crude protein content of second crop rice in the C_2 cropping system as influenced by nutrient management during 1994-'95 and 1995-'96 are presented in Tables 25a and 25b respectively.

The mean crude protein content recorded during 1994-'95 and 1995-'96 were 8.71 per cent and 8.67 per cent respectively. The effect of nutrient management over C_2 was not significant with respect to the crude protein content of second crop rice during the first year and second year.

4.2.2.10 Nitrogen harvest index (per cent)

The results on the nitrogen harvest (NHI) of the second crop rice in C_2 cropping system as influenced by nutrient management are presented in Tables 26a and 26b.

The mean NHI of second crop rice was 36, 90 per cent in 1994-'95 and 36.00 per cent in 1995-'96. The different nutrient management levels over the C_2 cropping system exerted a non-significant influence on the NHI.

4.2.2.11 Nitrogen uptake (kg ha^{-1})

Tables 27a and 27b present the results on the effect of nutrient management on the nitrogen uptake by second crop rice of C_2 cropping system.

The mean nitrogen uptake recorded during the first year and second year were 95.38 kg ha^{-1} and 109.15 kg ha^{-1} respectively. Nitrogen uptake was affected significantly by nutrient management both during the first year and second year. N_5 and N_1 recorded the maximum and minimum uptake values for nitrogen during the first year and second year. N_5 and N_6, N_6 and N_4 and N_3 and N_2 were at par during 1994-'95. During 1995-'96, the treatments N_5, N_4 and N_6 and N_3 and N_2 were on par.

4.2.2.12 Phosphorus uptake (kg ha^{-1})

The results on phosphorus uptake of second crop rice as influenced by nutrient management over the C_2 cropping system are presented in Tables 28a and 28b.

The mean phosphorus uptake by second crop rice was 8.43 kg ha^{-1} in 1994-'95 and 8.65 kg ha^{-1} in 1995-'96. The effect of nutrient management on the phosphorus uptake was significant during both the years. N_5 recorded the maximum uptake value of 23.21 kg ha^{-1} and N_1 the minimum uptake value of 12.99 kg ha^{-1} during the first year. N_6, N_5, N_4 and N_3 were at par during the first year. During the second year, the maximum phosphorus uptake of 26.04 kg ha^{-1} was recorded by N_4 and the minimum uptake of 17.68 kg ha^{-1} by N_1. The treatments N_6, N_5 and N_4 and N_3 and N_2 were at par during the second year.

4.2.2.13 Potassium uptake (kg ha^{-1})

The results on the potassium uptake by second crop rice in the C_2 cropping system as influenced by nutrient management are presented in Tables 29a and 29b respectively.

The second crop rice in the C_2 cropping system recorded a mean potassium uptake of 138.50 kg ha^{-1} during 1994-'95 and 164.17 kg ha^{-1} during 1995-'96. In both the years significant influence was noticed for the different nutrient management levels over the potassium uptake. N_5 recorded the highest uptake value during 1994-'95, while N_4 recorded the highest uptake during 1995-'96. N_1 recorded the least uptake values during both the years. N_6 and N_4 and N_3 and N_2 were at par during the first year. During the second year it was observed that the treatments N_4, N_5 and N_6 and N_6, N_3 and N_2 were on a par.

The low uptake of nitrogen, phosphorus and potassium, recorded in the treatment may be due to the application of these major nutrients at sub-optimal doses and due to the low dry matter production recorded by these treatments. Integrated approach in nutrient management has been observed to improve the availability of nitrogen, phosphorus and potassium and consequently their uptake. The uptake of nitrogen and potassium has been observed to increase substantially during the second year. Similar results have been reported by Sasidhar (1978) and Pillai (1993) which indicated the superiority of raising a leguminous crop like groundnut during the summer season.

4.2.3 Groundnut

4.2.3.1 Number of mature pods per plant

Tables 34a and 34b show the results on the number of mature pods per plant.

Nutrient management showed significant influence on the number of mature pods per plant. During both the years N_6 produced the maximum number of mature pods per plant and N_1 the minimum. N_6 and N_5, N_5, N_4 and N_3 and N_4, N_3 and N_2 were at par during the first year. During the second year, the treatments, N_6, N_5, N_4 and N_3 and the treatments N_4, N_3 and N_3 were at par.

4.2.3.2 Pod yield (kg ha^{-1})

The results on the mean pod yield per hectare are presented in Tables 34a and 34b.

Table No. 34 Yield attributes, yield and oil content of groundnut as influenced by nutrient management

Table No. 34a 1994-'95

Nutrient management	Mature pods $plant^{-1}$	Pod yield ($kg\ ha^{-1}$)	Haulm yield ($kg\ ha^{-1}$)	Shelling percentage	Oil content (%)
N1	13.77	917.95	1756.89	57.40	43.95
N2	18.30	1092.90	2091.75	57.81	48.46
N3	19.78	1061.68	2033.54	58.40	48.39
N4	19.76	1052.67	2018.61	58.54	48.27
N5	21.11	1385.47	2651.71	59.47	48.22
N6	23.50	1391.66	2658.99	61.30	48.32
SEm	0.8708	54.1796	103.4382	0.4946	0.6109
CD (0.05)	2.6244	163.2806	311.7307	1.4907	1.8410

Table No. 34b 1995-'96

Nutrient management	Mature pods $plant^{-1}$	Pod yield ($kg\ ha^{-1}$)	Haulm yield ($kg\ ha^{-1}$)	Shelling percentage	Oil content (%)
N1	13.34	902.44	1672.74	56.71	45.41
N2	19.20	1077.10	1996.49	57.88	47.79
N3	19.52	1108.89	2055.42	58.12	48.03
N4	20.35	1192.06	2209.57	59.07	47.85
N5	21.82	1455.81	2698.46	60.23	48.25
N6	21.88	1467.78	2677.06	60.75	48.80
SEm	0.8372	74.1368	140.5926	0.3759	0.5178
CD (0.05)	2.5230	223.4253	423.7023	1.1327	1.5606

Significant influence was observed for nutrient management on the pod yield of groundnut. The maximum pod yield was recorded by the treatment N_6 and N_1 recorded the minimum pod yield. N_6 and N_5, N_2, N_3 and N_4 and N_3, N_4 and N_1 were at par during 1994-'95. N_6 and N_5, N_4, N_3 and N_2 and N_3, N_2 and N_1 were at par during 1995-'96.

The number of mature pods per plant and pod yield of groundnut showed an increasing trend from N_1 to N_6. However considerable difference was not observed among the different nutrient management levels, indicating that there was no residual effect for the treatments given to rice. However the minimum pod yield recorded by N_1 indicates the inefficiency of the treatment. Superiority of the other treatments may be due to the optimal dose of manures, fertilisers and especially lime which were applied to groundnut (as per the package of practices recommendations). The higher yields under N_5 and N_6 indicates a possibility of generating some residual effect of these treatments following the preceding crops of rice.

4.2.3.3 Haulm yield (kg ha^{-1})

Tables 34a and 34b show the mean haulm yield of groundnut.

Haulm yield of groundnut was influenced significantly by nutrient management. The maximum haulm yield was recorded by N_6 during 1994-'95 and by N_5 during 1995-'96 and the minimum haulm yield was recorded by N_1. The treatments N_6 and N_5, N_4, N_3 and N_2 and N_4, N_3 and N_1 were at par in the first year. During the second year N_6 and N_5, N_4, N_3 and N_2 and N_3, N_2 and N_1 were at par.

As in the case of pod yield, the absence of considerable difference among the different levels of nutrient management indicate the lack of residual effect for the treatments applied to the preceding crops of rice on the succeeding crop of groundnut. However some residual effect can be expected in the long run as indicated by the better yield recorded by the treatments N_5 and N_6.

4.2.3.4 Shelling percentage

The results on the shelling percentage of groundnut are presented as Tables 34a and 34b.

There was significant influence for nutrient management on the shelling percentage. A shelling percentage of 61.30 per cent and 60.75 per cent were recorded by the treatment N_6 during 1994-'95 and 1995-'96 respectively. N_1 recorded the lowest value for this parameter during both the years. The treatments N_4, N_3, N_2 and N_1 were on a par in the first year. During the second year N_6 and N_5, N_4 and N_3 and N_3 and N_2 were at par.

Shelling percentage increases under optimal doses of nitrogen (Dahatonde, 1982), phosphorus and potassium (Ibrahim *et al*., 1982). The higher values of shelling percentage recorded by N_6 and N_5 suggests the possibility of residual effect of N_5 and N_6 applied to the preceding crops of rice.

4.2.3.5 Oil content of ground nut (per cent)

The results on the oil content of groundnut are presented in Tables 34a and 34b.

Oil content of groundnut was significantly influenced by the various treatments. However, except N_1 which recorded the lowest oil content, all the other treatments were on a par during 1994-'95 and 1995-'96.

The sub-optimal doses of nutrients applied may be the reason for the poor oil content of groundnut at N_1. Nitrogen, phosphorus and potassium application were observed to exert a positive influence on the oil content of groundnut (Suraj Bhan and Misra, 1971).

4.2.3.6 Nitrogen uptake (kg ha^{-1})

The results on the nitrogen uptake by groundnut over the different nutrient management levels are presented in Tables 31a and 31b.

Nitrogen uptake by groundnut under the varying nutrient management levels showed significant difference during the first year and second year. N_1 was significantly inferior to all the other treatments. N_6 and N_5 and N_4, N_3 and N_2 were at par during 1994-'95 and the treatments N_6 and N_5, N_4 and N_3 and N_2 were at par during 1995-'96.

4.2.3.7 Phosphorus uptake (kg ha^{-1})

Tables 32a and 32b present the results on the phosphorus uptake by groundnut under different nutrient management levels.

The effect of the nutrient management on groundnut was significant during the first year and not significant during the second year. N_6 recorded the highest phosphorus uptake and N_1 the lowest value. N_6 and N_5, N_5 and N_4, N_4 and N_3 and N_3 and N_2 were on a par during the first year.

4.2.3.8 Potassium uptake (kg ha^{-1})

The results on the potassium uptake by groundnut under varying nutrient management levels are presented in Tables 33a and 33b.

Potassium uptake by groundnut was influenced significantly by nutrient management during the first year and second year. N_1 was significantly inferior to all the other treatments. N_6 recorded the highest value for potassium uptake. During the first year and second year, the treatments N_6 and N_5 and N_4, N_3 and N_2 were at par.

As in the case of other crops the application of sub-optimal doses of nutrients and the consequent poor dry matter production might be the reasons for the low nutrient uptake at N_1. The higher uptake of nitrogen, phosphorus and potassium at higher levels of these nutrients can be attributed to the poor nutrient status of the soil and might have resulted from the dense canopy, luxuriant growth, root proliferation by phosphorus and due to the complementary effect of potassium. These results are in conformity with those of Yakadri and Satyanarayana (1995).

4.3 Rice-rice-cowpea system (C_3)

4.3.1 First crop rice

4.3.1.1 Number of productive tillers per square metre at harvest

The results on the number of productive tillers per square metre at harvest as influenced by nutrient management are presented in Tables 4a and 4b.

The mean number of productive tillers per square metre at harvest was 282 during 1994-'95 and 281 during 1995-'96. This yield attribute of the first crop rice component of the C_3 cropping system was influenced significantly by nutrient management both during 1994-'95 and 1995-'96. The treatments N_2 to N_6 recorded more number of productive tillers than N_1 (farmers' practice). N_6 gave the best response in both the years.

The positive influence of the treatment N_6 may be attributed to the effect of integration of inorganic fertilisers, farmyard manure, vermicompost and *Azospirillum* as discussed earlier. In addition to nitrogen fixation *Azospirillum* has been reported to have the capacity to produce growth promoting substances (Gamo, 1991). The increase in the number of producti..ve tillers following the combined application of bio-organics and inorganics have been reported by Rao *et al*. (1996).

4.3.1.2 Number of spikelets per panicle

The results on the number of spikelets per panicle of first crop rice in the C_3 cropping system as influenced by nutrient management are presented in Tables 5a and 5b.

The mean number of spikelets per panicle during the first year was 85 and during the second year 88. Nutrient management showed no significant influence on the number of spikelets per panicle, during the two years of experimentation.

4.3.1.3 Percentage of filled grains

The results on the percentage of filled grains of first crop rice of the C_3 cropping system as influenced by nutrient management are presented in Tables 6a and 6b.

The mean percentage of filled grains recorded by the first crop rice of the C_3 cropping system was 80.11 per cent in the first year and 80.42 per cent in the second year. The percentage of filled grains of the first crop rice of the C_3 cropping system was not influenced significantly by the different nutrient levels during both the years.

4.3.1.4 Thousand grain weight (g)

The results on the effect of nutrient management on the thousand grain weight of first crop rice of the C_3 cropping system during the experimental years are presented in Tables 7a and 7b.

The mean thousand grain weight recorded during the first and second years were 25.7 g and 25.9 g respectively. The thousand grain weight of the first crop rice in the C_3 cropping system was affected significantly by nutrient management in the first year only. However considerable difference could not be observed among the different nutrient management levels.

4.3.1.5 Grain yield (kg ha^{-1})

The results on the grain yield of first crop rice in the C_3 cropping system as influenced by nutrient management are presented in Tables 8a and 8b and graphically in Fig. 3a and 3b.

The mean grain yield recorded by the first crop rice in the C_3 cropping system was 2687 kg ha^{-1} in 1994-'95 and 2806 kg ha^{-1} in 1995-'96. Grain yield was not affected significantly by nutrient management during the first year. N_6 produced significantly higher grain yield during the second year. A progressive increase in grain yield was observed with the nutrient management levels.

The treatment N_6 recorded the maximum grain yield (pooled) as shown in Table 37.

The superiority of the treatments N_2 to N_6 as compared to N_1 have been discussed earlier. An overall increase in grain yield was observed during the second year. This may be attributed to the influence of the preceeding cowpea crop. Similar results have been reported by Sasidhar (1978), John *et al*. (1989) and Singh *et al*. (1996). Large quantity of farmyard manure applied to cowpea might have produced some residual effect on the succeeding first crop rice by way of availability of nutrients. Furthermore, legumes improve soil nitrogen, physical conditions of the soil and help in controlling weeds, insect pests and diseases (Doolette, 1974).

4.3.1.6 Straw yield (kg ha^{-1})

The results on the straw yield of first crop rice in the C_3 cropping system as influenced by nutrient management are presented in Tables 9a and 9b and graphically in Fig. 4a and 4b.

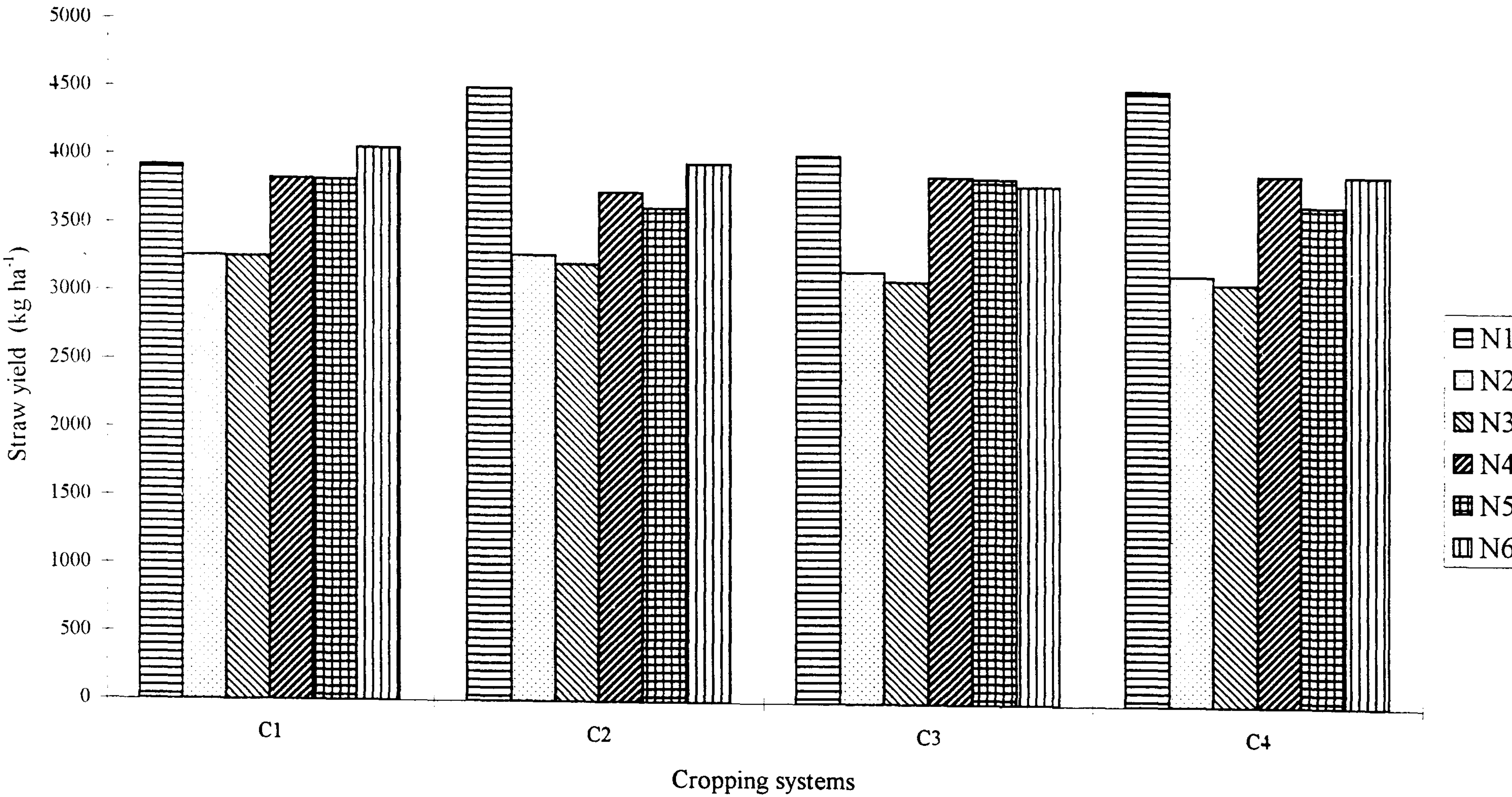


Fig.4a First crop rice (1994 - '95) - Straw yield (kg ha^{-1})

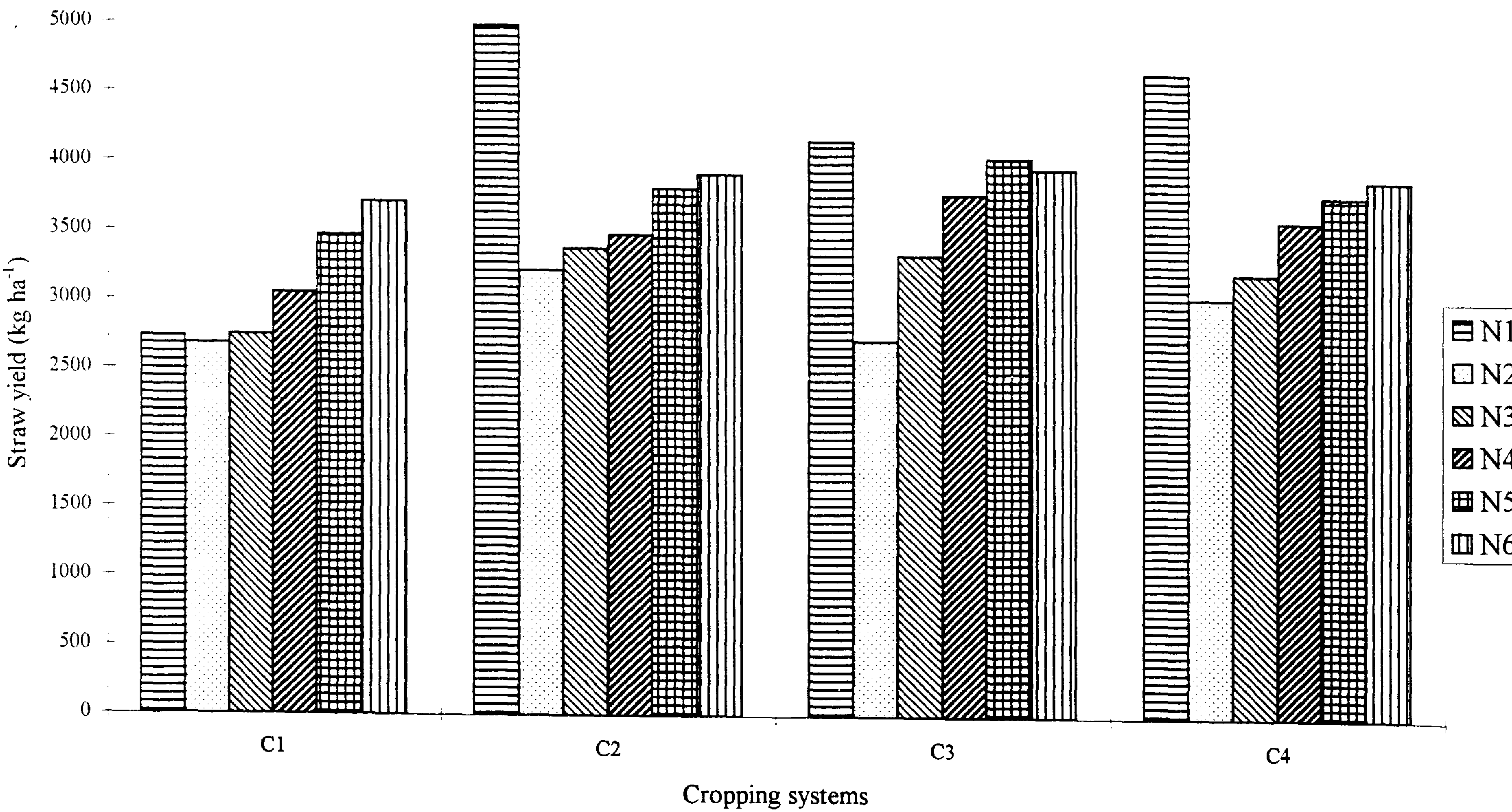


Fig.4b First crop rice (1995 - '95) - Straw yield (kg ha^{-1})

The mean straw yield of the first crop rice as influenced by nutrient management the cropping system C_3, were 3650 kg ha^{-1} and 3680 kg ha^{-1} respectively during the first year and second year. The influence of nutrient management on the straw yield over the C_3 cropping system was non-significant during the first year, but significant during the second year. Although N_1 recorded the highest straw yield, it was on a par with N_5 and N_6. Further the treatments N_5, N_6 and N_4 were also on a par during the second year.

Integrated nutrient management has been observed to improve the straw yield. The improvement of straw yield in the treatment N_1 was at the expense of grain yield. Thus the nitrogen contributed by the preceding crop of cowpea had been utilised for straw production in N_1. But in the case of N_5 and N_6 the increase in straw yield was accompanied by an equivalent increase in grain yield. Higher levels of nitrogen at sub-optimal levels of phosphorus and potassium favours increased vegetative growth (as in N_1). Similar results have been reported from IRRI (1988). The positive influence of N_5 and N_6 in straw yield may also be attributed to the additional supply of potassium through vermicompost.

4.3.1.7 Straw : grain

Tables 10a and 10b present the straw : grain of the first crop rice in C_3 system as influenced by nutrient management.

The mean straw : grain recorded by the first crop rice in the C_3 system was 1.47 during 1994-'95 and 1.50 during 1995-'96. Nutrient management was found to influence the straw : grain of the first crop rice significantly during both the years. N_1 and N_6 recorded the maximum and minimum straw : grain respectively, both during the first year and second year. The treatments N_4, N_3 and N_2 were on a par during 1994-'95. The treatments N_5, N_4 and N_3 and N_4, N_3 and N_2 were on a par during 1995-'96.

Straw : grain reveals the relative efficiency of the different treatments on straw and grain yields. A narrow ratio means more of grain while a wide ratio indicates less grain yield. The grain production efficiency of the integrated use of farmyard manure, vermicompost, *Azospirillum* and inorganic fertilisers is indicated by the narrow straw : grain with N_6. The wide straw : grain recorded by N_1 may be due to higher vegetative growth under the influence of the application of nutrients at sub-optimal levels and in an imbalanced manner, as reported by Sreekumaran (1981).

4.3.1.8 Harvest index

The results on the harvest index of first crop rice in the C_3 cropping system as influenced by nutrient management are presented in Tables 11a and 11b.

The mean harvest index recorded by the first crop rice was 0.418 and 0.428 respectively, during the first year and second year. The effect of nutrient management over C_3 was not significant during the first year. But it showed significant difference during the second year. N_6 and N_1 recorded the maximum and minimum values for harvest index during the first year and second year respectively. N_2 (package of practices) was at par with N_3 and N_4. N_6 and N_5 recorded a better harvest index in both the years.

The influence of nutrient management on the harvest index of first crop rice has been discussed earlier. The increase in the value of harvest index during the second year may be attributed to the beneficial effects of the preceding crop of cowpea mainly by way of nitrogen fixation, in producing higher economic yields.

4.3.1.9 Crude protein content (per cent)

The results on the effect of nutrient management on the crude protein content of first crop rice of the C_3 cropping system are presented in Tables 12a and 12b.

The mean crude protein content recorded by first crop rice in the C_3 cropping system was 8.24 per cent during 1994-'95 and 8.29 per cent during 1995-'96. The influence of nutrient management over the C_3 cropping system on the crude protein content of first crop rice was not significant during both the years.

4.3.1.10 Nitrogen harvest index (per cent)

Tables 13a and 13b present the results on the effect of nutrient management in the C_3 cropping system on the nitrogen harvest index (NHI) of first crop rice.

The mean NHI recorded by the C_3 cropping system was 51.20 per cent during both the years. NHI was not affected significantly by nutrient management during the first year. Significant difference was observed among the NHI values recorded by the different nutrient management levels during the second year. N_6 recorded the highest NHI and was significantly superior to all the other treatments. N_5 and N_4 and N_4, N_3 and N_2 were at par.

The nitrogen in organic combinations (farmyard manure, vermicompost, etc.) undergo complex changes in the soil leading to the formation of simpler products such as amino nitrogen, ammonium compounds, nitrites and nitrates. These are easily assimilated by the crops. These effects of organics combined with the nitrogen fixation by *Azospirillum* might have contributed to the higher NHI in the treatment N_6.

4.3.1.11 Nitrogen uptake (kg ha^{-1})

The results on the nitrogen uptake by first crop rice in the C_3 cropping system as influenced by nutrient management are presented in Tables 14a and 14b.

The mean nitrogen uptake of first crop rice as influenced by nutrient management was 89.44 kg ha^{-1} during 1994-'95 and 104.40 kg ha^{-1} during 1995-'96. Nitrogen uptake was influenced significantly by nutrient management. N_5 and N_4 recorded the maximum uptake values during the first year and second year respectively. N_1 was found to be significantly inferior to all the other treatments during both the years. N_5 and N_6, N_6 and N_4 and N_3 and N_2 were at par during the first year. N_4 and N_5, N_5 and N_6 and N_3 and N_2 were at par during the second year.

4.3.1.12 Phosphorus uptake (kg ha^{-1})

The results on the effect of nutrient management on the phosphorus uptake by first crop rice of the C_3 cropping system, are presented in Tables 15a and 15b.

The mean phosphorus uptake recorded during 1994-'95 was 18.08 kg ha^{-1} and that during 1995-'96 was 21.54 kg ha^{-1}. Nutrient management showed significant influence over the C_3 system with respect to the phosphorus uptake by first crop rice. N_5 recorded the maximum uptake (22.41 kg ha^{-1}) during the first year, while the maximum uptake of 25.43 kg ha^{-1} was recorded by N_4 during the second year. N_1 recorded significantly lower phosphorus uptake during both the years. N_5 and N_6, N_6 and N_4 and N_3 and N_2 were at par during 1994-'95. N_4, N_5 and N_6 and N_3 and N_2 were at par during 1995-'96.

4.3.1.13 Potassium uptake (kg ha^{-1})

The results on the influence of nutrient management on the potassium uptake by first crop rice in the C_3 cropping system, are presented in Tables 16a and 16b.

The mean potassium uptake was 130.02 kg ha^{-1} during 1994-'95 and 158.12 kg ha^{-1} during 1995-'96. Significant difference was observed among the nutrient management levels with respect to the potassium uptake by first crop rice. N_5 and N_4 recorded significantly higher potassium uptake values during the first year and second year respectively. The treatments N_5 and N_4, N_4, N_6 and N_3 and N_2 were at par during the first year. N_5 and N_6 and N_3 and N_2 were at par during the second year.

Integrated use of manures, fertilisers and/or biofertiliser was helpful in increasing the uptake of nutrients. As a rule the increased plant availability of nutrients improves the crop growth. Increase in nutrient recovery from soil following the addition of organic matter has been reported by Azam (1990). Manickam (1993) observed that increased organic matter in the soil improved the nutrient retention capacity of the soil and minimised nutrient loss. Increased nutrient uptake following vermicompost application have been reported by Zachariah (1995). Shuxin *et al.* (1991) observed that the application of organic manures improved the soil environment helping in root proliferation and increased nutrient availability. The role of *Azospirillum* in improving the nutrient uptake by crops has been reported by Sumner (1989).

4.3.2 Second crop rice

4.3.2.1 Number of productive tillers per square metre at harvest

The results on the number of productive tillers per square metre of second crop rice are presented in Tables 17a and 17b.

The mean number of productive tillers per square metre at harvest was 287 in 1994-'95 and 311 in 1995-'96. Nutrient management levels were exerted a significant influence over this yield parameter. N_5 and N_6 produced the maximum number of productive tillers during the fistt year and second year respectively. Compared to N_2 (package of practices), N_5 and N_6 gave a better response in both the years. N_1 recorded significantly low number of productive tillers per square metre at harvest during both the years.

The influence of the treatments N_5 and N_6 in recording the maximum number of productive tillers may be attributed to the favourable effects of the combined application of inorganics, organics and/or biofertiliser, as discussed earlier. Further, the increase in the number of productive tillers during the second year as compared to that in the first year can be attributed to the considerable increase in the nitrogen content of the soil after the cowpea crop. Similar results were also reported by Sasidhar (1978).

4.3.2.2 Number of spikelets per panicle

Tables 18a and 18b present the results on the effect of nutrient management on the number of spikelets per panicle.

The mean number of spikelets per panicle was 84 during 1994-'95 and 83 during 1995-'96. This yield attribute of the second crop rice was not affected significantly by nutrient management during the first year. During the second year, N_6 recorded significantly higher number of spikelets per panicle. The treatments N_4 and N_3 and N_2 and N_1 were at par.

The influence of N_6 on the number of spikelets per panicle may be attributed to the combined influence of organics, inorganics and biofertiliser as already discussed.

4.3.2.3 Percentage of filled grains

The results on the influence of nutrient management on the percentage of filled grains of the second crop rice in the C_3 cropping system are presented in Tables 19a and 19b.

The mean filled grain percentage recorded by second crop rice of the C_3 cropping system was 81.23 per cent in 1994-'95 and 81.20 per cent in 1995-'96. Significant difference was observed for the effect of nutrient levels on the percentage of filled grains, during the first year only. N_4 recorded the highest percentage of filled grains. N_4, N_3 and N_5 and N_2 and N_6 were on a par during the first year.

The relative importance of addition of organic matter (Prakash *et al.*, 1990) and application of potassium (Ganal and Singh, 1990) in increasing the filled grain percentage have been discussed earlier. Judicious application of inorganic fertilisers especially nitrogen has been observed essential for reducing the chaff percentage (Sajith Babu, 1996).

4.3.2.4 Thousand grain weight (g)

The results on the thousand grain weight of second crop rice of the C_3 cropping system are presented in Tables 20a and 20b.

The mean thousand grain weight recorded were 26.3 g and it was 26.1 g. The influence of nutrient management on the thousand grain weight of second crop rice of the C_3 cropping system was non-significant during both the years.

4.3.2.5 Grain yield (kg ha^{-1})

The results on the effect of nutrient management on the grain yield of second crop rice of the C_3 cropping system are presented in Tables 21a and 21b and graphically in Fig. 5a and 5b..

The mean grain yield recorded during 1994-'95 was 2731 kg ha^{-1} and that during 1995-'96 was 3023 kg ha^{-1}. The treatments N_2 to N_6 recorded significantly higher grain yield than N_1 (farmers' practice). N_2 (package of practices) recorded a response which was more or less on a par with N_3 and N_4. N_5 and N_6 were observed to record the best results in both the years.

The grain yield (pooled) was highest at N_6 (Table 38) due to the combined favourable effects of organics, inorganics and biofertiliser.

The variation in yield recorded by the treatments N_1 to N_6 may be attributed to the influence of integrated nutrient management as discussed earlier. The mean grain yield of second crop increased during the second year. The soil became more fertile with respect to nitrogen by cowpea. Further cowpea had been supplied with large quantity (20 t ha^{-1}) of

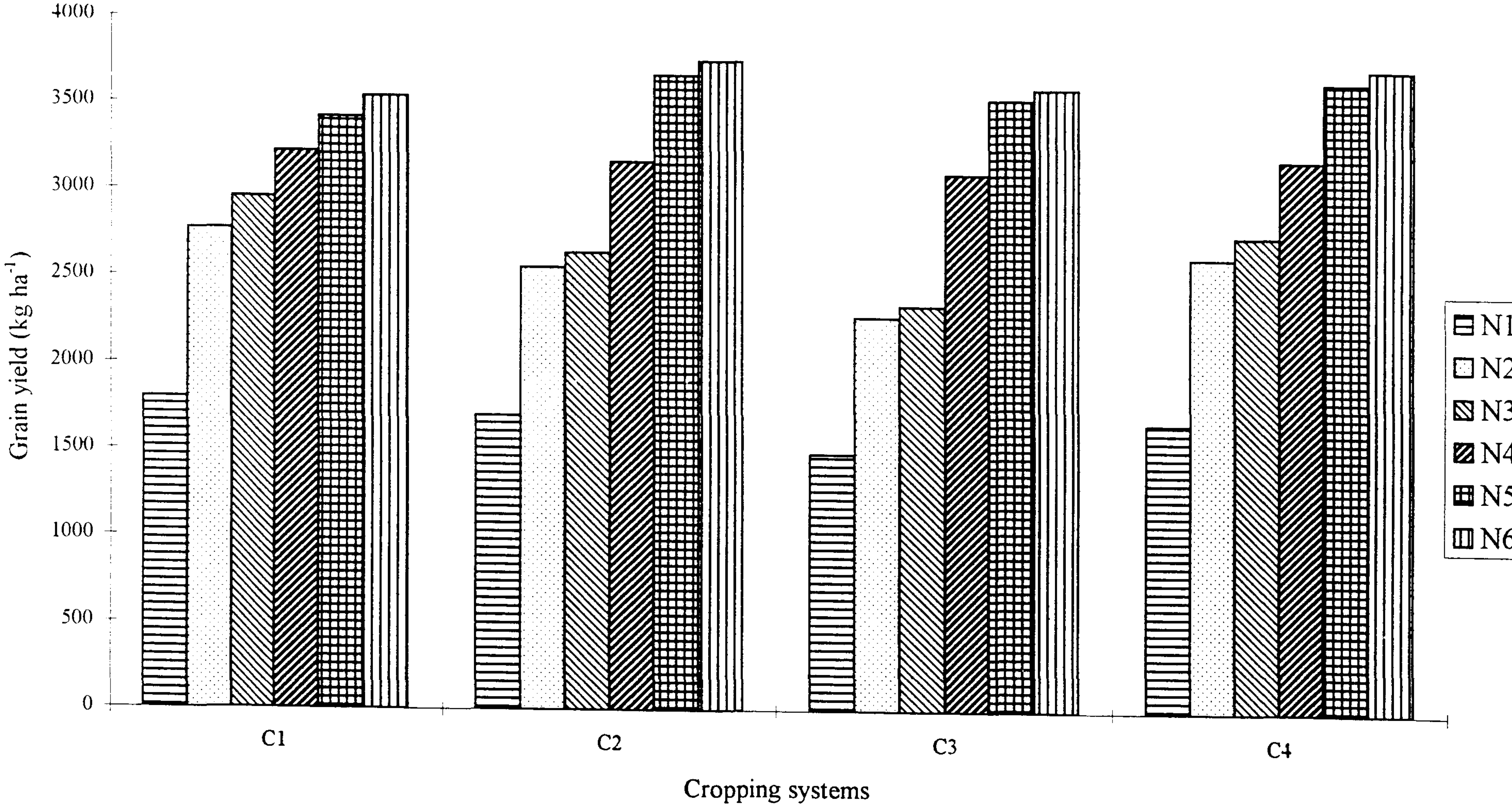


Fig. 5a Second crop rice (1994 - '95) - Grain yield (kg ha^{-1})

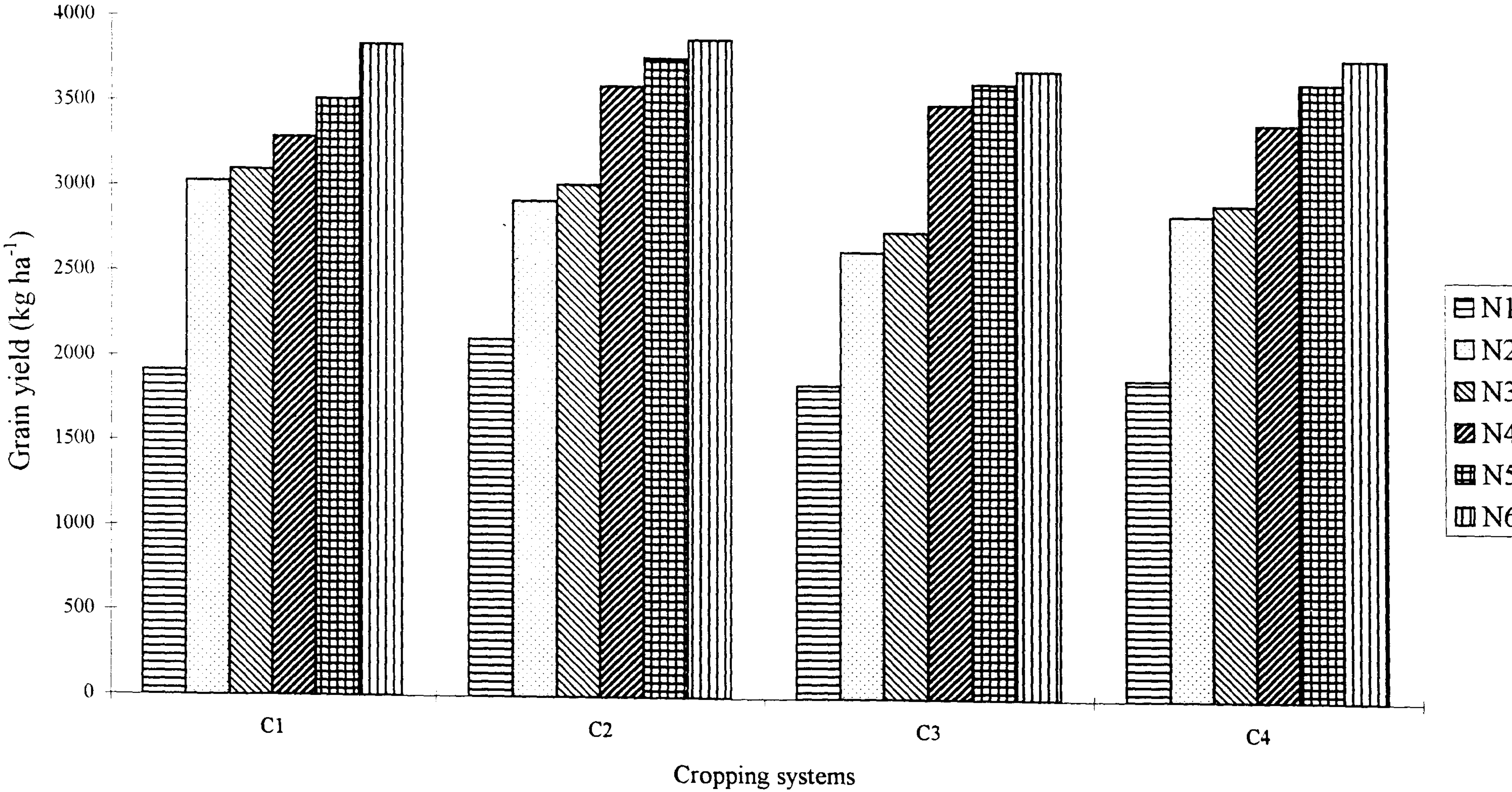


Fig.5b Second crop rice (1995 - '96) - Grain yield (kg ha^{-1})

farmyard manure and this might have left some residual effect on the succeeding crops of rice. Organic matter is the most dynamic component of the soil and has profound influence on the fertility and productive capacity of the soil (Manickam, 1993). Tanveer *et al*. (1993) observed that yield of rainy season rice was influenced significantly by the residual effect of farmyard manure applied to the previous summer crops.

4.3.2.6 Straw yield (kg ha^{-1})

The results on the straw yield of second crop rice of the C_3 cropping system as influenced by nutrient management are presented in Tables 22a and 22b and graphically in Fig.6a and 6b.

The mean straw yield of second crop rice of the C_3 cropping system was 6770 kg ha^{-1} in 1994-'95 and 8219 kg ha^{-1} in 1995-'96. The effect of nutrient management over the C_3 cropping system with respect to the straw yield of second crop rice was significant during the first year and second year. N_5 and N_4 recorded the maximum and N_1 the minimum straw yield during the first year and second year respectively. N_5 and N_4, N_4 and N_6 and N_3 and N_2 were at par during the first year. The straw yield increased from N_1 to N_5 and thereafter it decreased. During the second year, the straw yield increased from N_1 to N_4 and there after it decreased. The treatments N_6, N_2 and N_3 were at par during the second year.

Integrated use of organics and inorganics have been observed to improve the straw yield of rice. The probable reasons for this have been discussed earlier. The higher straw yield recorded during the second year may be attributed to the legume effect of cowpea and to the residual effect of farmyard manure applied to cowpea.

4.3.2.7 Straw : grain

The results on the straw : grain of the second crop rice are presented the Tables 23a and 23b.

The mean straw : grain recorded by the second crop rice of the C_3 cropping system was 2.57 during 1994-'95 and 2.79 during 1995-'96. In both the years a non-significant influence for nutrient management on the straw : grain.

4.3.2.8 Harvest index

The results on the harvest index of second crop rice as influenced by nutrient management are presented in Tables 24a and 24b.

The mean harvest index recorded during 1994-'95 was 0.281 and during 1995-'96 was 0.265. The effect of nutrient management on the harvest index of rice of the C_3 cropping system was non-significant in both the years.

4.3.2.9 Crude protein content (per cent)

The results on the crude protein content of the second crop rice of C_3 cropping system as influenced by nutrient management are presented in Tables 25a and 25b.

The mean crude protein content recorded was 8.65 per cent during the first year and 8.68 per cent during the second year. The influence of nutrient management on the crude protein content was observed to be not significant both during the first year and second year.

4.3.2.10 Nitrogen harvest index (per cent)

The results on the effect of nutrient management on the nitrogen harvest index (NHI) of second crop rice of the C_3 cropping system are presented in Tables 26a and 26b.

The mean nitrogen harvest index recorded was 36.70 per cent during 1994-'95 and 35.30 per cent during 1995-'96. NHI of the second crop rice was not affected significantly by nutrient management in the C_3 cropping system.

4.3.2.11 Nitrogen uptake (kg ha^{-1})

Tables 27a and 27b present the results on the nitrogen uptake by second crop rice as influenced by nutrient management over the C_3 cropping system.

The mean nitrogen uptake recorded was 89.44 kg ha^{-1} during the first year and 104.40 kg ha^{-1} during the second year. The different nutrient management levels exerted a significant influence on the nitrogen uptake by second crop rice of the C_3 cropping system both during the first year and second year. While N_1 recorded the minimum value for nitrogen uptake during both the years the maximum nitrogen uptake values were recorded by N_5 and N_4 respectively during the first year and second year.

4.3.2.12 Phosphorus uptake (kg ha^{-1})

Tables 28a and 28b present the results on the influence of nutrient management in the C_3 cropping system with respect to the phosphorus uptake by second crop rice.

The mean phosphorus recorded was 18.08 kg ha^{-1} in 1994-'95 and 21.54 kg ha^{-1} in 1995-'96. Nutrient management exerted a significant influence on the phosphorus uptake by second crop rice of the C_3 cropping system. N_1 recorded the least value for phosphorus uptake during both the years. N_5 and N_4 recorded the highest values for phosphorus uptake during the first year and second year respectively. N_5 and N_6, N_6 and N_4 and N_3 and N_2 were at par during the first year. N_4, N_5 and N_6 and N_3 and N_2 were at par during the second year.

4.3.2.13 Potassium uptake (kg ha^{-1})

Tables 29 a and 29b present the results on the influence of nutrient management on the C_3 cropping system with respect to the potassium uptake of the second crop rice..

The mean potassium uptake recorded was 130.02 kg ha^{-1} during 1994-'95 and 158.12 kg ha^{-1} during 1995-'96. The influence of nutrient management on the potassium uptake by second crop rice of the C_3 cropping system was significant. While N_5 and N_4 recorded the maximum uptake values during the first year and second year respectively. N_1 recorded the minimum uptake value in both the years. N_5 and N_4, N_4 and N_6 and N_3 and N_2 were on a par during the first year. N_4 and N_5, N_5 and N_6 and N_3 and N_2 were on a par during the second year.

In general, application of nutrients in an integrated manner improved the nutrient uptake of the second crop rice. Nutrient balance studies conducted by Nambiar and Ghosh (1984) indicated considerable build up of nutrients with the addition of organic matter in combination with fertilisers. A better nutrient uptake as a result of inocu-lation with *Azospirillum* has been reported by George (1996).

4.3.3 Cowpea

4.3.3.1 Number of pods per plant

The results on the number of pods per plant are presented in Tables 35a and 35b.

The number of pods per plant was affected significantly by the treatments. The treatment N_5 recorded the highest value for this yield attribute during both the years.

N_1 was significantly inferior to all the other treatments. During both the years N_6, N_5, N_4, N_3 and N_2 were at par.

4.3.3.2 Number of seeds per pod

The results on the number of seeds per pod are presented in Tables 35a and 35b.

The number of seeds per pod was not influenced significantly by nutrient management.

4.3.3.3 Seed yield (kg ha^{-1})

Tables 35a and 35b show the results on the seed yield of cowpea.

Seed yield of cowpea was influenced significantly by the different treatments N_5 recorded the highest grain yield and N_1 the lowest grain yield during both the years. The treatments N_2 to N_6 were at par.

The lack of considerable difference among the treatments N_2 to N_6 implies the fact that the residual effect of the treatments applied to the preceding crops of rice was very low or practically nil. The very low seed yield of cowpea at N_1 can be related to the low number of pods per plant observed at N_1. This in turn may be to the poor soil nutrient status in this treatment. The other treatments (N_2 to N_6) which followed the KAU package recommendations received

Table No. 35 Yield attributes and yield of cowpea as influenced by nutrient management

Table No. 35a 1994-'95

Nutrient management	Pods $plant^{-1}$	Seeds pod^{-1}	Seed yield ($kg\ ha^{-1}$)	Haulm yield ($kg\ ha^{-1}$)
N1	2.32	14.93	313.81	838.33
N2	3.92	14.95	507.15	1110.67
N3	4.01	14.88	544.40	1197.87
N4	4.24	14.93	588.16	1292.92
N5	4.37	15.00	606.76	1332.50
N6	4.27	14.95	597.66	1310.95
SEm	0.1563	0.3545	20.4666	50.4269
CD (0.05)	0.4709	-	61.6801	151.9708

Table No. 35b 1995-'96

Nutrient management	Pods $plant^{-1}$	Seeds pod^{-1}	Seed yield ($kg\ ha^{-1}$)	Haulm yield ($kg\ ha^{-1}$)
N1	2.35	14.88	314.79	690.79
N2	3.80	14.95	509.52	1119.85
N3	4.10	14.83	553.19	1212.18
N4	4.41	14.88	591.54	1295.34
N5	4.57	14.95	611.56	1342.03
N6	4.47	15.03	603.47	1323.04
SEm	0.1442	0.3298	19.7159	43.2508
CD (0.05)	0.4347	-	59.4176	130.3445

farmyard manure, fertilisers and rhizobial inoculation at optimum levels. Cowpea has been observed to respond positively to rhizobial inoculation and NPK fertilisation (Rajput and Singh, 1996).

4.3.3.4 Haulm yield (kg ha^{-1})

The results on the haulm yield of cowpea are presented in Tables 35a and 35b.

Significant influence was observed for nutrient management on the haulm yield of cowpea. As in the case of grain yield of cowpea N_5 and N_1 recorded the highest and lowest values respectively for haulm yield during both the years. The treatments N_2 to N_6 were on a par.

As in the case of grain yield, haulm yield also failed to record any significant residual effect for the treatments applied to the preceding crops of rice, as is indicated by the lack of considerable variation among the treatments N_2 to N_6. Application of nutrients at optimum levels coupled with rhizobial inoculation might have resulted in the better haulm yield recorded by these treatments.

4.3.3.5 Nitrogen uptake (kg ha^{-1})

The results on the effect of nutrient management over cowpea are presented in Tables 31a and 31b.

Nitrogen uptake by cowpea was influenced significantly by the various treatments, during both the years. N_1 recorded a significantly lower value for nitrogen uptake. N_6, N_5, N_4 and N_3 and N_5, N_4, N_3 and N_2 were at par during the first year. N_6, N_5, N_4, N_3 and N_2 were at par during the second year.

4.3.3.6 Phosphorus uptake (kg ha^{-1})

The results on the phosphorus uptake by cowpea as influenced by nutrient management are presented in Tables 32a and 32b.

Phosphorus uptake was influenced significantly by nutrient management during the first year only. N_6 recorded the maximum uptake. The treatments N_6, N_5, N_4 and N_3 and N_4, N_3 and N_2 were at par.

4.3.3.7 Potassium uptake (kg ha^{-1})

The results on the potassium uptake by cowpea as influenced by nutrient management are presented in Tables 33a and 33b.

There was significant influence for nutrient management on the potassium uptake by cowpea during both the years. N_8 and N_5 recorded the highest uptake values and N_1 the minimum during the first year and second years respectively.

In general, the treatments N_2 to N_6 recorded higher values of nutrient uptake compared to N_1. However, the lack of considerable difference among the treatments N_2 to N_6, indicated the absence of residual effect of treatments applied to the preceding crops of rice which can be utilised by cowpea. Nutrient uptake also increased significantly with the application of nitrogen, phosphorus and potassium (Rajput and Singh, 1996) and seed inoculation with *Rhizobium*.

4.4 Rice-rice-bhindi system (C_4)

4.4.1 First crop rice

4.4.1.1 Number of productive tillers per square metre at harvest

The results on the number of productive tillers per square metre at harvest of first crop rice as influenced by nutrient management on the C_4 cropping system are presented in Tables 4a and 4b.

The mean number of productive tillers per square metre at harvest recorded during 1994-'95 was 283 and during 1995-'96 was 306. The influence of the nutrient management on the cropping system C_4 was significant in both the years. The treatments N_2 to N_6 recorded a higher count of productive tillers than N_1 (farmers' practice). N_6 recorded the best response in both the years. N_2 (package of practices) was on a par with N_3 in the first year.

The significant influence of N_6 on the number of productive tillers per square metre may be attributed to the better nutrition provided by this treatment by way of integrated use of farmyard manure, vermicompost and *Azospirillum* along with chemical fertilisers. Integrated nutrient supply and management system helps to restore and sustain soil fertility. Application of organic manures help to improve the availability of nutrients. Further, organic manures also help to reduce the loss of nutrients. The ability of *Azospirillum* to increase the number of productive tillers has been reported by Govindasamy *et al.* (1992). The increase in the mean number of productive tillers during the second year may be attributed to the residual effect of the large quantity of farmyard manure (12 t ha^{-1}) applied to the bhindi crop.

4.4.1.2 Number of spikelets per panicle

The results on the number of spikelets per panicle of first crop rice as influenced by nutrient management over the C_4 cropping system are presented in Tables 5a and 5b.

The mean number of spikelets per panicle recorded was 83 in the first year and 85 in the second year. The influence of nutrient management over the C_4 cropping system with respect to the number of spikelets per panicle of first crop rice was non-significant.

4.4.1.3 Percentage of filled grains

The results on the effect of nutrient management in the C_4 cropping system with respect to the percentage of filled grains of first crop rice are presented in Tables 6a and 6b.

The mean percentage of filled grains recorded during 1994-'95 and 1995-'96 were 80.13 and 80.17 respectively. The treatment effects were not significant during both the years of experimentation.

4.4.1.4 Thousand grain weight (g)

The results on the thousand grain weight of first crop rice as influenced by nutrient management in the C_4 cropping system are presented in Tables 7a and 7b.

The mean thousand grain weight recorded during 1994-'95 was 25.9 g and that during 1995-'96 was 26.0 g. The effect of nutrient management on the thousand grain weight was significant during the first year only. All the treatments except N_1 were on a par during the first year. N_1 recorded the lowest thousand grain weight.

The poor level of nutrition offered by N_1 (farmers' practice) may be the reason for decrease in thousand grain weight.

4.4.1.5 Grain yield (kg ha^{-1})

The results on the grain yield of first crop rice as influenced by nutrient management in the C_4 cropping system are presented in Tables 8a and 8b and graphically in Fig. 3a and 3b.

The mean grain yield recorded during the first year and second year were 2709 kg ha^{-1} and 2736 kg ha^{-1} respectively. The effect of nutrient management in the C_4 cropping system with respect to the grain yield of first crop rice was significant only during the second year. N_6 produced significantly higher grain yield over all the other treatments. N_1 recorded the minimum grain yield.

The perusal of the data on the pooled analysis of grain yield (Table 37) showed that the treatment N_6 recorded the maximum grain yield.

The beneficial effect of the application of farmyard manure, vermicompost and *Azospirillum* in conjunction with chemical fertilisers may be the reason for the increase in grain yields recorded by N_6. When inorganic forms, on appearance are immobilised or appropriated by the organisms involved in the transformations, crops have to be satisfied with only what is left available. Higher the original content of nitrogen in the organic substances, more will be the mineralised forms of nitrogen available for the crops to assimilate. Urea is the source of inorganic nitrogen applied to rice and losses of applied nitrogen (as urea) is very high under water-logged condition especially in sandy soils. When organic matter is applied in conjunction with urea, it reduces the time lag between the application and hydrolysis of urea and thereby minimise the losses. Further it also increases the urea retention capacity of the soil colloids and thus minimise the leaching loss (Manickam, 1993). Organic matter also improve the availability of phosphorus and potassium. These benefits of organics coupled with the growth promoting and nitrogen fixing capacity of *Azospirillum* might have contributed towards the increase in the grain yield of rice.

4.4.1.6 Straw yield (kg ha^{-1})

The results on the straw yield of first crop rice as influenced by nutrient management in the C_4 cropping system are presented in Tables 9a and 9b and graphically in Fig.4a and 4b.

The mean straw yield recorded during 1994-'95 and 1995-'96 were 3713 kg ha^{-1} and 3710 kg ha^{-1} respectively. Straw yield of first crop rice of the C_4 cropping system was influenced significantly by nutrient management during the second year only. N_1 recorded the maximum and N_2 the minimum straw yield. N_6, N_5 and N_4 and N_3 and N_2 were at par.

The high straw yield recorded by the treatment N_1 was accompanied by low grain yield, suggesting a higher utilisation of the applied nutrients for straw production. This might have been due to the nutrient imbalances at sub-optimal levels of application and the inappropriate stages of the crop growth when nutrients are applied. The beneficial effects of integrated nutrient management (as discussed earlier) might have contributed to the better straw - grain proportion in the other treatments. It is worth mentioning the superiority of the treatments N_3 to N_6 over the package of practices recommendations (N_2).

4.4.1.7 Straw : grain

The results recorded on the effect of nutrient management on the C_4 cropping system with respect to the straw : grain ratio of first crop rice are presented in Tables 10a and 10b.

The mean straw : grain recorded was 1.47 in the first year and 1.45 in the second year. Straw : grain of first crop rice of the C_4 cropping system was significantly influenced by nutrient management during the first year and second year. N_1 recorded the maximum straw : grain during both the years. During the first year the straw : grain decreased from N_1 to N_3, increased slightly with N_4 and thereafter it decreased upto N_6. The treatments N_5 and N_6 and N_2, N_3 and N_4 were at par during the first year. During the second year the straw : grain decreased progressively from N_1 to N_6. Further, the treatments N_5 and N_4 and N_4 and N_3 were at par.

A narrow straw : grain recorded by the treatments N_5 and N_6 indicated the superiority of the integrated supply of nutrients in producing a straw : grain which can result in high grain yield and straw yield.

4.4.1.8 Harvest index

The results recorded on the harvest index of first crop rice as influenced by nutrient management on the C_4 cropping system are presented in Tables 11a and 11b.

The mean harvest index recorded by the first crop rice of the C_4 cropping system were 0.418 and 0.422. The influence of nutrient management on the cropping system C_4 with respect to the harvest index of first crop rice was significant only during the second year. N_6 recorded the maximum value for harvest index. N_5, N_4 and N_3 were at par. N_2 (package of practices) recorded a lower harvest index in both the years.

A higher harvest index indicates higher proportion of economic yield (grain yield) as compared to the biological yield (grain yield plus straw yield). The better availability of nutrients under the influence of organic matter in combination with the growth promoting and nitrogen fixing capacity of *Azospirillum* might have resulted in the higher economic yield in N_6.

4.4.1.9 Crude protein content (per cent)

The results on the crude protein content of first crop rice as influenced by nutrient management over the C_4 cropping system are presented in Tables 12a and 12b.

The mean crude protein content was 8.22 per cent during 1994-'95 and 8.31 per cent 1995-'96. The various nutrient management levels had no significant influence on the crude protein content of first crop rice of the C_4 cropping system.

4.4.1.10 Nitrogen harvest index (per cent)

The results on the influence of nutrient management on the C_4 cropping system with respect to the nitrogen harvest index (NHI) of first crop rice are presented in Tables 13a and 13b.

The mean nitrogen harvest index was 51.30 per cent during the first year and 50.60 per cent during the second year. NHI of first crop rice of the C_4 cropping system was influenced significantly by nutrient management during the second year only. N_6 recorded the maximum NHI and was significantly different from the other treatments. The treatments N_5 and N_4 and N_4 and N_3 were at par. The treatment N_2 (package of practices) recorded a lower NHI compared to the treatments N_3 to N_6.

The favourable influence of applying chemical fertilisers in conjunction with organic and/or biofertiliser, on the NHI of rice have been discussed earlier.

4.4.1.11 Nitrogen uptake (kg ha^{-1})

The results on the influence of nutrient management over the C_4 cropping system with respect to the nitrogen uptake by first crop rice are presented in Tables 14a and 14b.

The mean nitrogen uptake recorded were 60.56 kg ha^{-1} and 61.61 kg ha^{-1}. Nitrogen uptake by first crop rice of the C_4 cropping system was influenced significantly by the nutrient levels, during the second year only. N_6 was significantly superior to all the other treatments. N_2 recorded the lowest nitrogen uptake.

4.4.1.12 Phosphorus uptake (kg ha^{-1})

The results on the phosphorus uptake by first crop rice as influenced by nutrient management cropping system are presented in Tables 15a and 15b.

The mean phosphorus uptake recorded was 13.52 kg ha^{-1} during 1994-'95 and 13.99 kg ha^{-1} during 1995-'96. Nutrient management influenced the phosphorus uptake by first crop rice of the C_4 cropping system during the second year only. N_6 was observed to be significantly superior to all the other treatments. N_2 recorded the least phosphorus uptake.

4.4.1.13 Potassium uptake (kg ha^{-1})

The results on the influence of nutrient management on the potassium uptake by first crop rice of the C_4 cropping system are presented in Tables 16a and 16b.

The mean potassium uptake recorded during 1994-'95 was 78.03 kg ha^{-1} and that during 1995-'96 was 79.49 kg ha^{-1}. Nutrient management exerted a significant influence on the potassium only in the second year. N_1 recorded the maximum uptake. The treatments N_1, N_6 and N_5, N_5 and N_4 and N_3 and N_2 were on a par.

The high straw yield and the higher content of potassium in straw may be the possible reasons for the high uptake values of potassium in N_1. On the other hand, the high potassium uptake values recorded by N_6 and N_5 are due to the higher total dry matter production.

In general, integration of organics, inorganics and biofertilisers have been observed to increase the uptake of nitrogen, phosphorus and potassium. The influence of inorganic fertilisers and organic matter on nutrient uptake have been discussed earlier. Sumner (1989) while reviewing the inoculation response to *Azospirillum* observed that the bacterial association enhanced water and nutrient uptake through a kind of sponge effect and it was the primary reason for the yield increases resulting from inoculation.

4.4.2 Second crop rice

4.4.2.1 Number of productive tillers per square metre at harvest

Tables 17a and 17b present the results on the effect of nutrient management over the second crop rice of the C_4 cropping system with respect to the number of productive tillers per square metre at harvest.

The mean number of productive tillers produced at harvest by second crop rice of the cropping system, C_4 was 310 during 1994-'95 and 321 during 1995-'96. This yield attributing parameter of second crop rice was influenced significantly by nutrient management in both the years. The number of productive tillers was significantly higher in the treatments N_2 to N_6 compare to N_1 (farmers' practice). While N_2 (package of practices) was on a par with N_3 in both the years, the treatments N_6 and N_5 recorded the best response.

As in the earlier cases a positive influence of integrated nutrient supply was observed in the case of the number of productive tillers per square metre also. There was an increase in the number of productive tillers during the second year. This may be attributed to the residual effect of the farmyard manure applied to the summer bhindi crop at 12 t ha^{-1}. Similar results have been reported by Pillai (1993).

4.4.2.2 Number of spikelets per panicle

The results recorded on the influence of nutrient management on the second crop rice in the C_4 cropping system with respect to the number of spikelets per panicle are presented in Tables 18a and 18b.

The mean number of spikelets per panicle recorded were 85 and 87 during the first year and second year respectively. The influence of nutrient management on the number of spikelets per panicle of second crop rice of the C_4 cropping system was not significant during the first year but significant during the second year. N_6 was observed to produce the maximum number of spikelets per panicle and was significantly superior to all other treatments. The treatments N_5 and N_4, N_4 and N_3 and N_2 and N_1 were at par.

The better availability of nutrients especially nitrogen at N_6 might have contributed to the increase in the number of spikelets.

4.4.2.3 Percentage of filled grains

Tables 19a and 19b present the results on the influence of nutrient management in the C_4 cropping system with respect to the percentage of filled grains of second crop rice.

The mean percentage of filled grains recorded was 80.99 both during the first year and second year. Nutrient management exerted a significant influence on the percentage of filled grains of second crop rice during the first year. N_4 recorded the maximum filled grain percentage during 1994-'95.

Physiologically, grain filling is a function of nitrogen and potassium combination by way of transporting photosynthates from the source to the sink. Organic matter added in conjunction with chemical fertilisers improves the availability of these nutrients. Further *Azospirillum* might have improved the availability of nitrogen and uptake of nutrients. Potassium has been observed to maintain the ratio between reducing and non-reducing sugars at a moderate level and provide more sucrose for conversion to insoluble polysaccharides for storage (Kundu and Sircar, 1969). The integrated use of organic, inorganic and biofertiliser in N_4 might have contributed to a higher filled grain percentage.

4.4.2.4 Thousand grain weight (g)

The results recorded on the influence of nutrient management in the C_4 cropping system with respect to the thousand grain weight of second crop rice are presented in Tables 20a and 20b respectively.

The mean thousand grain weight recorded by second crop rice in the C_4 cropping system was 26.1 g both during 1994-'95 and 1995-'96. Thousand grain weight of second crop rice did not vary significantly with nutrient management in both the years.

4.4.2.5 Grain yield (kg ha^{-1})

Tables 21a and 21b and Fig. 5a and 5b present the results on grain yield of second crop rice as influenced by nutrient management on the C_4 cropping system.

The cropping system, C_4 recorded a mean grain yield of 2942 kg ha^{-1} during the first year and 3094 kg ha^{-1} during the second year. The different nutrient management levels were observed to exert a significant influence on the grain yield of second crop rice of the C_4 cropping system. A progressive increase in grain yield was observed from N_1 to N_6 with N_6 recording the maximum and N_1 the minimum grain yield during both the years. The treatments N_6 and N_5 and N_3 and N_2 (package of practices) were at par.

The pooled analysis of the grain yield (Table 38) showed that the treatment N_6 was superior to all the other treatments, with respect to grain yield.

The application of nutrients at sub-optimal doses may be the reason for the poor yield recorded at N_1. The treatment N_6 included chemical fertilisers, farmyard manure, vermicompost and *Azospirillum*. The effect of organics and *Azospirillum* have been discussed earlier. The nutrients in vermicompost are in a readily available form (Albanell *et al.*, 1988). Thus the usefulness of farmyard manure in increasing crop yields was more pronounced when used in conjunction with fertilisers.

But vermicompost stimulated crop growth alone as well as in combination with fertilisers. The possibility of replacing chemical fertilisers with vermicompost has been reported by Senapathi *et al.* (1985). There was an increase in grain yield during the second year. Kumar *et al.* (1993) observed that the total rice grain yield of wet and dry seasons was higher after bhindi. The effect of summer crops may be attributed to the effective utilisation of soil moisture and nutrients as effected by the different rooting patterns of the different summer crops raised.

4.4.2.6 Straw yield (kg ha^{-1})

Tables 22a and 22b and Fig. 6a and 6b present the results recorded on straw yield of second crop rice as influenced by nutrient management.

The cropping system, C_4 recorded a mean straw yield of 7287 kg ha^{-1} during 1994-'95 and 7948 kg ha^{-1} during 1995-'96. Nutrient management exerted a significant influence on the C_4 cropping system with respect to the straw yield of second crop rice during the first year and second year. N_5 recorded the maximum and N_1 the minimum straw yields during both the first and second year. N_5 and N_4, N_4 and N_8, N_6 and N_3 and N_3 and N_2 were on a par during 1994-'95. N_5, N_4, N_6 and N_2 and N_4, N_6, N_2 and N_3 were on a par during 1995-'96.

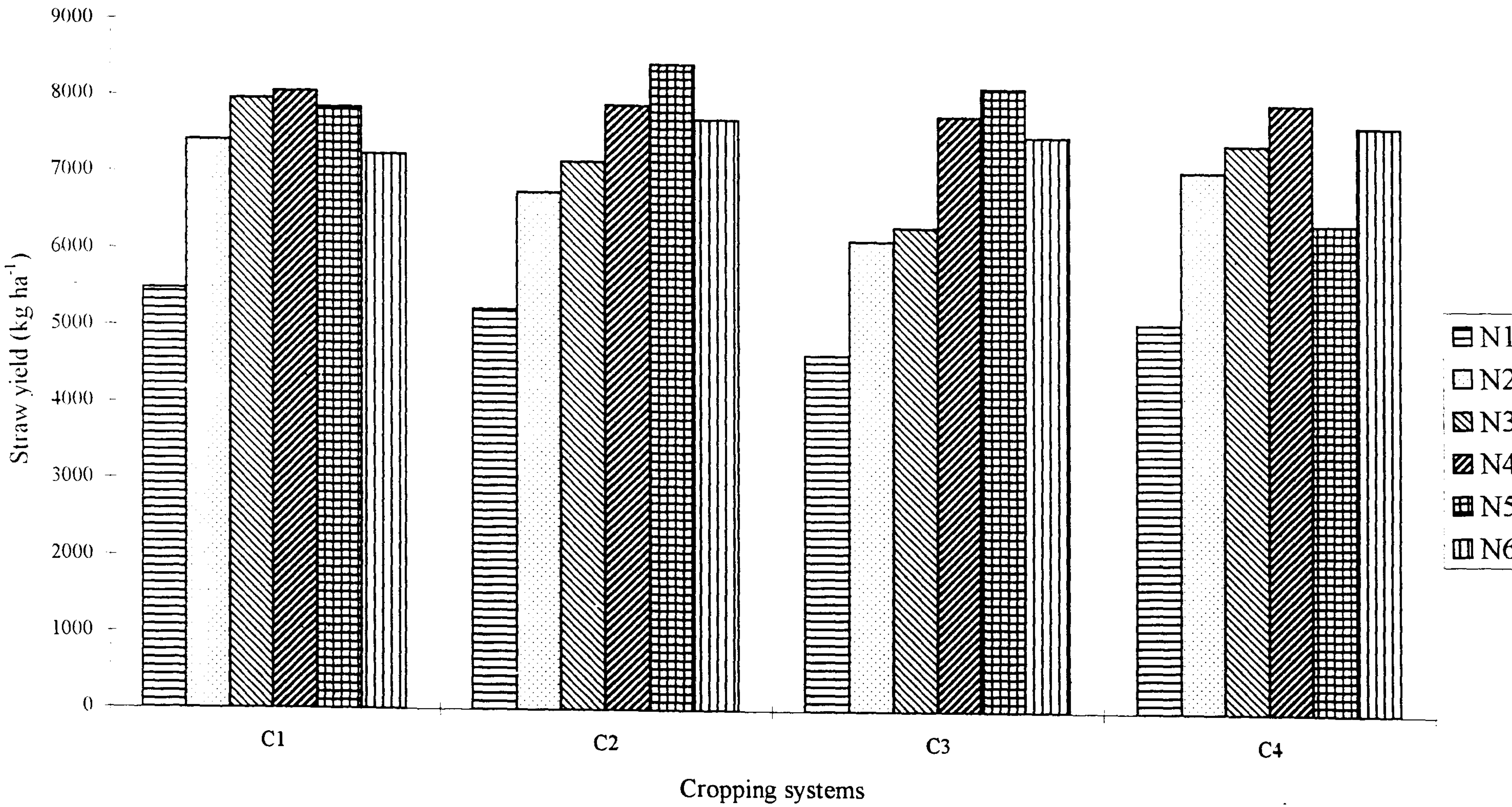


Fig. 6a Second crop rice (1994 '95) - Straw yield (kg ha^{-1})

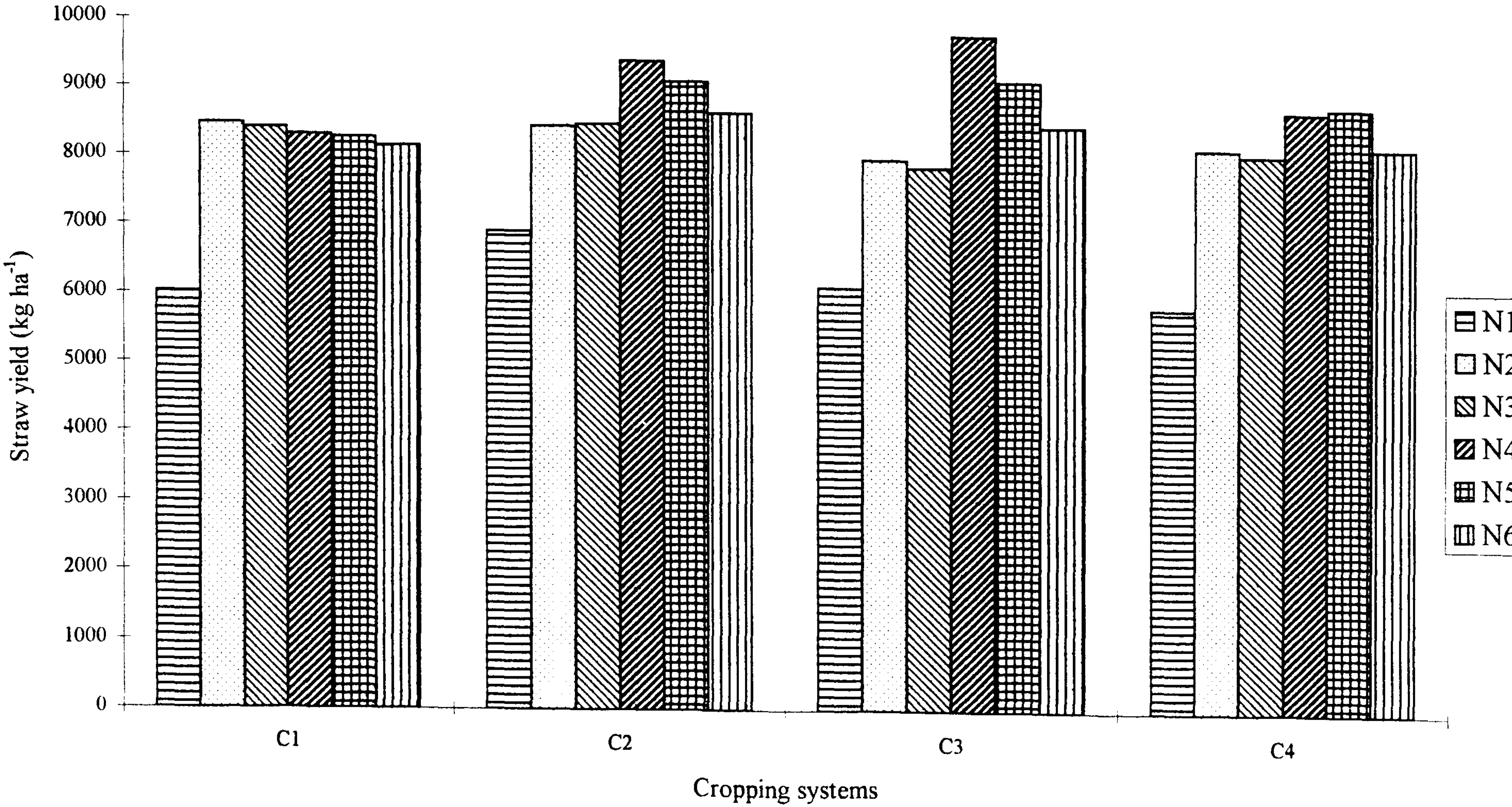


Fig. 6b Second crop rice (1995 '96) - Straw yield (kg ha^{-1})

The influence of the treatment N_5 (inorganics + farm yard manure + vermicompost) in increasing the straw yield of rice has been discussed earlier. However the lack of considerable difference between the levels of integrated nutrition and the package recommendation (N_2) indicates the similar effects for these treatments.

4.4.2.7 Straw : grain

The results recorded on the influence of nutrient management over the C_4 cropping system with respect to the straw : grain of second crop rice are presented in Tables 23a and 23b.

The mean straw : grain recorded was 2.55 during 1994-'95 and 2.63 during 1995-'96. Straw : grain of second crop rice was not affected significantly by the various nutrient management during both the years.

4.4.2.8 Harvest index

Tables 24a and 24b present the results recorded on the influence of nutrient management over the C_4 cropping system with respect to the harvest index of second crop rice.

The mean harvest index recorded in the cropping system C_4 during the first year was 0.283 and that during the second year was 0.279. The influence of nutrient management on the harvest index of second crop rice of the C_4 cropping system was not significant during 1994-'95 and during 1995-'96.

4.4.2.9 Crude protein content (per cent)

The results on the crude protein content of second crop rice as influenced by nutrient management in the C_4 cropping system, recorded are presented in Tables 25a and 25b.

The mean crude protein content of second crop rice in the C_4 cropping system was 8.64 per cent during the first year and 8.68 per cent during the second year. The crude protein content was not affected significantly by nutrient management during both the years.

4.4.2.10 Nitrogen harvest index (per cent)

The results recorded on the nitrogen harvest index (NHI) of second crop rice of the C_4 cropping system as influenced by nutrient management are presented in Tables 26a and 26b.

The mean NHI of second crop rice in the C_4 cropping system was 37.0 per cent during the first year and 36.6 per cent during the second year. NHI of second crop rice was not affected significantly by nutrient management in the C_4 cropping system.

4.4.2.11 Nitrogen uptake (kg ha^{-1})

Tables 27a and 27b present the results recorded on the nitrogen uptake by second crop rice as influenced by the nutrient management over the C_4 cropping system.

The second crop rice of the cropping system, C_4 recorded a mean nitrogen uptake of 96.30 kg ha^{-1} during the first year and 102.98 kg ha^{-1} during the second year. Nitrogen uptake was influenced significantly by nutrient management both during the first year and second year. N_5 recorded the maximum and N_1 the minimum value for nitrogen uptake during both the years. During the first year, the treatments N_5 and N_6, N_6 and N_4 and N_3 and N_2 were at par. During the second year, the treatments N_5, N_6 and N_4 and N_3 and N_2 were at par.

4.4.2.12 Phosphorus uptake (kg ha^{-1})

Tables 28a and 28b present the results recorded on the influence of nutrient management in the C_4 cropping system with respect to the uptake of phosphorus by second crop rice.

The mean phosphorus uptake recorded by the second crop rice of the C_4 cropping system was 19.46 kg ha^{-1} during the first year and 21.25 kg ha^{-1} during the second year. The different nutrient management levels were observed to have a significant influence on the phosphorus uptake by second crop rice of the C_4 cropping system. N_5 recorded the maximum and N_1

the minimum values for phosphorus uptake during both the years. The treatments N_5, N_6 and N_4 and N_3 and N_2 were at par during the first year and second year.

4.4.2.13 Potassium uptake (kg ha^{-1})

Tables 29a and 29b present the results recorded on the influence of nutrient management on the C_4 cropping system with respect to the potassium uptake by second crop rice.

The mean potassium uptake by second crop rice of the C_4 cropping system was 139.79 kg ha^{-1} during 1994-'95 and 153.45 kg ha^{-1} during 1995-'96. Potassium uptake of the second crop rice was affected significantly by nutrient management over the C_4 cropping system during the first year and second year. N_5 and N_1 recorded the maximum and minimum potassium uptake respectively during both the years. N_5 and N_4, N_4 and N_6 and N_6 and N_3 were on a par during the first year. N_5, N_4 and N_6 and N_4, N_6, N_2 and N_3 were on a par during the second year.

Nutrient uptake, in general, was observed to be higher with integration of nutrient sources. The influence of integrated nutrient management in improving the availability of nutrients have been discussed earlier. The higher dry matter production might also have contributed to the higher nutrient uptake at N_5. Nutrient uptake was observed to be higher during the second year. This may be attributed to the residual effect of farmyard manure applied to the summer crop of bhindi. Similar results have been reported by Pillai (1993).

4.4.3 Bhindi

4.4.3.1 Number of fruits per plant

The results on the number of fruits per plant during the first year and second year are presented in Tables 36a and 36b respectively.

Number of fruits per plant was influenced significantly by the different treatments during both the years. N_6 and N_1 recorded the highest and lowest values respectively for the number of fruits per plant during 1994-'95 and 1995-'96. The treatments N_6, N_5, N_4, N_3 and N_2 were at par during both the years.

4.4.3.2 Length and girth of fruits (cm)

The results on the length and girth of fruits are presented in Tables 36a and 36b.

Both these parameters were affected significantly by the different nutrient levels. N_1 recorded significantly lower values for both length and girth of fruits during the first and second year. N_6, N_4, N_3 and N_2 treatments were at par in the first year and second year.

4.4.3.3 Fruit yield (kg ha^{-1})

The results on the fruit yield of bhindi are presented in Tables 36a and 36b.

Fruit yield of bhindi was influenced significantly by nutrient management during the first year. However the treatments N_3, N_5, N_4, N_3 and N_2 were at par. N_6 recorded the highest fruit yield and N_1 the lowest fruit yield during the first year.

The number of fruits per plant, length and girth of fruits and consequently fruit yield was observed to be low at N_1. The lack of considerable difference among the treatments N_2 to N_6 indicate the absence of any residual effect for the treatments applied to the preceding rice crops. Unlike the other summer crops, bhindi was supplied with farmyard manure and poultry manure, at N_1. The cumulative and residual effect of organics applied to the preceding crops especially at low fertility levels as in N_1 might have contributed towards the non-significant effect of the treatments during the second year.

4.4.3.4 Bhusa yield (kg ha^{-1})

Tables 36a and 36b present the results on the bhusa yield of bhindi.

Table No. 36 Growth, yield attributes, yield and crude fibre content of bhindi as influenced by nutrient management

Table No. 36a 1994-'95

Nutrient management	Fruit plant^{-1}	Length of fruit (cm)	Girth of fruit (cm)	Fruit yield (kg ha^{-1})	Bhusa yield (kg ha^{-1})	Total dry matter production (kg ha^{-1})	Crude fibre (%)
N1	6.15	11.64	4.77	5643.71	2169.78	3884.47	8.520
N2	9.90	13.58	6.10	6681.16	2615.66	4561.01	11.655
N3	10.17	13.56	6.09	6745.07	2758.09	4675.84	11.360
N4	10.07	13.80	6.17	7190.39	2834.30	4905.32	11.385
N5	10.36	13.25	6.06	7241.64	2838.95	4941.45	13.280
N6	11.25	13.19	6.21	7421.53	2997.86	5181.63	13.283
SEm	0.4664	0.4346	0.1947	287.2026	100.0906	186.4289	0.1494
CD (0.05)	1.4055	1.3098	0.5868	865.5394	301.6420	561.8388	0.4501

Table No. 36b 1995-'96

Nutrient management	Fruit plant^{-1}	Length of fruit (cm)	Girth of fruit (cm)	Fruit yield (kg ha^{-1})	Bhusa yield (kg ha^{-1})	Total dry matter production (kg ha^{-1})	Crude fibre (%)
N1	9.63	11.74	4.70	5612.85	1888.68	3774.95	9.050
N2	11.62	13.42	5.76	6652.07	2625.58	4439.05	11.875
N3	11.80	13.60	5.76	6942.55	2696.88	4628.11	11.880
N4	11.84	13.38	6.17	6847.56	2690.06	4560.57	11.873
N5	11.88	13.25	5.62	6896.95	2693.16	4601.66	13.353
N6	12.31	13.19	5.70	6897.91	2680.11	4574.72	13.365
SEm	0.5459	0.3210	0.1927	358.0078	133.1976	235.3029	0.2606
CD (0.05)	1.6451	0.9673	0.5807	-	401.4162	-	0.7853

Bhusa yield of bhindi was affected significantly by the treatments, during both the years. N_1 recorded significantly low values during both the years. All the other treatments were on a par, with N_6 recording the highest bhusa yield during the first year N_3 in the second year.

As in the case of fruit yield, the absence of residual effect might have contributed towards the lack of considerable difference among the treatments, N_2 to N_6.

4.4.3.5 Total dry matter production (kg ha^{-1})

The results on the total dry matter production of bhindi are presented in Tables 36a and 36b.

During the first year, the total dry matter production was affected significantly by the treatments with N_6 recording the highest value and N_1 the lowest value. The treatments did not show any significant influence on the total dry matter production during the second year.

The cumulative and residual effects of the organic matter and fertilisers might have contributed to a better dry matter production in N_1 during the second year. Such effects are more pronounced at low levels of fertility as in N_1. This might be the reason for the non-significant effect of the treatment in the second year. Similar results were reported by Sajitharani (1993).

4.4.3.6 Crude fibre content of bhindi (per cent)

The results on the crude fibre content of bhindi are presented in Tables 36a and 36b.

Crude fibre content of bhindi was significantly influenced by nutrient management. N_6 recorded the highest crude fibre content and N_1 the lowest. The data showed that the treatments, N_6 and N_5 and N_4, N_3 and N_2 were on a par.

Crude fibre content of bhindi has been reported to be less at sub-optimal levels of nutrients. The application of nutrients at optimum levels have been reported to result in comparatively higher crude fibre contents (Sajitharani, 1993).

4.4.3.7 Nitrogen uptake (kg ha^{-1})

Tables 31a and 31b present the results on the effect of nutrient management on the nitrogen uptake by bhindi.

Nitrogen uptake by bhindi was influenced significantly by the nutrient levels during the first year. N_6 and N_1 recorded the highest and lowest nitrogen uptake values both during the first year and second year. N_6, N_5, N_4, N_3 and N_2 were at par during 1994-'95. Significant difference was not observed among the nitrogen uptake values during the second year.

4.4.3.8 Phosphorus uptake (kg ha^{-1})

The results on the phosphorus uptake by bhindi are presented in Tables 32a and 32b.

Phosphorus uptake by bhindi was influenced significantly by nutrient management only during the first year. N_6, N_5 and N_4, N_5, N_4 and N_3 and N_2 were at par.

4.4.3.9 Potassium uptake (kg ha^{-1})

The results on the potassium uptake by bhindi as influenced by nutrient management are presented in Tables 33a and 33b.

Potassium uptake by bhindi was influenced significantly by nutrient management. N_1 recorded significantly lower uptake values for potassium, both during the first year and second year. N_6, N_5 and N_4 and N_3 and N_2 were at par during the first year and during the second year.

Nutrient uptake is the product of the total dry matter production and content of the concerned nutrient. The low dry matter production at N_1 may be the reason for the poor uptake of all the three major nutrients. More or less similar values of nutrient uptake recorded by the treatments N_2 to N_6 suggests the absence of any residual effect for the treatments applied to the preceding crops.

4.5 Pooled analysis of grain yield

4.5.1 First crop rice

The results on the influence of the cropping systems and nutrient management on the grain yield (pooled) of first crop rice are presented in Table 37 and graphically in Fig. 7.

Cropping systems and nutrient management and their interaction influenced the grain yield (pooled) of first crop rice significantly. Rice-rice-groundnut (C_2) recorded the maximum grain yield, while rice-rice-sesamum (C_1) recorded the minimum grain yield for first crop rice. C_2 was on a par with C_3 (rice-rice-cowpea) and C_4 (rice-rice-bhindi). The favourable effects of inclusion of legumes in cropping systems has been well documented. Legumes, in general, increase the soil nitrogen and organic matter content, thereby improve the soil productivity and benefit the succeeding crop yield (Meelu and Morris, 1984). The favourable effect of cowpea and groundnut in cropping systems have been reported by Sasidhar (1978) and Dwivedi (1981).

N_6 recorded the maximum grain yield for first crop rice and was significantly superior to all other treatments. The treatments N_2 to N_6 recorded a higher grain yield than N_1 (farmers' practice). N_2 (package of practices) produced a grain yield much lower than that at N_3 to N_6. The treatment N_6,

Table No. 37 Grain yield (pooled) of first crop rice as influenced by cropping systems and nutrient management (kg ha^{-1})

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1444	2198	2318	2670	2982	3346	2493
C2	1852	2464	2598	2813	3144	3638	2752
C3	1645	2295	2564	2992	3321	3661	2746
C4	1763	2319	2480	2938	3149	3686	2722
Mean	1676	2319	2490	2853	3149	3583	

SEm C - 50.75 N - 29.44 CN - 46.68

CD C - 145.6 N - 83.3 CN - 129.4

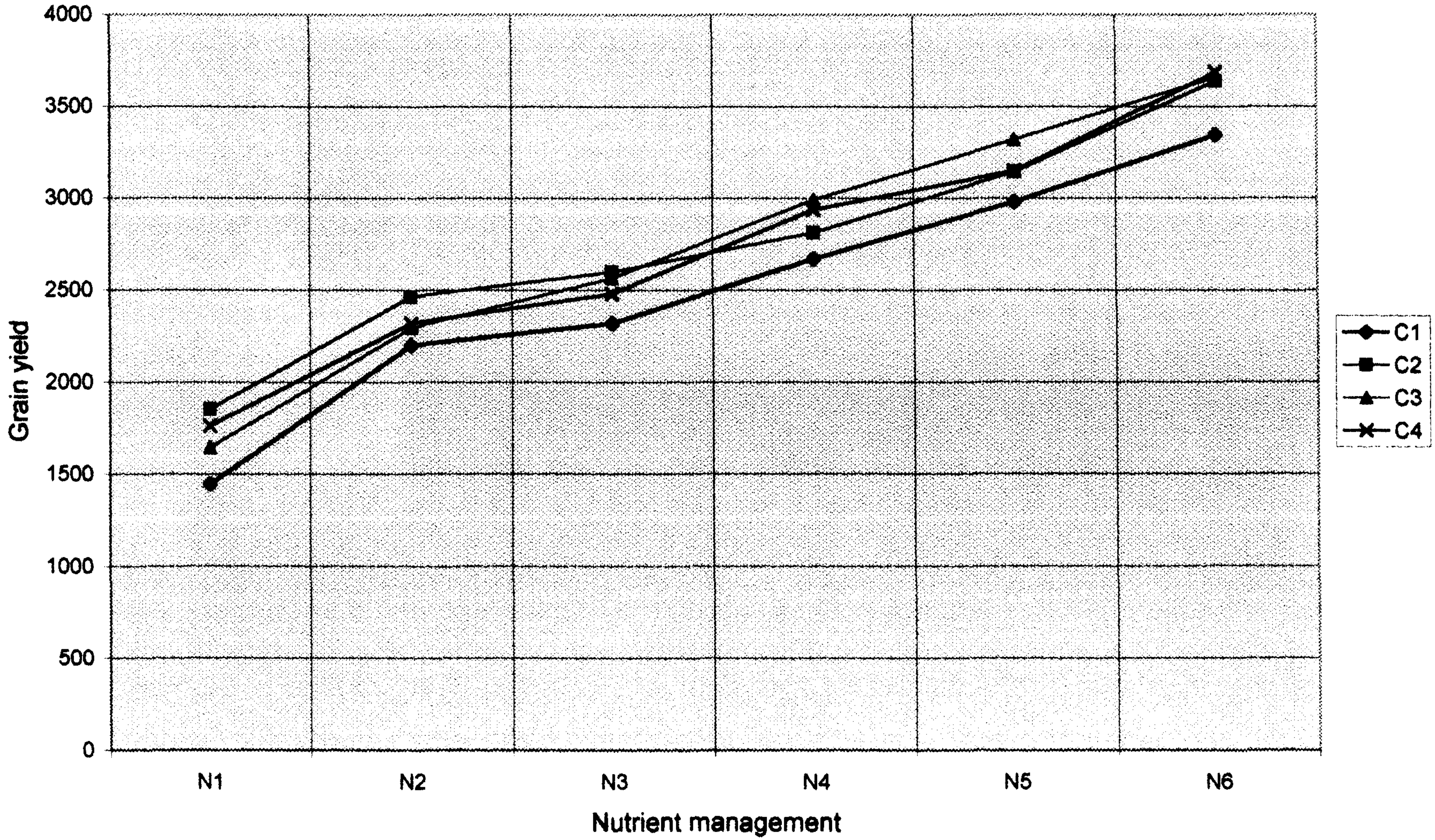
Table No. 38 Grain yield (pooled) of second crop rice as influenced by cropping systems and nutrient management (kg ha^{-1})

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1858	2900	3031	3258	3471	3693	3035
C2	1906	2744	2836	3390	3726	3823	3071
C3	1671	2464	2555	3314	3593	3663	2877
C4	1784	2753	2847	3306	3656	3765	3018
Mean	1805	2715	2817	3317	3611	3736	

SEm C - 36.19 N - 31.96 CN - 48.56

CD C - 103.8 N - 90.4 CN - 134.6

Fig. 7 Grain yield (pooled) of first crop rice in $kgha^{-1}$



combined the favourable effects of farmyard manure, vermicompost and *Azospirillum*, in an integrated manner along with inorganic fertilisers. Several workers have reported the favourable effects of farmyard manure (Sharma and Mitra, 1990; Tanveer *et al*., 1993), vermicompost (Kale and Bano, 1983; Vasanthy and Kumaraswamy, 1996) and *Azospirillum* (Murali and Purushothaman, 1987; Resmi, 1993; Vasudevan and Rangasamy, 1995) either alone or in combination with inorganic fertilisers on the grain yield of rice.

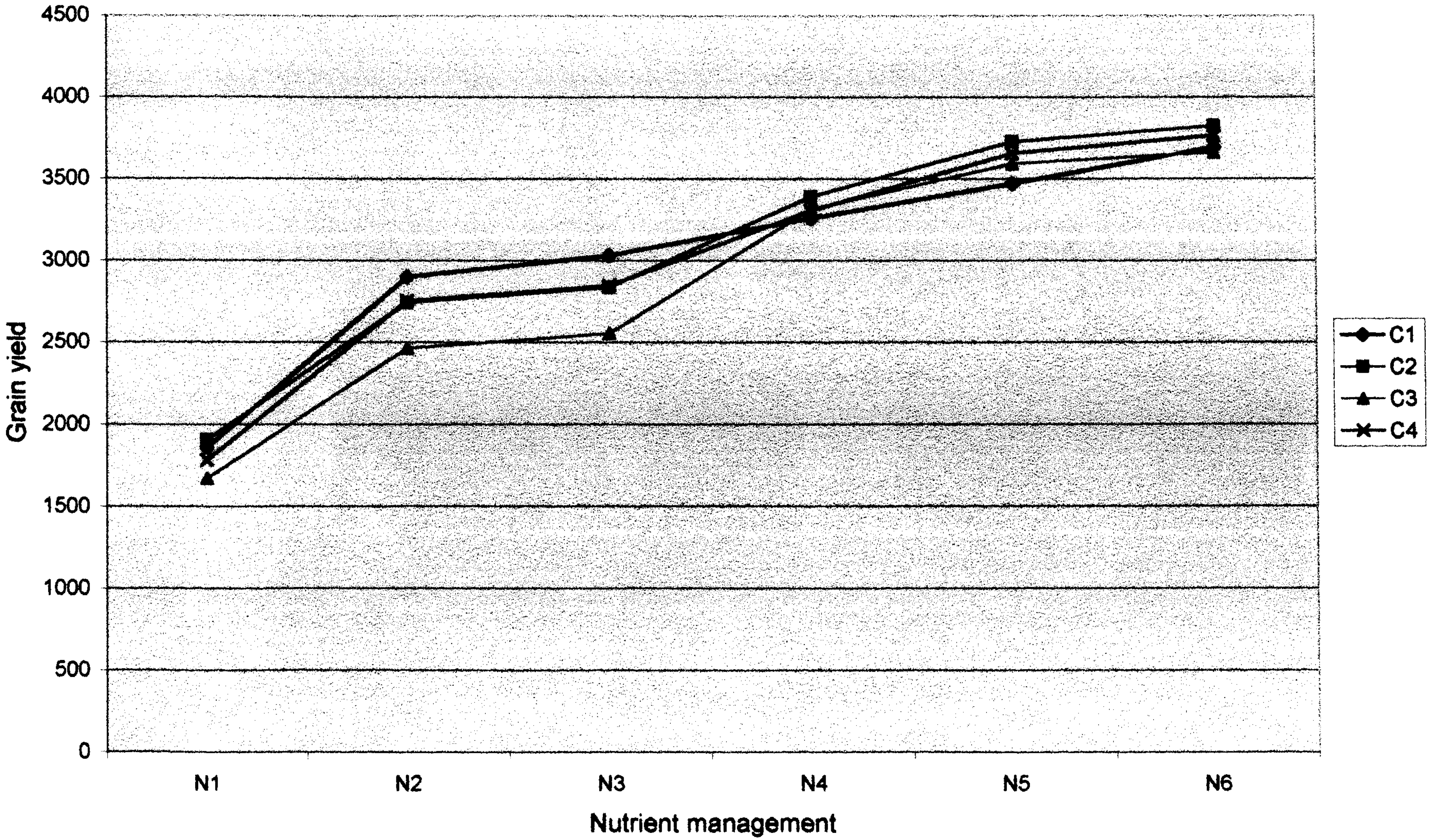
The perusal of data on the interaction of cropping systems and nutrient management on the grain yield of first crop rice showed that irrespective of cropping system, N_6 produced the maximum grain yield and was significantly superior to all the other treatments. N_1 recorded the minimum grain yield in all the cropping systems.

4.5.2 Second crop rice

Table 38 and Fig. 8 present the results on the grain yield (pooled) of second crop rice as influenced by cropping systems and nutrient management.

Grain yield (pooled) of second crop rice was influenced significantly by the cropping systems and nutrient management and their interaction. C_2 recorded the maximum grain yield for second crop rice and was on a par with C_1 and C_4. C_3 recorded the least grain yield.

Fig.8 Grain yield (pooled) of second crop rice in kgha^{-1}



The perusal of the data on the effect of nutrient management on the grain yield of second crop rice showed that N_6 recorded the maximum grain yield, which was significantly greater than all the other treatments. This may be due to the effect of the integration of bio-organic sources and inorganic fertilisers as discussed earlier in the case of the grain yield (pooled) of first crop rice.

N_6 recorded the maximum grain yield for second crop rice in all the cropping systems. In C_2, C_3 and C_4, the treatments N_6 and N_5 were at par. N_1 recorded the lowest grain yield for second crop rice in all the cropping systems, indicating the inferiority of farmers' practice over other treatments. Further, among all the cropping systems studied the treatments N_2 (package of practices) and N_3 (chemical fertilisers + farmyard manure) were on a par.

4.6 Production efficiency (kg ha^{-1} day^{-1})

The results on the production efficiency as influenced by cropping systems and nutrient management are presented in Tables 39a and 39b.

Production efficiency was influenced significantly by the cropping systems and nutrient management during both the years. However the interaction of the treatments was

Table No. 39 Production efficiency as (kg ha^{-1} day^{-1}) influenced by cropping systems and nutrient management

Table No. 39a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	10.69	15.96	16.68	18.82	20.25	21.77	17.36
C2	11.97	16.76	16.99	19.18	22.26	23.96	18.52
C3	9.51	14.84	15.18	18.75	20.96	22.08	16.89
C4	24.75	32.13	32.76	36.43	38.37	40.58	34.17
Mean	14.23	19.92	20.40	23.29	25.46	27.10	

SEm C - 0.692 N - 0.341 CN - 0.488

CD C - 2.213 N - 1.029 CN - 1.390

Table No. 39b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	9.55	15.09	15.97	17.49	19.20	21.04	16.39
C2	13.99	17.92	18.94	21.18	23.43	25.03	20.08
C3	11.15	15.13	17.07	20.50	21.84	23.01	18.12
C4	25.60	32.27	34.03	36.35	37.76	39.56	34.26
Mean	15.07	21.10	21.50	23.88	25.56	27.16	

SEm C - 0.657 N - 0.435 CN - 0.544

CD C - 2.102 N - 1.311 -

significant only during the first year. Rice-rice-bhindi (C_4) recorded significantly higher values for production efficiency during both the years. The lowest value for production efficiency was recorded by rice-rice-sesamum (C_1). The production of edible portion was highest in C_4. This may be the reason for higher production efficiency in rice-rice-bhindi cropping system. Kumar *et al*. (1993) has reported that the rice-rice-bhindi cropping system is the most productive and rice-rice-sesamum, the least productive.

Production efficiency was maximum with N_6 and minimum with N_1 during both the years. It was further observed that the treatments N_2 and N_3 were at par. N_1, which was the farmers' practice received manures and fertilisers at sub-optimal levels. It is a well established fact that the productivity of crops decrease at sub-optimal levels of nutrients. The treatments N_2 to N_6 received nutrients at optimal levels. Furthermore, in the treatments N_3, N_4, N_5 and N_6 there was an improved integration of organic, inorganic and/or biological sources, for the preceding first and second crop rice. Integrated nutrient management have been reported to improve the production efficiency of crops besides providing favourable residual effect on the succeeding crops (Inodo, 1984; Saravanan *et al*., 1987; Arumugam *et al*., 1992; Jana and Ghosh, 1996).

During the first year, the influence of nutrient management over cropping systems was significant. Irrespective of the cropping system, production efficiency was observed to be maximum in N_6 and minimum in N_1. N_2 and N_3 were at par in all the cropping systems. In rice-rice-cowpea (C_3) N_5 and N_6 were also on a par. Thus the treatment N_6 comprising 75 per cent recommended dose of nitrogen as chemical combined with 12.5 per cent each of recommended nitrogen as farmyard manure and vermicompost respectively, along with *Azospirillum* inoculation (for first and second crop rice) followed by the package of practices recommendations for the third season (summer) crops recorded the maximum production efficiency in all the cropping systems.

4.7 Land use efficiency (per cent)

The land use efficiency recorded are presented in Table 40.

The mean land use efficiency was maximum for rice-rice-bhindi (C_4) followed by rice-rice-groundnut (C_2), rice-rice-cowpea (C_3) and rice-rice-sesamum (C_1). Field duration was highest for C_4 and hence it recorded the maximum value for land use efficiency.

Table No. 40 Land use efficiency (%) of different cropping systems

Cropping systems	Land use efficiency (%)		Mean
	1994-'95	1995-'96	
C1	95.89	95.89	95.89
C2	99.73	99.18	99.46
C3	96.43	96.16	96.30
C4	100.00	99.73	99.87

4.8 Physico-chemical properties of the soil as influenced by cropping systems and nutrient management

4.8.1 Physical properties of the soil

4.8.1.1 Bulk density (g cc^{-1})

Tables 41a and 41b present the results on the bulk density of the soil as influenced by cropping systems and nutrient management.

Cropping systems showed significant influence on the bulk density of the soil. Rice-rice-cowpea (C_3) recorded a significantly lower bulk density. This reduction in bulk density was to the tune of 0.004 g cc^{-1} during 1994-'95 and 0.014 g cc^{-1} during 1995-'96. All the other systems were on a par. The decrease in bulk density noticed after cowpea may mainly be due to the effect of farmyard manure (20 t ha^{-1}) applied to this crop. The organic manure might have improved the soil structure and increased the pore space there by decreasing the bulk density of the soil. Similar results have been reported by Sasidhar (1978), Lal and Mathur (1989) and Singh and Dixit (1994). Inclusion of legumes in rotation has been reported to improve the physical condition of the soil (Bavaskar and Zende, 1973; Paeth and Azizi, 1974).

The nutrient management ranging from N_1 to N_6 exerted significant influence on the bulk density of the soil during

Table No. 41 Effect of cropping systems and nutrient management on the bulk density of the soil (g cc^{-1})

Table No. 41a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.590	1.592	1.590	1.589	1.588	1.590	1.590
C2	1.595	1.592	1.592	1.592	1.592	1.592	1.592
C3	1.591	1.586	1.587	1.586	1.587	1.587	1.587
C4	1.598	1.590	1.588	1.588	1.589	1.588	1.590
Mean	1.593	1.590	1.589	1.589	1.589	1.589	

SEm C - 0.0019 N - 0.0010 CN - 0.0017

CD C - 0.003 - -

Table No. 41b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.591	1.588	1.590	1.590	1.588	1.595	1.596
C2	1.595	1.592	1.592	1.591	1.591	1.589	1.591
C3	1.590	1.567	1.568	1.568	1.573	1.573	1.573
C4	1.598	1.587	1.587	1.588	1.588	1.588	1.589
Mean	1.593	1.583	1.584	1.584	1.585	1.586	

SEm C - 0.002 N - 0.001 CN - 0.002

CD C - 0.005 N - 0.003 CN - 0.005

the second year. N_1 recorded a higher value for bulk density. All the other treatments were at par. The results indicated that the integration of organic manures and inorganic fertilisers resulted in a lower bulk density. N_1 was farmers' practice wherein there was only poor integration of these two components. A lowering of bulk density through integrated nutrient management has been reported by several workers (Biswas *et al.*, 1969; Muthuvel *et al.*, 1981; Lal and Mathur, 1989; Johnkutty and Anilakumaran, 1991). Venkateswarlu (1984) opined that organic manures could counteract the deleterious effect on bulk density that may be caused by the continuous use of mineral fertilisers.

The influence of nutrient levels over the cropping systems was significant during the second year. In C_1, the treatment N_5 recorded the least bulk density of 1.588. In C_2, the treatments N_4 and N_5 recorded lower bulk density of 1.591 each. In C_3, the treatment N_2 recorded the least bulk density and was at par with N_3 and N_4. In C_4, the treatment N_2 recorded the least bulk density and was once par with N_3, N_4, N_5 and N_6. In general integrated nutrient management was observed to lower the bulk density in the long run.

4.8.1.2 Particle density (g cc^{-1})

Tables 42a and 42b present the results on the particle density of the soil as influenced by cropping systems and nutrient management.

Table No. 42 Effect of cropping systems and nutrient management on the particle density of the soil (g cc^{-1})

Table No. 42a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2.598	2.608	2.603	2.606	2.603	2.610	2.605
C2	2.600	2.599	2.599	2.599	2.599	2.601	2.599
C3	2.602	2.588	2.593	2.590	2.591	2.591	2.593
C4	2.597	2.594	2.595	2.595	2.596	2.593	2.595
Mean	2.599	2.597	2.597	2.598	2.597	2.599	

SEm C - 0.0014 N - 0.0023 CN - 0.0037

CD C - 0.0040 - -

Table No. 42b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2.596	2.610	2.603	2.606	2.605	2.610	2.605
C2	2.600	2.599	2.598	2.598	2.600	2.599	2.599
C3	2.603	2.600	2.600	2.600	2.600	2.600	2.600
C4	2.598	2.600	2.601	2.605	2.601	2.600	2.601
Mean	2.599	2.602	2.600	2.601	2.601	2.602	

SEm C - 0.0010 N - 0.0020 CN - 0.0040

CD C - 0.0030 - -

Particle density of the soil was influenced significantly by the cropping systems during both the years. Rice-rice-sesamum (C_1) recorded the highest particle density (2.605 g cc^{-1}). In general, higher the quantity of organic manure applied, lower the particle density. Organic matter weighs much less than an equal volume of mineral solids. Consequently the quantity of this constituent in the soil markedly affects the particle density (Brady, 1988). Sheeba and Chellamuthu (1996a) observed an inverse relationship between the organic matter content and particle density. This may be the reason for the lower values of particle density recorded in rice-rice-cowpea (C_3) during both the years.

4.8.1.3 Water holding capacity (per cent)

Tables 43a and 43b present the results on the water holding capacity of the soil as influenced by cropping systems and nutrient management.

Cropping systems significantly influenced the water holding capacity of the soil during the second year. Rice-rice-cowpea (C_3) recorded the maximum value for water holding capacity (18.71 per cent). This showed a slight improvement (0.36 per cent) over the initial water holding capacity (18.35 per cent). All the other treatments were on a par. Cowpea was supplied with 20 t of farmyard manure per hectare in all the treatments except in farmers' practice. The role of organic

Table No. 43 Effect of cropping systems and nutrient management on the water holding capacity of the soil (%)

Table No. 43a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	18.37	18.31	18.45	18.50	18.49	18.55	18.44
C2	18.34	18.37	18.38	18.38	18.37	18.41	18.38
C3	18.33	18.36	18.41	18.42	18.37	18.39	18.38
C4	18.25	18.36	18.39	18.65	18.43	18.39	18.41
Mean	18.32	18.35	18.41	18.49	18.41	18.43	

SEm C - 0.033 N - 0.042 CN - 0.092

CD - - -

Table No. 43b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	18.33	18.58	18.47	18.51	18.55	18.48	18.48
C2	18.27	18.42	18.46	18.41	18.41	18.46	18.40
C3	18.34	18.82	18.83	18.78	18.76	18.74	18.71
C4	18.24	18.48	18.48	18.57	18.48	18.45	18.45
Mean	18.30	18.57	18.56	18.57	18.55	18.53	

SEm C - 0.029 N - 0.029 CN - 0.061

CD C - 0.092 N - 0.089 -

manures in improving the water holding capacity of the soil has well documented (Lal and Mathur, 1989; Kumar *et al.*, 1992; Varghese, 1993; Sheeba and Chellamuthu, 1996a).

Water holding capacity of the soil was also affected significantly by nutrient management. N_1 recorded significantly lower water holding capacity (18.30 per cent). Water holding capacity recorded under the influence of the other treatments (N_2 to N_6) were on a par. But the treatments N_2 to N_6 recorded water holding capacity values which were higher than the initial value. Integration of inorganic fertilisers and farmyard manure has been observed to improve the water holding capacity of the soil (Manickam and Venkitaramanan, 1972; Meelu, 1981; Nambiar, 1994). This may be the reason for higher water holding capacity in the treatments N_2 to N_6. The farmers' practice (N_1) was the treatment that received the lowest quantity of organic manures in all the cropping systems. Further there was only very low level of integration of organic manure and chemical fertilisers in N_1. Both these factors might have contributed to a lower value for water holding capacity in N_1.

4.8.1.4 Water stable aggregates (per cent)

The results on the effect of cropping systems and nutrient management on the water stable aggregates of different sizes are presented in Tables 44a and 44b (> 2 mm size), Tables 44c and 44d (1-2 mm size), Tables 44e and 44f (0.5-1 mm size),

Table No. 44 Effect of cropping systems and nutrient management on the water stable aggregates (> 2mm) of the soil (%)

Table No. 44a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	10.03	9.98	10.00	10.07	10.07	10.10	10.05
C2	9.99	10.01	10.01	10.02	10.01	10.03	10.01
C3	9.99	10.01	10.03	10.03	10.01	10.01	10.01
C4	9.95	10.01	10.03	10.03	10.03	10.02	10.01
Mean	9.99	10.00	10.03	10.04	10.03	10.04	

SEm C - 0.014 N - 0.013 CN - 0.036

CD - - -

Table No. 44b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	9.98	10.12	10.09	10.08	10.11	10.10	10.08
C2	9.81	10.02	10.00	10.02	10.03	10.05	9.99
C3	9.99	10.24	10.25	10.23	10.21	10.22	10.19
C4	9.94	10.07	10.06	10.09	10.07	10.06	10.05
Mean	9.93	10.11	10.10	10.10	10.10	10.10	

SEm C - 0.020 N - 0.026 CN - 0.054

CD C - 0.063 N - 0.079 -

Tables 44g and 44h (0.25 - 0.5 mm size) and in Tables 44i and 44j (0.1 - 0.25 mm size) during the first year and second year respectively.

Water stable aggregates greater than 2 mm in size was affected significantly by cropping systems and nutrient management during the second year. Rice-rice-cowpea (C_3) recorded the maximum value for this parameter while all the other systems were at par. N_1 recorded a significantly lower water stable aggregate percentage of size greater than 2 mm. The treatments N_2 to N_6 were at par. However they recorded values which were slightly higher than the initial value.

Cropping systems and nutrient management had significant influence on the water stable aggregates of size 1-2 mm, during both the years. Rice-rice-groundnut system (C_2) recorded the highest value (6.45 per cent) during the first year and 6.46 per cent during the second year (6.46 per cent). The initial value was 6.41 per cent. N_1 recorded the least percentage of water stable aggregates of size 1-2 mm during both the years. The treatments N_2 to N_6 were on a par. However, these treatments showed a slight increase in the percentage of water stable aggregates of 1-2 mm size.

The percentage of water stable aggregates of 0.5-1mm size was influenced significantly by nutrient management during both the years. Cropping systems exerted significant influence

Table No. 44 Effect of cropping systems and nutrient management on the water stable aggregate (1-2 mm) of the soil (%)

Table No. 44c 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	6.41	6.41	6.44	6.43	6.45	6.45	6.43
C2	6.41	6.46	6.46	6.47	6.46	6.46	6.45
C3	6.40	6.44	6.44	6.44	6.46	6.46	6.44
C4	6.41	6.42	6.43	6.44	6.44	6.44	6.43
Mean	6.41	6.43	6.44	6.44	6.45	6.45	

SEm C - 0.004 N - 0.007 CN - 0.016

CD C - 0.014 N - 0.022 -

Table No. 44d 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	6.42	6.43	6.46	6.43	6.46	6.46	6.44
C2	6.42	6.46	6.46	6.47	6.47	6.47	6.46
C3	6.41	6.45	6.44	6.45	6.47	6.47	6.45
C4	6.42	6.42	6.43	6.43	6.44	6.44	6.43
Mean	6.41	6.44	6.45	6.45	6.46	6.46	

SEm C - 0.004 N - 0.008 CN - 0.015

CD C - 0.014 N - 0.023 -

on this parameter during the second year only. Rice-rice-cowpea system (C_3) recorded the highest percentage of water stable aggregates of 0.5 - 1 mm size (6.74 per cent). All the cropping systems recorded water stable aggregate percentages which were lower than the initial value. N_1 recorded the lowest value for this parameter. The treatments N_2 to N_6 were on a par.

Cropping systems and nutrient management significantly influenced the percentage of water stable aggregates of 0.25 - 0.5 mm size. Rice-rice-cowpea (C_3) recorded the maximum percentage of 12.58 during 1994-'95 and 12.70 during 1995-'96, the initial value being 11.42 per cent. All the cropping systems improved this parameter. With regard to the nutrient levels the treatments N_2 to N_6 were at par, while N_1 recorded significantly the least value for this parameter. The same trend was observed during the second year also.

Water stable aggregates of 0.1 - 0.25 mm size were influenced significantly by cropping systems and nutrient management both during the first year and second year. Rice-rice-cowpea (C_3) recorded the maximum percentage of 0.1 - 0.25 mm sized aggregates during the first year (10.18 per cent) and during the second year (10.45 per cent). The initial value was 10.10 per cent. The treatments N_2 to N_6 which were on a par and recorded values slightly greater than the initial value.

Table No. 44 Effect of cropping systems and nutrient management in the water stable aggregates (0.5 - 1 mm) of the soil (%)

Table No. 44e 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	6.50	6.66	6.66	6.67	6.68	6.67	6.64
C2	6.55	6.67	6.66	6.69	6.68	6.68	6.66
C3	6.57	6.68	6.69	6.69	6.69	6.72	6.67
C4	6.57	6.72	6.72	6.73	6.73	6.73	6.70
Mean	6.55	6.68	6.68	6.69	6.69	6.70	

SEm C - 0.018 N - 0.018 CN - 0.041

CD - N - 0.053 -

Table No. 44f 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	6.50	6.67	6.67	6.68	6.69	6.69	6.65
C2	6.56	6.70	6.67	6.69	6.68	6.69	6.67
C3	6.56	6.79	6.75	6.77	6.77	6.79	6.74
C4	6.57	6.74	6.76	6.75	6.77	6.77	6.73
Mean	6.55	6.72	6.71	6.72	6.72	6.73	

SEm C - 0.017 N - 0.010 CN - 0.040

CD C - 0.053 N - 0.030 -

Table No. 44 Effect of cropping systems and nutrient management on the water stable aggregates (0.25 - 0.5 mm) of the soil (%)

Table No. 44g 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	12.49	12.38	12.53	12.55	12.52	12.57	12.51
C2	12.36	12.49	12.51	12.48	12.47	12.51	12.47
C3	12.43	12.58	12.56	12.57	12.64	12.67	12.58
C4	12.42	12.49	12.50	12.53	12.47	12.48	12.48
Mean	12.43	12.48	12.52	12.53	12.53	12.56	

SEm C - 0.023 N - 0.022 CN - 0.048

CD C - 0.075 N - 0.065 -

Table No. 44h 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	12.43	12.59	12.52	12.54	12.56	12.57	12.53
C2	12.32	12.48	12.47	12.48	12.50	12.50	12.46
C3	12.46	12.77	12.78	12.75	12.74	12.74	12.70
C4	12.46	12.62	12.61	12.64	12.61	12.60	12.59
Mean	12.42	12.61	12.59	12.60	12.60	12.60	

SEm C - 0.019 N - 0.018 CN - 0.041

CD C - 0.060 N - 0.055 -

Table No. 44 Effect of cropping systems and nutrient management on the water stable aggregates (0.1 - 0.25 mm) of the soil (%)

Table No. 44i 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	10.00	10.10	10.08	10.09	10.09	10.09	10.08
C2	10.08	10.14	10.14	10.15	10.15	10.15	10.14
C3	10.11	10.21	10.21	10.19	10.19	10.20	10.18
C4	10.10	10.14	10.14	10.14	10.14	10.14	10.13
Mean	10.07	10.15	10.14	10.14	10.14	10.14	

SEm C - 0.014 N - 0.009 CN - 0.024

CD C - 0.045 N - 0.028 -

Table No. 44j 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	10.04	10.18	10.12	10.14	10.16	10.11	10.13
C2	10.02	10.08	10.07	10.10	10.12	10.16	10.09
C3	10.25	10.51	10.51	10.49	10.48	10.48	10.45
C4	10.01	10.24	10.24	10.25	10.24	10.23	10.20
Mean	10.08	10.25	10.23	10.25	10.25	10.25	

SEm C - 0.016 N - 0.017 CN - 0.034

CD C - 0.052 N - 0.050 -

N_1 was significantly inferior to all the other treatments and recorded values lower than the initial.

Cropping systems affect the soil structure directly and indirectly. Direct protection is afforded by the leaves and stems against the impact of rain drops. This helps in the development of granulation and porosity through root activity which aids in the regeneration of structure. The indirect effects may be the changes in granulation that are caused by the organic matter produced by plant growth (Baver, 1963). Root penetration into larger aggregates may cause separation of aggregate soil particles, while non-aggregated soil particles may be trapped and compressed into aggregates by the net work of roots. Further the growing roots may excrete substances which act as binding agents. Stallings (1953) opined that the microbial conversion of plant root excretions and residues into soil binding agents is a major mechanism by which aggregation is effected.

Aggregate stability is affected considerably by the application of manures and fertilisers. The major agency in the encouragement of granular and crumb type aggregate formation in surface soil horizons is organic matter, which not only binds but also lightens and expands, making possible the porosity so characteristic of individual soil aggregates (Brady, 1988). The favourable effect of organic manures on soil aggregation have been reported by Biswas and Khosla (1971), Muthuvel *et al*. (1981), Bhatia and Shukla (1982), Sharma *et al*. (1987), Lal and Mathur (1989) and Johnkutty and Anilakumaran (1991). This positive effect of organic manures may be the reason for the favourable influence of the treatments N_2 to N_6 on soil aggregation. The poor effect of N_1 on soil aggregation may be due to low quantity of organic manures applied to this treatment. Cultivation generally results in the deterioration of soil structure. However organic manure can counteract this deleterious effect of cultivation to a certain extent (Sasidhar, 1978).

The water stable aggregates, except those of 0.5-1 mm in size, were observed to increase after sesamum, groundnut, cowpea and bhindi, maximum increase being noticed after groundnut and cowpea. Legumes are reported to have a structure improving effect. This may be due to the rooting habit of the legumes or due to the addition of nitrogen, helping in the conservation of organic matter or due to the secretion of structure improving materials by legumes (Sasidhar, 1978). In the case of sesamum and bhindi, increase in water stable aggregates may be due to the addition of organic manures to these crops.

4.8.2 Chemical properties of the soil

4.8.2.1 Soil reaction (pH)

The results on the soil reaction (pH) as influenced by cropping systems and nutrient management are presented in Tables 45a and 45b.

The influence of cropping systems and nutrient management was significant with regard to the soil reaction. The interaction effect was also significant. Rice-rice-groundnut (C_2) recorded significantly higher values for soil reaction and rice-rice-bhindi (C_4) recorded lower values in this respect. Except rice-rice-groundnut, all the other cropping systems were observed to lower the soil pH. Several workers have reported that the soil pH decreases with increase in cropping intensity. Lal (1973) reported a decrease in soil pH with the increase in cropping intensity from 100 per cent to 400 per cent.

The higher soil pH recorded after the groundnut crop may be due to the effect of lime applied to this crop. Similarly the reduction in soil pH observed after bhindi may be due to the application of ammonium sulphate to the crop. Application of ammonium sulphate at the rate of 840 kg ha^{-1} has been reported to reduce the pH of a sandy soil by 0.8 units in one year (Black, 1968). Similar results have been reported by Sharma *et al*. (1987), Varghese (1993) and Nambiar (1994).

Table No. 45 Soil reaction (pH) as affected by the cropping systems and nutrient management

Table No.45a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	5.0	5.1	5.1	5.0	5.1	5.1	5.1
C2	5.2	5.9	5.9	5.9	5.9	5.9	5.8
C3	5.1	5.0	5.1	5.2	5.2	5.2	5.1
C4	4.9	4.6	4.6	4.6	4.6	4.6	4.6
Mean	5.1	5.1	5.2	5.2	5.2	5.2	

SEm C - 0.042 N - 0.026 CN - 0.072

CD C - 0.130 N - 0.080 CN - 0.210

Table No. 45b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	5.0	5.0	5.1	5.0	5.1	5.2	5.1
C2	5.2	5.8	5.8	5.8	5.8	5.8	5.7
C3	5.1	4.9	5.1	5.2	5.2	5.2	5.1
C4	4.5	4.7	4.7	4.7	4.6	4.5	4.6
Mean	4.9	5.1	5.1	5.2	5.2	5.2	

SEm C - 0.036 N - 0.026 CN - 0.070

CD C - 0.114 N - 0.080 CN - 0.200

Although significant influence was observed for the different nutrient management levels on the soil reaction, the variation in soil pH from the initial value was very negligible, the initial value being 5.2. The treatments showed a very small variation in the pH. The treatment N_1 recorded a slightly higher reduction in soil pH during the second year (0.3 units). Organic matter has been reported to have two effects. The first is a lowering of pH during its decomposition. The second is the buffering action of organic manures whereby it prevents wide fluctuations in soil pH (Raychaudhury, 1977; Lund and Dass, 1980). The input of organic manure was very low in N_1, the farmers' practice, when compared to the other treatments.

4.8.2.2 Organic carbon (per cent)

Tables 46a and 46b present the results on the organic carbon content of the soil as influenced by cropping systems and nutrient management.

The organic carbon content of the soil influenced significantly by the cropping systems and nutrient management during the first year and second year. Organic carbon status of the soil increased after all the cropping systems, the maximum being after cowpea and the minimum after sesamum. Singha *et al*. (1993) and Singh *et al*. (1996a) have reported an increase in the organic carbon content of the soil in rice

Table No. 46 Organic carbon content of the soil (%) as affected by the cropping systems and nutrient management

Table No.46a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.405	0.430	0.430	0.430	0.434	0.434	0.427
C2	0.405	0.451	0.451	0.451	0.451	0.452	0.443
C3	0.425	0.472	0.478	0.472	0.472	0.472	0.465
C4	0.415	0.448	0.448	0.444	0.448	0.452	0.443
Mean	0.413	0.450	0.451	0.449	0.451	0.452	

SEm C - 0.0020 N - 0.0031 CN - 0.0045

CD C - 0.0071 N - 0.0090 -

Table No. 46b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.402	0.429	0.428	0.429	0.433	0.433	0.426
C2	0.405	0.453	0.452	0.452	0.452	0.452	0.444
C3	0.427	0.473	0.479	0.473	0.473	0.473	0.466
C4	0.414	0.446	0.443	0.444	0.447	0.451	0.441
Mean	0.412	0.450	0.450	0.450	0.451	0.452	

SEm C - 0.0021 N - 0.0030 CN - 0.0041

CD C 0.0061 N 0.0090 -

based cropping systems involving cowpea. Such an increase in the organic carbon content has been attributed to accumulation of root residues and shedding of leaves by the leguminous crops (Thakur and Sharma, 1988). The large quantity of farmyard manure applied to cowpea (20t ha^{-1}) may be another factor that contributed to a positive change in the organic carbon content. Similar increase in organic carbon content due to the application of farmyard manure has been reported by Sharma *et al*. (1987) and Nambiar (1994).

N_1 recorded a slight decrease in the organic content over the initial value. Intensive cultivation has been reported to decrease the organic carbon content of the soil especially at suboptimal doses of NPK and farmyard manure (Nambiar, 1994). On the other hand the organic carbon content was reported to increase over the initial level at optimal NPK dose and the increase was reported to be even greater with incorporation of farmyard manure along with optimal NPK dose. This may be the reason for the positive change in the soil organic carbon content in the treatments N_2 to N_6.

4.8.2.3 Total nitrogen (per cent)

The results on the total nitrogen content of the soil as influenced by cropping systems and nutrient management are presented in Tables 47a and 47b.

Table No. 47 Total nitrogen content of the soil (%) as influenced by the cropping systems and nutrient management

Table No. 47a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.035	0.037	0.037	0.037	0.037	0.037	0.037
C2	0.035	0.126	0.039	0.039	0.039	0.039	0.053
C3	0.037	0.041	0.041	0.041	0.041	0.041	0.040
C4	0.036	0.039	0.039	0.038	0.039	0.039	0.038
Mean	0.036	0.060	0.039	0.039	0.039	0.039	

SEm C - 0.0072 N - 0.0088 CN - 0.0178

CD - - -

Table No. 47b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.035	0.037	0.037	0.037	0.037	0.037	0.037
C2	0.035	0.039	0.039	0.039	0.039	0.039	0.038
C3	0.037	0.041	0.041	0.041	0.041	0.041	0.040
C4	0.036	0.038	0.038	0.038	0.039	0.039	0.038
Mean	0.035	0.039	0.039	0.039	0.039	0.039	

SEm C - 0.0002 N - 0.0030 CN - 0.0821

CD C - 0.0011 N - 0.0010 -

Cropping systems and nutrient management were observed to exerted a significant influence on the total nitrogen content of the soil during the second year. Rice-rice-cowpea (C_3) recorded a significantly higher nitrogen content compared to the other cropping systems which were at par. The rate of increase was 0.0045 per cent each during the first year and second year. The increase in total nitrogen after cowpea may be due to the residual effect of organic manures applied coupled with the additional fixation of nitrogen in the root nodules. Inclusion of legumes in rotation has been observed to be desirable for the maintenance of soil fertility (Deka and Singh, 1984; Mahapatra *et al.*, 1985; Pandey *et al.*, 1985). Legumes have also been observed to improve the organic matter status of the soil (Reddy *et al.*, 1993). This has been attributed to the profuse rooting pattern and their resistance to easy decomposition. Root system of legumes favour accumulation of humus in the soil, even during the growing period of the plants through the death of portions of the root system (Sasidhar, 1978). The present study indicated a greater increase in the total nitrogen content of the soil, after cowpea when compared to that following groundnut. Fixation of nitrogen by cowpea has been estimated to be greater than that by groundnut (Nutman, 1971). Similar result has been reported by Sasidhar (1978).

N_1 recorded significantly lower values for the total nitrogen content of the soil during the second year.

There was hardly any improvement in the total soil nitrogen with N_1. All the other treatments recorded improved values for this parameter and they were at par. An integrated use of organic manures alongwith optimal dose of NPK has been observed to improve the total nitrogen content of the soil (Sandhu and Meelu, 1974; Sharma *et al*., 1987; Hegde and Dwivedi, 1993; Nambiar, 1994). This may be the reason for the higher total soil nitrogen content in the treatments N_2 to N_6 compared with that in N_1.

4.8.2.4 Available nitrogen (kg ha^{-1})

Tables 48a and 48b and Fig. 9 present the results on the available nitrogen content of the soil as influenced by cropping systems and nutrient management.

The available nitrogen content of the soil was observed to be influenced significantly by the different cropping systems and nutrient management levels during the first year and second year. The effect of the nutrient levels over the cropping systems (interaction) was also observed to be significant during both the years. Rice-rice-cowpea (C_3) recorded the highest available nitrogen content in the soil followed by rice-rice-bhindi, during both the years. The higher quantity of farmyard manure applied to cowpea (20 t ha^{-1}) and bhindi (12 t ha^{-1}) can be attributed as the reason for this. Sharma *et al*. (1987) has reported an increase in the available

Table No. 48 Effect of cropping systems and nutrient management on the available nitrogen content of the soil (kg ha^{-1})

Table No.48a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	85.78	204.42	193.13	177.05	172.42	134.86	161.27
C2	122.16	216.61	193.75	171.31	145.30	179.73	171.48
C3	143.79	328.40	311.37	276.97	268.73	254.35	263.93
C4	136.07	270.36	248.21	226.62	222.49	190.96	215.78
Mean	121.95	254.94	236.61	212.98	202.23	189.98	

SEm C - 3.137 N - 2.605 CN - 4.317

CD C - 10.035 N - 7.851 CN - 12.303

Table No. 48b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	89.94	259.05	220.88	192.07	179.21	109.30	166.74
C2	173.11	236.95	201.76	162.09	118.09	120.07	168.67
C3	105.54	416.85	391.40	331.48	324.58	303.55	312.73
C4	108.67	334.71	303.44	250.93	238.18	182.19	234.69
Mean	119.31	311.89	279.37	234.14	215.02	178.78	

SEm C - 4.680 N - 5.039 CN - 7.533

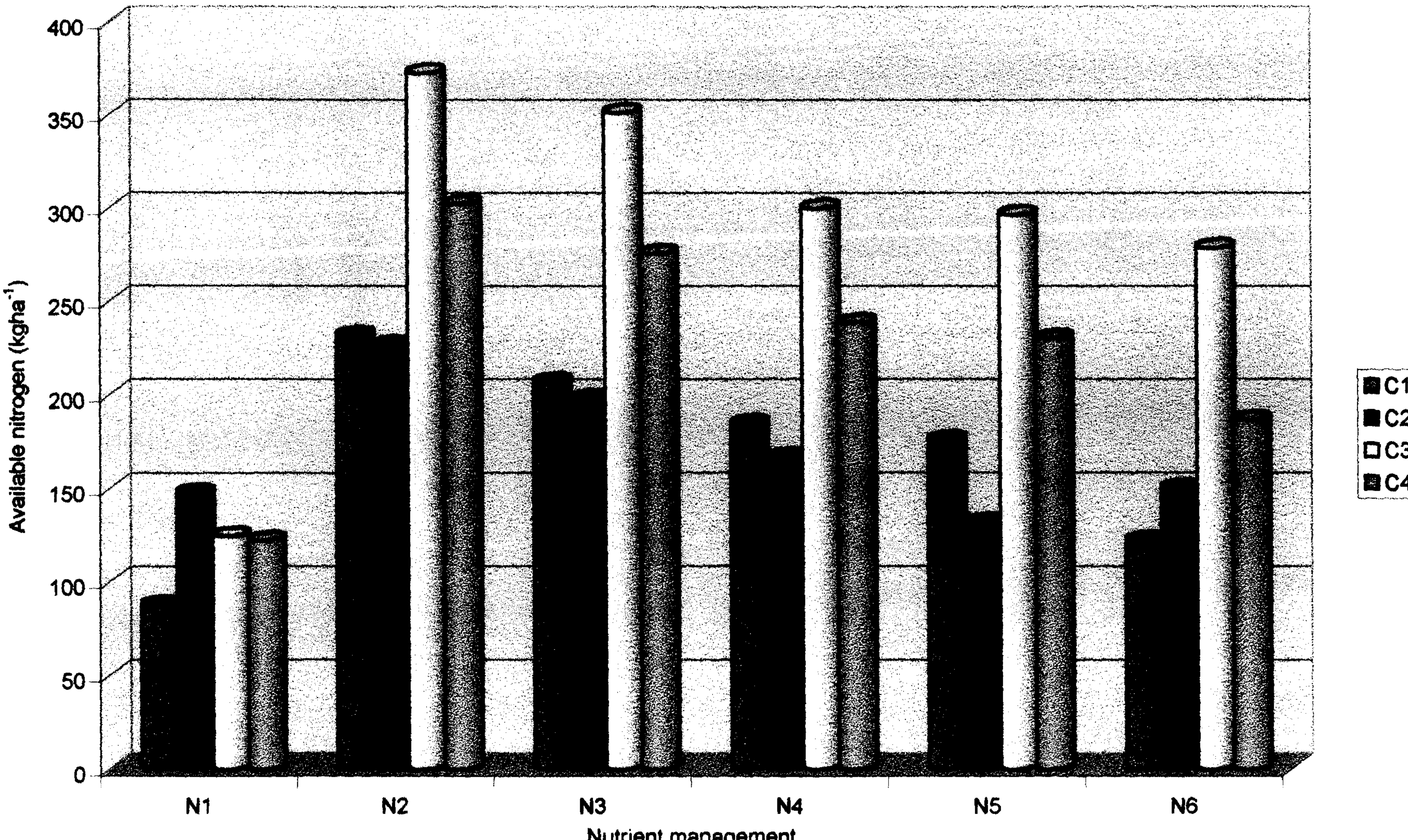
CD C - 14.970 N - 15.186 CN - 21.468

nitrogen content of the soil due to the application of farmyard manure. The increase in the available nitrogen content after cowpea may also be due the nitrogen fixing capacity of the crop.

N_1 recorded significantly lower available nitrogen content in the soil during both the years. Among the other treatments N_2 recorded the maximum available nitrogen content in the soil and it was found to decrease progressively upto N_6. The quantity of nitrogen applied in the treatments N_2 to N_6 through chemical fertilisers and organic sources (farmyard manure and vermicompost) was the same. However, the perusal of data in Tables a and b for the total nitrogen uptake indicated a progressive increase in the total nitrogen uptake of the cropping systems from N_2 to N_6. The quantity of nitrogen taken up by the component crops over and above the quantity that was applied might have been obtained from the soil. This in turn might have led to a decrease in the available nitrogen content of the soil over the treatments N_2 to N_6.

When the available nitrogen content of the soil was compared with the initial status of available nitrogen it was found to decrease substantially by 50.36 kg ha^{-1} during the first year and by 53.00 kg ha^{-1} during the second year in the treatment N_1. The treatments N_2 to N_6 recorded available soil nitrogen content greater than the initial status. This is in

Fig.9 Available nitrogen content of the soil in $kgha^{-1}$ (mean over two years)



conformity with the reports of Nambiar (1994) wherein an increase in the available nitrogen content of the soil was observed as a result of addition of organic manures along with optimal NPK dose.

The perusal of data on the interaction of cropping system and nutrient levels showed that irrespective of the cropping system, N_2 recorded the highest available nitrogen and N_1 the least. In C_1, the treatments N_4 and N_5 were at par. In C_2, the treatments N_6 and N_5 were at par. The treatments N_4 and N_5 and N_5 and N_6 were on a par in C_3. In C_4, the treatments N_4 and N_5 were on a par. In general irrespective of the cropping system, integrated nutrient management improved the available nitrogen status in soil.

4.8.2.5 Available phosphorus (kg ha^{-1})

Tables 49a and 49b and Fig. 10 present the results recorded on the effect of cropping systems and nutrient management on the available phosphorus content of the soil.

The available phosphorus content of the soil was significantly influenced by the cropping system during the first year only and by nutrient management during both the years. The influence of nutrient levels over the cropping systems was observed to be significant during both the years. Rice-rice-sesamum (C_1) recorded the least value for this

Table No. 49 Effect of cropping systems and nutrient management on the available phosphorus content of the soil (kg ha^{-1})

Table No. 49a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	17.80	23.66	25.03	24.94	23.22	22.99	22.94
C2	21.84	25.31	27.09	25.94	23.10	22.51	24.30
C3	23.15	23.62	25.10	25.30	23.79	24.48	24.24
C4	21.84	24.77	23.32	25.30	24.79	25.46	24.25
Mean	21.16	24.34	25.14	25.37	23.73	23.86	

SEm C - 0.232 N - 0.631 CN - 0.822

CD C - 0.741 N - 1.902 CN - 2.344

Table No. 49b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	43.67	42.43	42.70	42.61	47.00	46.33	44.12
C2	38.20	46.08	45.40	47.44	47.43	47.41	45.33
C3	45.34	43.78	43.98	44.02	49.51	49.05	45.95
C4	39.85	43.21	46.35	49.41	50.94	50.95	46.79
Mean	41.76	43.87	44.61	45.87	48.72	48.44	

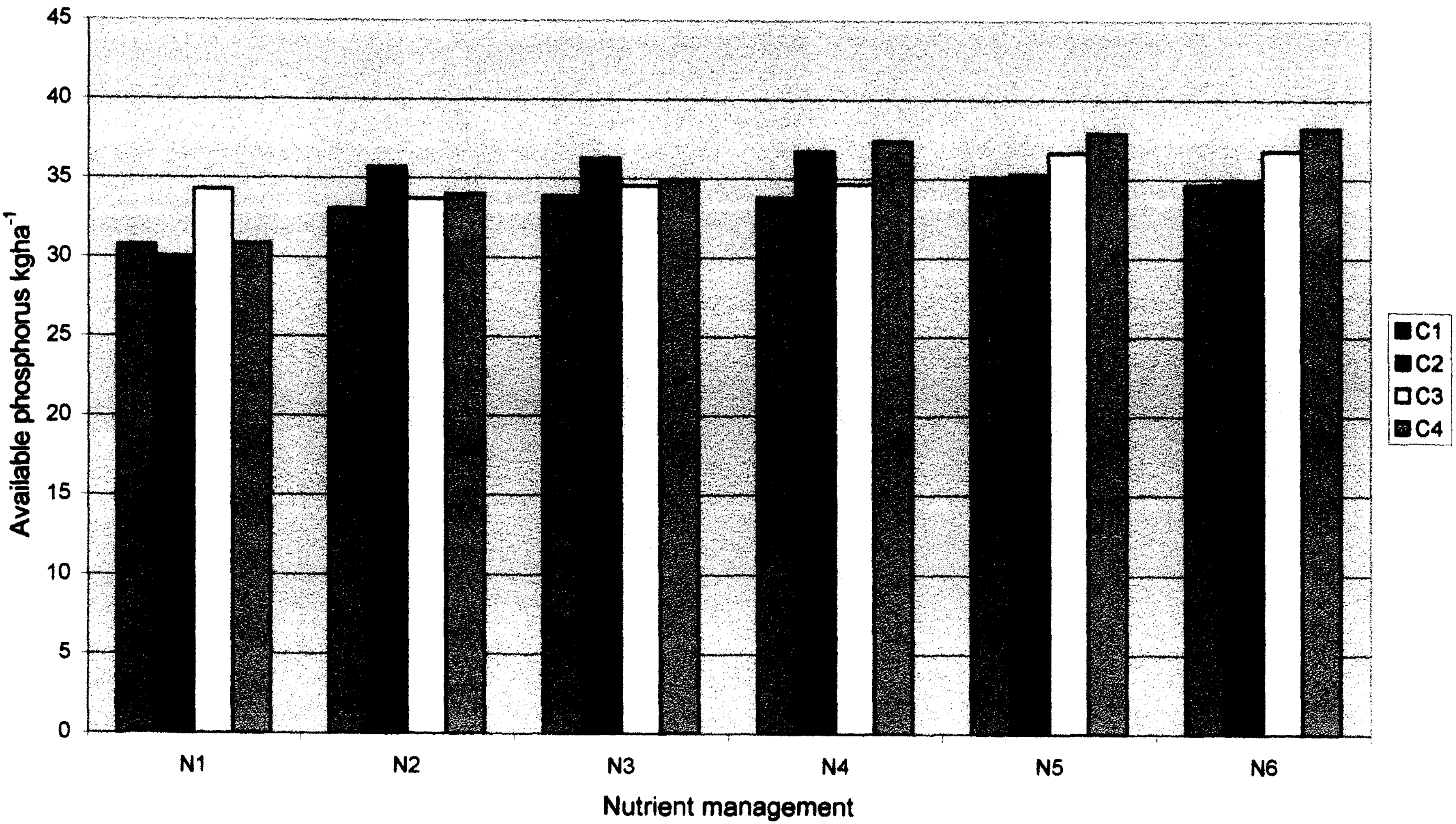
SEm C - 1.362 N - 0.857 CN - 1.639

CD - N - 2.582 CN - 4.672

parameter. All the other cropping systems were at par during the first year. In general, there was an increase in the available phosphorus content of soil over the initial status after sesamum, groundnut, cowpea and bhindi during both the years. The effect of cowpea and groundnut may partly be due to the "legume effect". The humus or humic substances produced by the legume residues and the mineralising and solubilising effect of soil microflora supported by the specific plants and the CO_2 produced by both the roots and associated micro-organisms may favour the solubilisation of phosphate. Soil contains adequate quantities of phosphorus which can be tapped by deep rooted crops and made use of in their growth (Raheja, 1966). This unique behavior of legume crops would have been responsible for the increase in available phosphorus after groundnut and cowpea crops. Similar results have been reported by Sasidhar (1978), Singh and Sandhu (1980), Sharma *et al*. (1987) and Singh *et al*. (1996b). The increase in the available phosphorus content after bhindi and sesamum may be attributed to the application of farmyard manure to these crops. Increase in available phosphorus content of the soil through the addition of organic manures have been reported by Sharma *et al*. (1987), Badanur *et al*. (1990), Sharma and Mittra (1991), Padmaja *et al*. (1993) and Madhu *et al*. (1996).

N_1 recorded lower values for available phosphorus when compared with the other treatments during both the years.

Fig.10 Available phosphorus content in the soil in $kgha^{-1}$
(Mean over the two years)



This may be due to the sub-optimal doses of organic manures and fertilisers applied in this treatment. Application of organic manures along with optimal NPK dose have been reported to increase the available phosphorus content of the soil (Biswas and Benbi, 1989; Nambiar and Abrol, 1989; Nambiar, 1994). This may be the reason for the increase in the available phosphorus content of the soil in the treatments N_2 to N_6.

The perusal of data on the effect of nutrient management over the cropping systems showed that in the cropping system C_1, the treatment N_5 recorded the maximum available phosphorus. However it was observed to be more or less similar to the other treatments. In C_2, the treatment N_4 recorded the maximum value for available phosphorus. N_4, N_6, N_6, N_2 and N_3 were at par. In C_3, although N_5 recorded the maximum available phosphorus, considerable difference was not observed between N_5 and the other treatments. The treatment N_6 recorded the maximum available phosphorus content in C_4. But considerable difference could not be observed between N_6 and the other treatments.

4.8.2.6 Available potassium (kg ha^{-1})

The results on the available potassium content of the soil as influenced by cropping systems and nutrient management are presented in Tables 50a and 50b and graphically in Fig. 11.

Table No. 50 Effect of cropping systems and nutrient management on the available potassium content of the soil (kg ha^{-1})

Table No. 50a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	25.71	60.10	66.89	72.65	92.20	92.70	68.38
C2	33.23	68.17	57.48	68.63	83.04	77.07	64.60
C3	31.23	47.13	50.70	50.63	51.71	54.03	47.57
C4	21.33	56.71	44.24	64.05	50.60	48.13	47.51
Mean	27.87	58.02	54.83	63.99	69.39	67.98	

SEm C - 6.663 N - 4.776 CN - 9.741

CD - N - 14.393 -

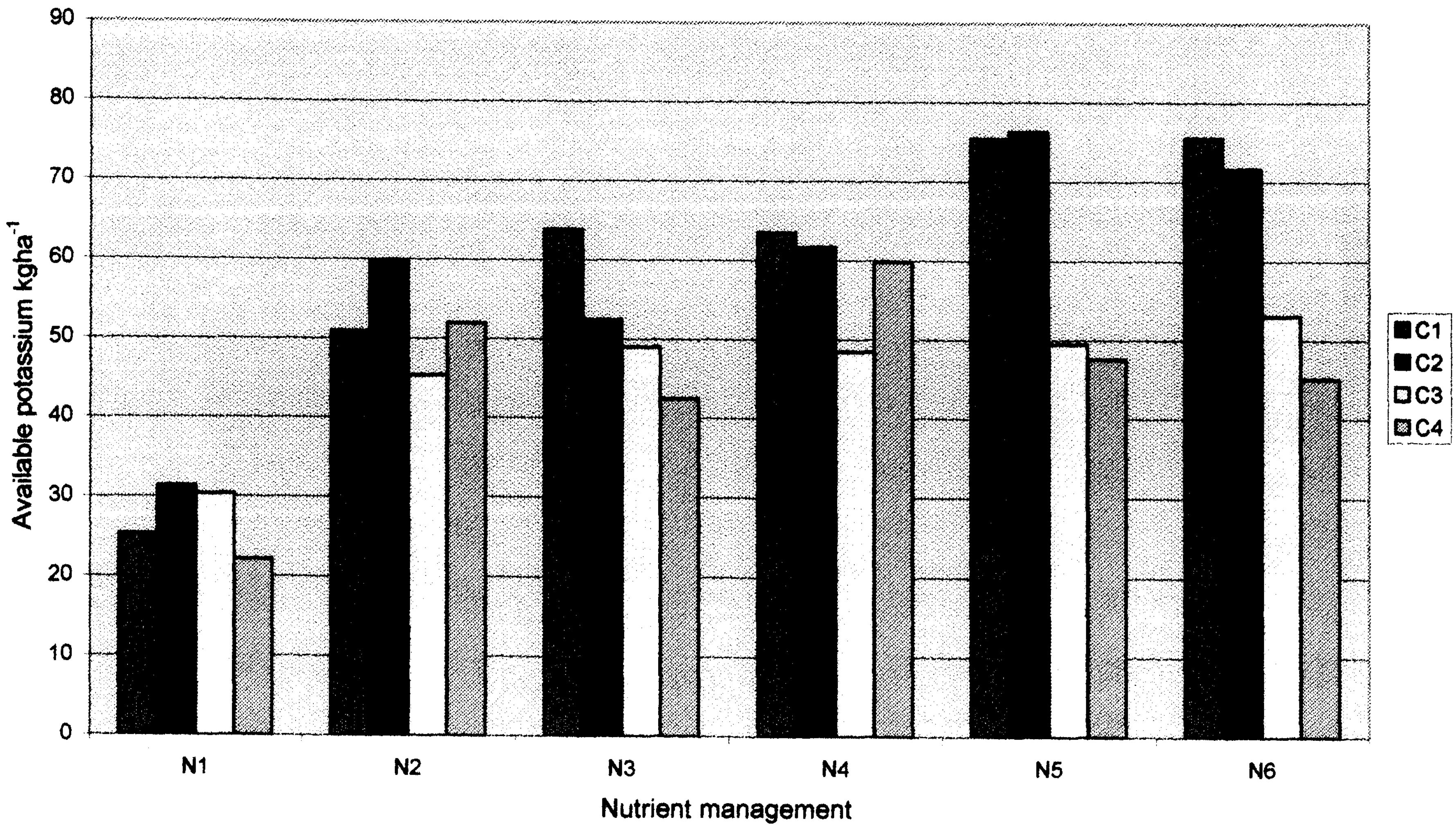
Table No. 50b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	24.96	41.59	60.72	54.29	58.62	58.29	49.74
C2	29.45	51.51	47.36	54.72	69.52	66.16	53.12
C3	29.51	43.55	47.25	46.21	47.26	52.07	44.31
C4	22.93	47.16	40.69	55.64	44.54	42.11	42.18
Mean	26.71	45.95	49.01	52.71	54.98	54.66	

SEm C - 3.061 N - 3.713 CN - 6.852

CD - N - 11.189 -

Fig.11 Available potassium content in soil in $kgha^{-1}$
(Mean over two years)



The available potassium content of the soil was influenced significantly, by the different nutrient management levels. The treatment N_1 recorded significantly low values for available potassium during both years.. N_5 recorded the maximum value for this parameter. N_5, N_6, N_4 and N_2 and N_6, N_4, N_2 and N_3 were at par during the first year. The treatments N_2, N_3, N_4, N_5 and N_6 were on a par during the second year. The integrated use of optimal NPK dose along with organic manures recorded higher availabile potassium status in soils (Nambiar, 1994; Madhu *et al*., 1996; Sheeba and Chellamuthu, 1996 b). In general, there was a decrease in the available potassium content of the soil in all the treatments, when compared to the initial status. This may be due to the fact that the total potassium uptake of the systems (Tables 54a and 54b) exceeded the total addition. Further, the soil of the experimental site was sandy loam in texture which might have contributed to the leaching loss of potassium. Palaniappan (1985) opined that in light soils or soils low in potassium, adequate K fertilisation is imperative for continued high productivity of the cropping systems.

4.9 Total dry matter production (kg ha^{-1})

The total dry matter production recorded by the different cropping systems under the influence of the varying nutrient management are presented in Tables 51a and 51b.

Table No. 51a Total dry matter production (kg ha^{-1}) as influenced by cropping systems and nutrient management - 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
Rice	5617	5724	5774	6765	7029	7668	
Rice	7282	10196	10926	11287	11280	10791	
Sesamum	1240	1370	1397	1548	1622	1756	
Total	14139	17290	18097	19600	19931	20215	18212
Rice	6240	5729	5697	6505	6674	7535	
Rice	6940	9329	9814	11079	12128	11481	
Groundnut	2675	3185	3095	3071	4037	4051	
Total	15855	18243	18606	20655	22839	23067	19878
Rice	5575	5618	5564	6779	7097	7389	
Rice	6146	8435	8682	10903	11708	11133	
Cowpea	1152	1618	1742	1881	1939	1909	
Total	12873	15671	15988	19563	20744	20431	17545
Rice	6249	5589	5563	6815	6747	7572	
Rice	6765	9724	10204	11183	12069	11427	
Bhindi	3884	4561	4676	4905	4941	5182	
Total	16898	19874	20443	22903	23757	24181	21343
Mean	14941	17770	18284	20680	21818	21974	

Table No. 51b Total dry matter production (kg ha^{-1}) as influenced by cropping systems and nutrient management - 1995-'96

Cropping systems	Nutrient levels						Mean
	N1	N2	N3	N4	N5	N6	
Rice	3923	4617	4868	5462	6234	6798	
Rice	7926	11493	11511	11601	11785	11994	
Sesamum	1255	1348	1408	1568	1608	1692	
Total	13104	17458	17787	18631	19627	20484	17849
Rice	6964	5708	6106	6353	7069	7632	
Rice	9027	11370	11499	13002	12881	12524	
Groundnut	2575	3074	3164	3402	4154	4145	
Total	18566	20152	20769	22757	24104	24301	21775
Rice	5919	4884	6036	6877	7471	7729	
Rice	7973	10619	10626	13295	12757	12178	
Cowpea	1006	1629	1765	1887	1954	1927	
Total	14898	17132	18427	22059	22182	21834	19422
Rice	6482	5271	5735	6582	6986	7621	
Rice	7724	11020	11003	12111	12414	11981	
Bhindi	3775	4439	4628	4561	4602	4575	
Total	17981	20730	21366	23254	24002	24177	21918
Mean	16137	18868	19587	21675	22479	22699	

The highest dry matter production was recorded by the rice-rice-bhindi (C_4) cropping system during the first year (21343 kg ha^{-1}) and during the second year (21918 kg ha^{-1}). Rice-rice-groundnut (C_2) ranked second. While rice-rice-sesamum (C_1) ranked third during the first year, rice-rice-cowpea (C_3) ranked third during the second year. The treatment N_6 recorded the maximum dry matter production in C_1, C_2 and C_4 during both the years. N_5 recorded the maximum dry matter production in the cropping system, C_3. Irrespective of cropping system, N_1 recorded the least total dry matter production. This clearly indicates the superiority of combined application of nutrient sources over the farmers' practice and the package of practices recommendation.

4.10 Total nutrient uptake by the cropping systems

4.10.1 Nitrogen uptake (kg ha^{-1})

The results on the total nitrogen uptake by the different cropping systems under the influence of the varying levels of nutrient management are presented in Tables 52a and 52b.

The rice-rice-groundnut (C_2) system recorded significantly high nitrogen uptake during the first year (238.99 kg ha^{-1}) and during the second year (255.41 kg ha^{-1}). Rice-rice-sesamum system (C_1) recorded the least nitrogen

Table No. 52 Total nitrogen uptake (kg ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 52a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	129.29	163.31	171.01	186.48	191.21	195.01	172.72
C2	186.13	215.74	222.40	244.62	280.26	284.82	238.99
C3	128.00	164.77	169.06	204.50	217.76	216.86	183.49
C4	135.46	161.96	169.38	192.22	201.89	206.57	177.91
Mean	144.72	176.44	182.96	206.95	222.78	225.81	

SEm C - 2.443 N - 3.405 CN - 3.551

CD C - 7.814 N - 10.262 CN - 10.118

Table No. 52b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	118.74	160.48	168.16	177.28	187.73	196.89	168.21
C2	203.29	235.18	242.92	264.93	291.18	294.99	255.41
C3	149.55	177.66	192.10	227.71	231.09	229.12	201.20
C4	146.47	172.15	177.38	196.59	204.51	209.56	184.44
Mean	154.51	186.37	195.13	216.63	228.63	232.64	

SEm C - 2.699 N - 2.997 CN - 3.807

CD C - 8.635 N - 9.032 CN - 10.848

uptake during both the years. Among the various summer crops, groundnut recorded the maximum uptake of nitrogen (Tables 31a and 31b) during both the years and the minimum nitrogen uptake was recorded by sesamum (Tables 31a and 31b). This may be the reason for the higher total nitrogen uptake in the rice-rice-groundnut system.

Among the different nutrient management levels, N_6 recorded the maximum nitrogen uptake and N_1, the minimum uptake during the first year and during the second year. However, N_6 and N_5 and N_3 and N_2 were at par. The increase in the total nitrogen uptake from N_1 to N_6 may be due to the higher dry matter production (Tables 51a and 51b).

4.10.2 Phosphorus uptake (kg ha^{-1})

The results on the total phosphorus uptake as influenced by cropping systems and nutrient management are presented in Tables 53a and 53b.

Rice-rice-bhindi (C_4) recorded the maximum uptake of phosphorus, during both the years. This may be attributed to the higher phosphorus uptake by bhindi crop (Tables 32a and 32b) during both the years. With regard to the impact of nutrient levels on the total phosphorous uptake it was observed that N_6 recorded the maximum uptake value and N_1 the minimum, during both the years. N_2 and N_3 and N_5 and N_6 were at par

Table No. 53 Total phosphorus uptake (kg ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 53a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	30.18	37.82	39.40	43.13	44.39	45.67	40.10
C2	31.79	36.87	38.45	42.80	47.69	48.70	41.05
C3	25.48	33.40	33.32	40.53	43.27	43.22	36.53
C4	33.46	40.80	41.95	47.23	49.30	50.82	43.93
Mean	30.23	37.22	38.28	43.42	46.16	47.10	

SEm C - 0.640 N - 0.625 CN - 0.690

CD C - 2.047 N - 1.883 CN - 1.966

Table No. 53b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	28.51	38.14	39.26	41.57	44.07	46.28	39.64
C2	38.19	40.01	43.09	48.59	51.00	51.86	45.46
C3	29.28	35.62	38.65	46.05	46.75	46.54	40.60
C4	36.40	42.80	44.52	48.94	50.57	51.48	45.79
Mean	33.27	39.14	41.38	46.29	48.10	49.04	

SEm C - 0.567 N - 0.653 CN - 0.712

CD C - 1.814 N - 1.969 CN - 2.028

during the first year. N_4 and N_5 and N_5 and N_6 were at par during the second year. The progressive increase in phosphorus uptake from N_1 to N_6 can be attributed to a similar increase in the total dry matter production from N_1 to N_6.

The influence of nutrient management over the cropping systems was observed to be significant during both the years. In C_1, N_6 and N_5, N_5 and N_4 and N_3 and N_2 were on a par. In C_2, C_3 and C_4, the treatments N_6 and N_5 and N_3 and N_2 were at par.

The results recorded in C_1 during the second year showed the treatments N_2 and N_3 to be at par. In C_2, the treatments N_5 and N_6 and N_1 and N_2 were at par. In C_3, the treatments N_4, N_5 and N_6 were at par. In C_4, the treatments N_6 and N_5, N_5 and N_4 and N_3 and N_2 were at par.

However, irrespective of the cropping system, N_6 recorded maximum and N_1 recorded minimum values for the total phosphorus uptake during both the years. Further, the phosphorus uptake was observed to increase progressively from N_1 to N_6 in all the cropping systems during both the years.

4.10.3 Potassium uptake (kg ha^{-1})

The results on the effect of cropping systems and nutrient management on the total potassium uptake are presented in Tables 54a and 54b.

Table No. 54 Total potassium uptake (kg ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 54a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	199.01	234.54	243.15	260.58	259.38	259.74	242.73
C2	210.74	230.14	235.63	261.34	282.81	279.68	250.06
C3	179.28	206.28	210.09	256.38	267.64	258.40	229.68
C4	212.48	237.59	245.82	272.08	285.09	280.21	255.54
Mean	200.38	227.14	233.67	262.60	273.73	269.51	

SEm C - 3.955 N - 4.247 CN - 4.501

CD C - 12.652 N - 12.798 CN - 12.826

Table No. 54b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	183.24	241.09	243.45	252.17	262.52	269.21	241.95
C2	254.40	261.71	268.10	291.80	303.27	300.32	279.93
C3	210.27	232.94	246.80	294.87	291.91	281.27	259.68
C4	256.54	255.91	262.33	281.18	291.64	286.74	272.39
Mean	226.11	247.91	255.17	280.00	287.39	284.39	

SEm C - 3.646 N - 5.214 CN - 8.036

CD C - 11.662 N - 15.713 CN - 22.901

The rice-rice-groundnut (C_2) system recorded the maximum value for potassium uptake during both the years. This can be attributed to the higher uptake of potassium by all the three component crops of the system (Tables 16a and 16b, Tables 29a and 29b, Tables 33a and 33b). As in the case of nitrogen uptake and phosphorus uptake, potassium uptake was also observed to be maximum with N_6 and minimum with N, during both the years.

The perusal of data on the effect of nutrient management over cropping systems showed that N_5 recorded the maximum value for potassium uptake and N_1 recorded the minimum value in all the cropping systems, except rice-rice-sesamum (C_1) where N_4 recorded the maximum potassium uptake during the first year and N_6 during the second year. Furthermore, in all the cropping systems the treatments N_2 and N_3 were observed to be at par during the first year. In addition to this in C_1 and C_3 the treatments N_4, N_5 and N_6 were at par during the first year. In C_2, the treatments N_5 and N_6 were at par. In C_4, the treatments N_5 and N_6 and N_6 and N_4 were at par.

During the second year, the treatments, N_4, N_5 and N_6 and N_2, N_3, N_4 and N_5 were at par in C_1, the treatments N_4, N_5 and N_6 and N_1, N_2 and N_3 were at par in C_2, the treatments, N_4, N_5 and N_6 and N_1 and N_2 and N_2 and N_3 were at par in C_3 and in C_4, the treatments N_4, N_5 and N_6, N_3 and N_4 and N_1, N_2 and N_3 were at par.

4.11 Balance sheet of nutrients

4.11.1 Balance sheet of nitrogen

The balance sheet of available nitrogen for the different cropping systems as influenced by the nutrient management are presented in Tables 55a and 55b and graphically in Fig.12 a and 12b.

The cropping systems, rice-rice-sesamum (C_1) and rice-rice-bhindi (C_4) recorded a loss in nitrogen, during both the years. However, there was gain in nitrogen in the cropping systems, rice-rice-cowpea (C_3) and rice-rice-groundnut (C_2), during both the years. The maximum gain was from rice-rice-groundnut during the first year and during the second year. The loss of nitrogen was to the tune of 29.70 kg ha^{-1} during the first year and 9.38 kg ha^{-1} during the second year for rice-rice-sesamum. Rice-rice-bhindi recorded a nitrogen loss of 12.55 kg ha^{-1} and 28.93 kg ha^{-1} during the first year and second year respectively. The gain in available nitrogen were 72.19 kg ha^{-1} and 48.32 kg ha^{-1} during the first year and 86.62 kg ha^{-1} and 22.70 kg ha^{-1} during the second year for the cropping systems, rice-rice-groundnut and rice-rice-cowpea respectively. Inclusion of legumes in intensive cropping systems have many ramifications. They are less demanding on soil resources and can fix atmospheric nitrogen in root nodules (Palaniappan, 1985). Similar results have been reported by Sasidhar (1978), Reddy *et al*. (1986) and Singh *et al*. (1996b).

Table No. 55a Balance sheet of available nitrogen in the soil as influenced by cropping systems and nutrient management (kg ha^{-1}) - 1994-'95

(a) Addition and removal of nitrogen (kg ha^{-1})

Cropping systems		Addition of nitrogen (kg ha^{-1})						Removal of nitrogen (kg ha^{-1})					
	Sources	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
C1	Soil contribution	172.31	172.31	172.31	172.31	172.31	172.31	129.29	163.31	171.00	186.48	191.21	195.01
	Manures and fertilisers	85.82	212.50	212.50	212.50	212.50	212.50						
	Total	258.13	384.81	384.81	384.81	384.81	384.81						
C2	Soil contribution	172.31	172.31	172.31	172.31	172.31	172.31	186.13	215.74	222.40	244.62	280.26	284.82
	Manures and fertilisers	85.82	182.00	182.00	182.00	182.00	182.00						
	Total	258.13	354.31	354.31	354.31	354.31	354.31						
C3	Soil contribution	172.31	172.31	172.31	172.31	172.31	172.31	128.00	164.77	169.06	204.50	217.76	216.86
	Manures and fertilisers	85.82	255.00	255.00	255.00	255.00	255.00						
	Total	258.13	427.31	427.31	427.31	427.31	427.31						
C4	Soil contribution	172.31	172.31	172.31	172.31	172.31	172.31	135.46	161.96	169.38	192.22	201.89	206.57
	Manures and fertilisers	118.62	257.00	257.00	257.00	257.00	257.00						
	Total	290.93	429.31	429.31	429.31	429.31	429.31						

(b) Net loss or gain in the available nitrogen content of the soil (kg ha^{-1}) - 1994-'95

Cropping systems	Computed balance of N computed (kg ha^{-1})						Actual balance of N Actual (kg ha^{-1})						Net loss or gain (kg ha^{-1})						Mean loss or gain (kg ha^{-1})
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	
C1	128.84	221.50	213.80	198.33	193.60	189.80	85.78	204.42	193.13	177.05	172.42	134.86	-43.06	-17.08	-20.67	-21.18	-21.18	-54.94	-29.70
C2	72.00	138.57	131.91	109.69	74.05	69.49	122.16	216.61	193.75	171.31	145.30	179.73	+50.16	+78.04	+61.84	+61.62	+71.25	+110.24	+72.19
C3	130.13	262.54	258.22	222.81	209.55	210.45	143.79	328.40	311.37	276.97	268.73	254.35	+13.66	+65.86	+53.15	+54.16	+59.18	+43.90	+48.32
C4	155.47	267.35	259.93	237.09	227.42	222.74	136.07	270.36	248.21	226.62	222.49	190.96	-19.40	+3.01	-11.72	-10.47	-4.93	-31.78	-12.55

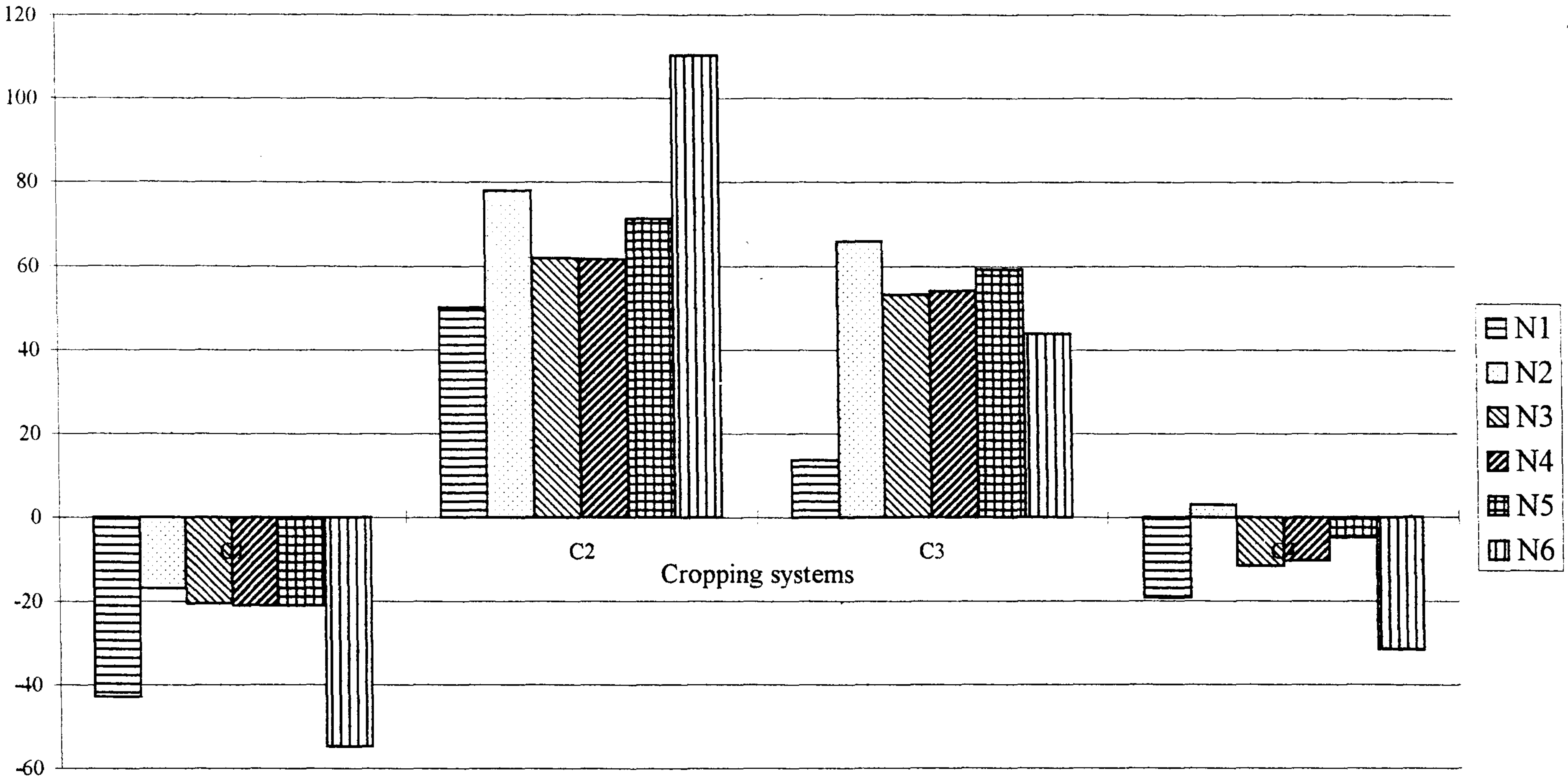


Fig.12a Net loss or gain in the available nitrogen content of the soil (kg ha^{-1}) - 1994 -'95

Table No. 55b Balance sheet of available nitrogen in the soil as influenced by cropping systems and nutrient management (kg ha^{-1}) - 1995-'96

(a) Addition and removal of nitrogen (kg ha^{-1}) - 1995-'96

Cropping systems	Sources	Addition of nitrogen (kg ha^{-1}) N1	N2	N3	N4	N5	N6	Removal of nitrogen (kg ha^{-1}) N1	N2	N3	N4	N5	N6
C1	Soil contribution	85.78	204.42	193.13	177.05	172.42	134.86	118.74	160.48	168.16	177.28	187.73	196.89
	Manures and fertilisers	85.82	212.50	212.50	212.50	212.50	212.50						
	Total	171.60	416.92	405.63	389.55	384.92	347.36						
C2	Soil contribution	122.16	216.61	193.75	171.31	145.30	179.73	203.29	235.18	242.92	264.93	291.18	294.99
	Manures and fertilisers	85.82	182.00	182.00	182.00	182.00	182.00						
	Total	207.98	398.61	375.75	353.31	327.30	361.73						
C3	Soil contribution	143.79	328.40	311.37	276.97	268.73	254.35	149.55	177.66	192.10	227.71	231.09	229.12
	Manures and fertilisers	85.82	255.00	255.00	255.00	255.00	255.00						
	Total	229.61	583.40	566.37	531.97	523.73	509.35						
C4	Soil contribution	136.07	270.36	248.21	226.62	222.49	190.96	146.47	172.15	177.38	196.59	204.51	209.56
	Manures and fertilisers	118.62	257.00	257.00	257.00	257.00	257.00						
	Total	254.69	527.36	505.21	483.62	479.49	447.96						

(b) Net loss or gain in the available nitrogen content of the soil (kg ha^{-1}) - 1995-'96

Cropping systems	Computed balance of N computed (kg ha^{-1})						Actual balance of N Actual (kg ha^{-1})						Net loss or gain (kg ha^{-1})						Mean loss or gain (kg ha^{-1})
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	
C1	52.86	256.44	237.47	212.27	197.19	150.47	89.94	259.05	220.88	192.07	179.21	109.30	+37.08	+2.61	-16.59	-20.20	+17.98	+41.17	-9.38
C2	4.69	163.43	132.83	88.38	36.12	66.74	173.11	236.95	201.76	162.09	118.07	120.07	+168.42	+73.42	+68.93	+73.71	+81.93	+53.33	+86.62
C3	80.06	405.74	374.27	304.26	292.64	280.23	105.54	416.85	391.40	331.48	324.58	303.55	+25.48	+11.11	+17.13	+27.22	+31.94	+23.32	+22.70
C4	108.22	355.21	327.83	287.00	274.98	238.40	108.67	334.71	303.44	250.93	238.18	182.19	+0.45	-20.50	-24.39	-36.10	-36.80	-56.21	-28.93

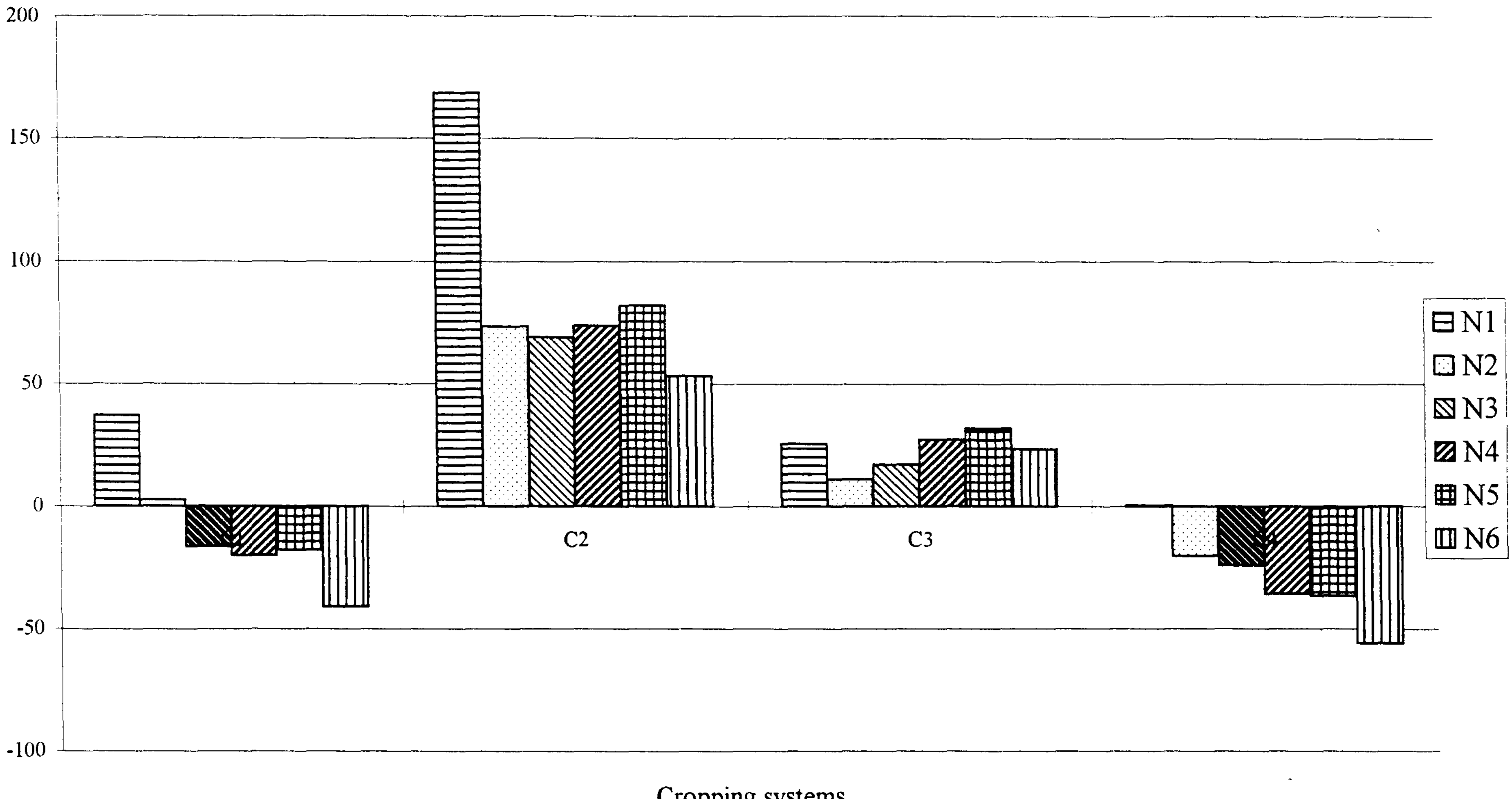


Fig.12b Net loss or gain in the available nitrogen content of the soil (kg ha^{-1}) - 1995 - '96

4.11.2 Balance sheet of phosphorus

The balance sheet of available phosphorus as influenced by cropping systems and nutrient management are presented in Tables 56a and 56b and graphically in Fig. 13a and 13b.

All the cropping systems studied recorded a negative balance for available phosphorus during the first year and during the second year. The magnitude of decrease ranged from 34.51 kg ha^{-1} (rice-rice-sesamum) to 74.98 kg ha^{-1} (rice-rice-cowpea) and from 19.16 kg ha^{-1} (rice-rice-sesamum) to 55.88 kg ha^{-1} (rice-rice-cowpea) during the first year and the second year respectively. The quantity of phosphorus added by fertilization was always greater than he quantity of crop removal, as indicated by positive balance for computed available phosphorus contents in the soil. Hence there may be a build up in the soil available phosphorus. But this may not be reflected in the actual available phosphorus as reported by Palaniappan (1985) since most of the added phosphorus is rapidly converted into insoluble forms. Similar results have been reported by Sadanandan and Mahapatra (1973) and Sasidhar (1978). The higher magnitude of decrease in available phosphorus in the cropping systems involving legumes may be attributed to the high phosphate requirement of legumes as reported by Singh and Prasad (1994).

Table No. 56a Balance sheet of available phosphorus in the soil as influenced by cropping systems and nutrient management (kg ha^{-1}) - 1994-'95

(a) Addition and removal of phosphorus (kg ha^{-1}) - 1994-'95

Cropping systems	Addition of phosphorus (kg ha^{-1})							Removal of phosphorus (kg ha^{-1})					
	Sources	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
C1	Soil contribution	17.57	17.57	17.57	17.57	17.57	17.57	30.18	37.82	39.40	43.13	44.39	45.67
	Manures and fertilisers	24.29	74.23	98.56	98.56	92.15	92.15						
	Total	41.86	91.80	116.13	116.13	109.72	109.72						
C2	Soil contribution	17.57	17.57	17.57	17.57	17.57	17.57	31.79	36.87	38.45	42.80	47.69	48.70
	Manures and fertilisers	24.29	92.57	116.90	116.90	110.49	110.49						
	Total	41.86	110.14	134.47	134.47	128.06	128.06						
C3	Soil contribution	17.57	17.57	17.57	17.57	17.57	17.57	25.48	33.40	33.32	40.53	43.27	43.22
	Manures and fertilisers	24.29	119.98	144.41	144.41	138.00	138.00						
	Total	41.86	137.55	161.98	161.98	155.57	155.57						
C4	Soil contribution	17.57	17.57	17.57	17.57	17.57	17.57	33.46	40.80	41.95	47.23	49.30	50.82
	Manures and fertilisers	40.01	89.41	113.84	113.84	107.43	107.43						
	Total	57.58	106.98	131.41	131.41	125.00	125.00						

(b) Net gain or loss in the available phosphorus content of the soil (kg ha^{-1}) - 1994-'95

Cropping systems	Computed balance of P (kg ha^{-1})						Actual balance of P (kg ha^{-1})						Net gain or loss (kg ha^{-1})						Mean loss or gain (kg ha^{-1})
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	
C1	11.68	53.98	76.73	73.00	65.33	64.05	17.80	23.66	25.03	24.94	23.22	22.99	+6.12	-30.32	-51.70	-48.06	-42.11	-41.06	-34.51
C2	10.07	73.27	96.02	91.67	80.37	79.36	21.84	25.31	27.09	25.94	23.10	22.51	+11.77	-47.96	-68.93	-65.73	-57.27	-56.85	-47.50
C3	16.38	104.15	128.66	121.45	112.30	112.35	23.15	23.62	25.10	25.30	23.79	24.48	+6.77	-80.53	-103.56	-96.15	-88.51	-87.87	-74.98
C4	24.12	66.18	89.46	84.18	75.70	74.18	21.84	24.77	23.32	25.30	24.79	25.46	-2.28	-41.41	-66.14	-58.88	-50.91	-48.72	-44.72

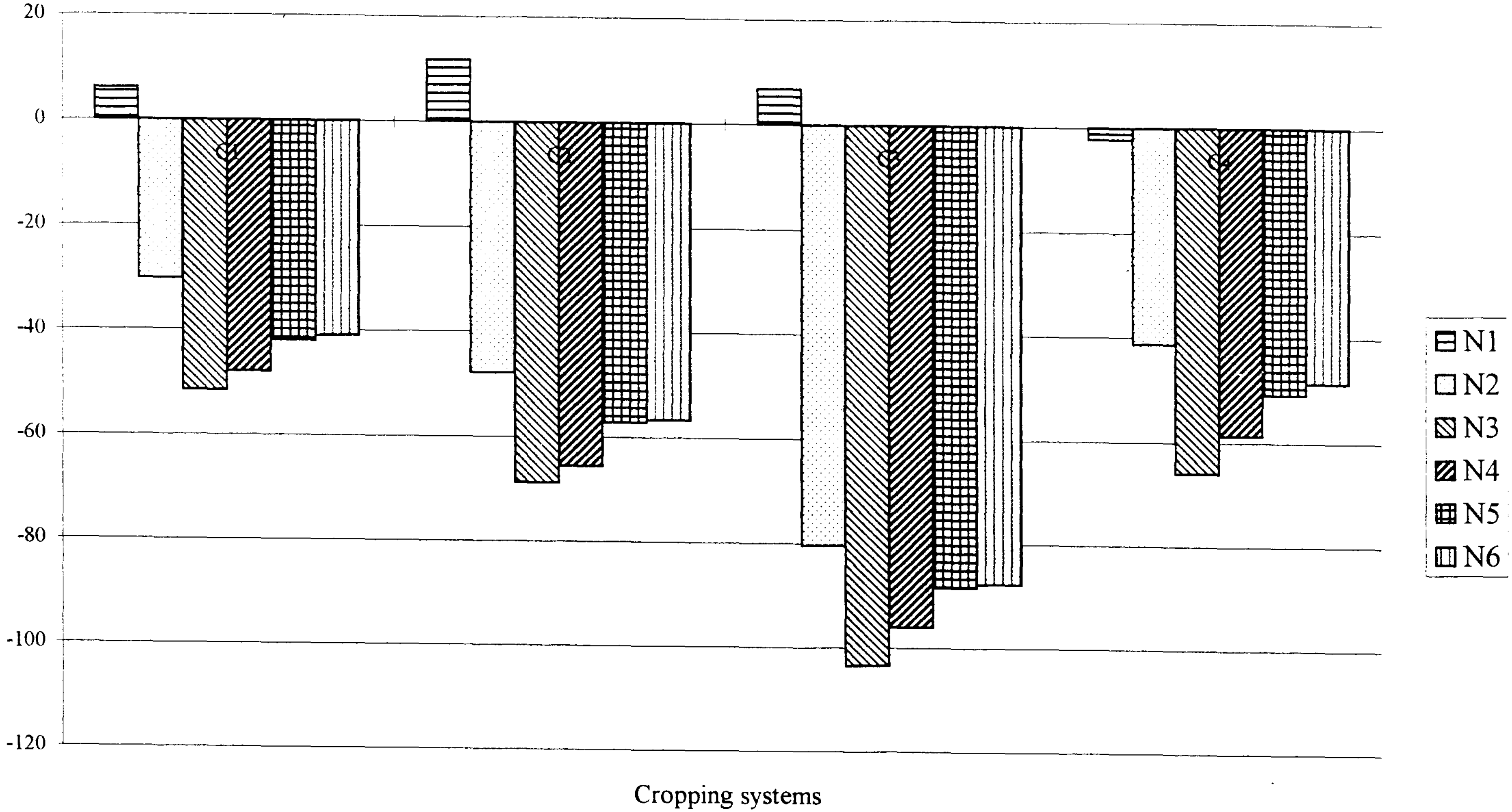


Fig.13a Net gain or loss in the available phosphorus content of the soil (kg ha^{-1}) - 1994 - '95

Table No. 56b Balance sheet of available phosphorus in the soil as influenced by cropping systems and nutrient management (kg ha^{-1}) - 1995-'96

(a) Addition and removal of phosphorus (kg ha^{-1}) - 1995-'96

Cropping systems	Sources	Addition of phosphorus (kg ha^{-1})						Removal of phosphorus (kg ha^{-1})					
		N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
C1	Soil contribution	17.80	23.66	25.03	24.94	23.22	22.99	28.51	38.14	39.26	41.57	44.07	46.28
	Manures and fertilisers	24.29	74.23	98.56	98.56	92.15	92.15						
	Total	42.09	97.89	123.59	123.50	115.37	115.14						
C2	Soil contribution	21.84	25.31	27.09	25.94	23.10	22.51	38.19	40.01	43.09	48.59	51.00	51.86
	Manures and fertilisers	24.29	92.57	116.90	116.90	110.49	110.49						
	Total	46.13	117.88	143.99	142.84	133.59	133.00						
C3	Soil contribution	23.15	23.62	25.10	25.30	23.79	24.48	29.98	35.62	38.65	46.05	46.75	46.54
	Manures and fertilisers	24.29	119.98	144.41	144.41	138.00	138.00						
	Total	47.44	143.60	169.51	169.71	161.79	162.48						
C4	Soil contribution	21.84	24.77	23.32	25.30	24.79	25.46	36.40	42.80	44.52	48.94	50.57	51.48
	Manures and fertilisers	40.01	89.41	113.84	113.84	107.43	107.43						
	Total	61.85	114.18	137.16	139.14	132.22	132.89						

(b) Net gain or loss in the available phosphorus content of the soil (kg ha^{-1}) - 1995-'96

Cropping systems	Computed balance of P (kg ha^{-1})						Actual balance of P (kg ha^{-1})						Net gain or loss (kg ha^{-1})						Mean loss or gain (kg ha^{-1})
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	
C1	13.58	59.75	84.33	81.93	71.30	68.86	43.67	42.43	42.70	42.61	47.00	46.33	+30.09	-17.32	-41.63	-39.32	-24.30	-22.53	-19.16
C2	7.94	77.87	100.90	94.25	82.59	81.14	38.20	46.08	45.40	47.44	47.43	47.41	+30.26	-31.79	-55.50	-46.81	-35.16	-33.73	-28.79
C3	17.46	107.98	130.86	123.66	115.04	115.94	45.34	43.78	43.98	44.02	49.51	49.05	+27.88	-64.20	-86.88	-79.64	-65.53	-66.89	-55.88
C4	25.45	71.38	92.64	90.20	81.65	81.41	39.85	43.21	46.35	49.41	50.94	50.95	+14.40	-28.17	-46.29	-40.79	-30.71	-30.46	-27.00

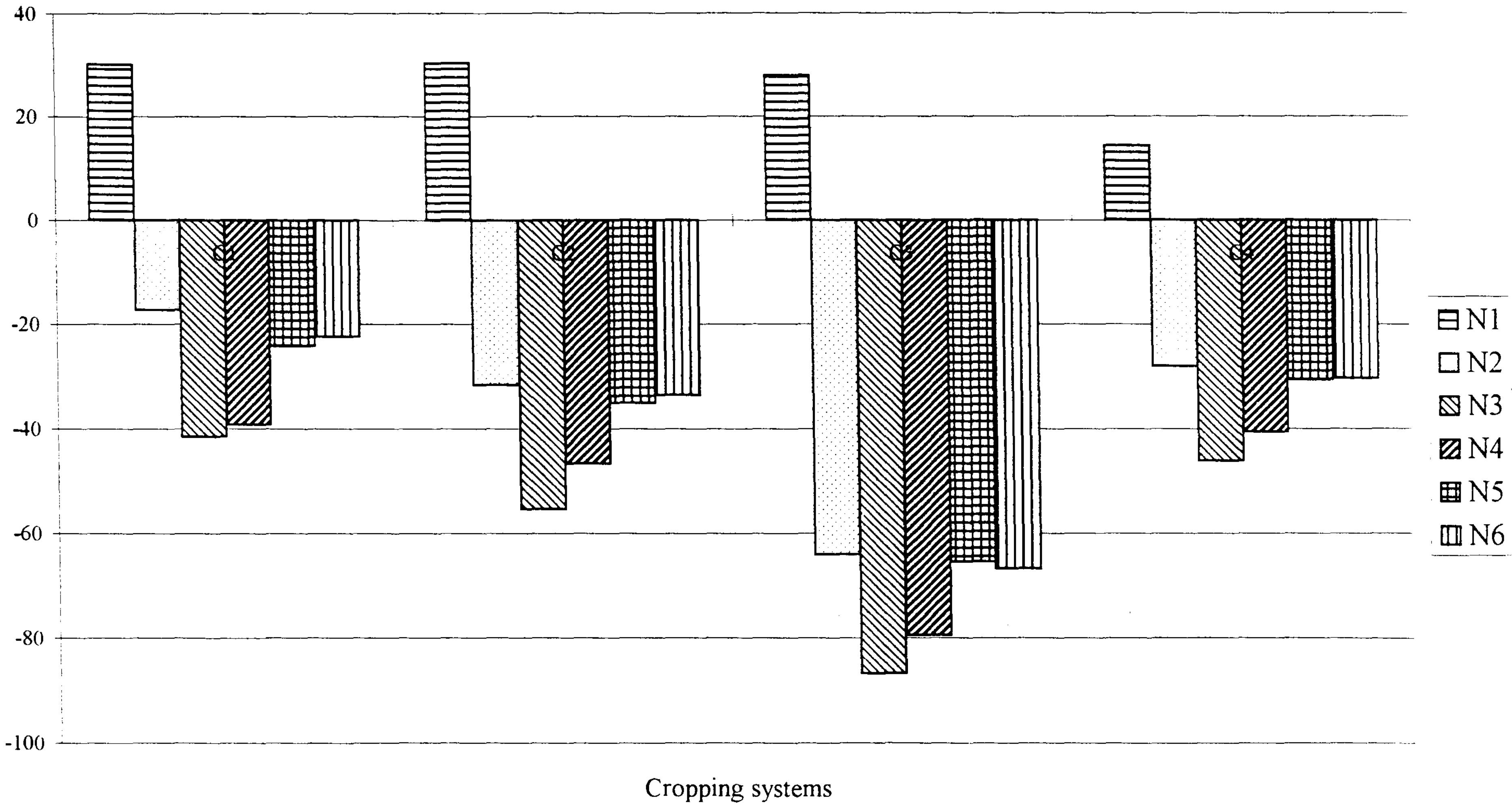


Fig.13b Net gain or loss in the available phosphorus content of the soil (kg ha^{-1}) - 1995- ' 96

The perusal of data on the effect of nutrient levels over the cropping systems indicated a positive balance for available phosphorus in the treatment N_1 during the first year (except in rice-rice-bhindi which recorded a very small negative balance) and during the second year. This may be due to the lower total uptake of phosphorus in N_1 (Tables 53a and 53b).

4.11.3 Balance sheet of potassium

Tables 57a and 57b and Fig. 14a and 14b present the results on the balance sheet of available potassium in the soil as influenced by cropping systems and nutrient management.

The balance sheet of available potassium in the soil recorded considerable gains during both the years. It was observed that the total uptake of potassium by the cropping systems exceeded the quantity added through the application of manures and fertilisers. The increase in the available potassium in excess of what had been applied through manures and fertilisers presumably came mostly from the non-exchangeable form in soil. The dynamic equilibrium existing among the various forms of soil potassium aids in the slow replenishment of available potassium by release from other forms of soil potassium, once the available potassium gets depleted (Palaniappan, 1985). This may be the reason why there was hardly any noticeable impact on soil available potassium

Table No. 57a Balance sheet of available potassium in the soil as influenced by cropping systems and nutrient management (kg ha^{-1}) - 1994-'95

(a) Addition and removal of potassium (kg ha^{-1}) - 1994-'95

Cropping systems	Sources	Addition of potassium (kg ha^{-1})						Removal of potassium (kg ha^{-1})					
		N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
C1	Soil contribution	62.14	62.14	62.14	62.14	62.14	62.14	199.01	234.54	243.15	260.58	259.38	259.74
	Manures and fertilisers	56.70	109.20	127.80	127.80	151.40	151.40						
	Total	118.84	171.34	189.94	189.94	213.54	213.54						
C2	Soil contribution	62.14	62.14	62.14	62.14	62.14	62.14	210.74	230.14	235.63	261.34	282.81	279.68
	Manures and fertilisers	56.70	140.70	159.30	159.30	182.90	182.90						
	Total	118.84	202.84	221.44	221.44	245.04	245.04						
C3	Soil contribution	62.14	62.14	62.14	62.14	62.14	62.14	179.28	206.28	210.09	256.38	267.64	258.40
	Manures and fertilisers	56.70	122.50	141.10	141.10	164.70	164.70						
	Total	118.84	184.64	203.14	203.14	226.84	226.84						
C4	Soil contribution	62.14	62.14	62.14	62.14	62.14	62.14	212.48	237.59	245.82	272.08	285.09	280.21
	Manures and fertilisers	68.70	119.00	137.60	137.60	161.20	161.20						
	Total	130.84	181.14	199.74	199.74	223.34	223.34						

(b) Net gain or loss in the available potassium content of the soil (kg ha^{-1}) - 1994-'95

Cropping systems	Computed balance of K (kg ha^{-1})						Actual balance of K (kg ha^{-1})						Net gain or loss (kg ha^{-1})						Mean loss or gain (kg ha^{-1})
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	
C1	-80.17	-63.20	-53.21	-70.64	-45.84	-46.20	25.71	60.10	66.89	72.65	90.20	92.70	+105.88	-123.30	-120.10	-143.29	-138.04	-138.90	+128.25
C2	-91.90	-3.44	+11.35	-34.94	-22.60	-13.36	33.23	68.17	57.48	68.63	83.04	77.07	+125.13	+71.61	+46.13	+103.57	+105.64	+90.43	+90.42
C3	-60.44	-21.64	-6.95	-53.24	-40.80	-31.56	31.23	47.13	50.70	50.63	51.71	54.03	+91.67	+68.77	+57.65	+103.87	+92.51	+85.89	+83.34
C4	-81.64	-56.45	-46.08	-72.34	-61.75	-56.87	21.33	56.71	44.24	64.05	50.60	48.13	+102.97	+113.16	+90.32	+136.39	+112.35	+105.00	+110.03

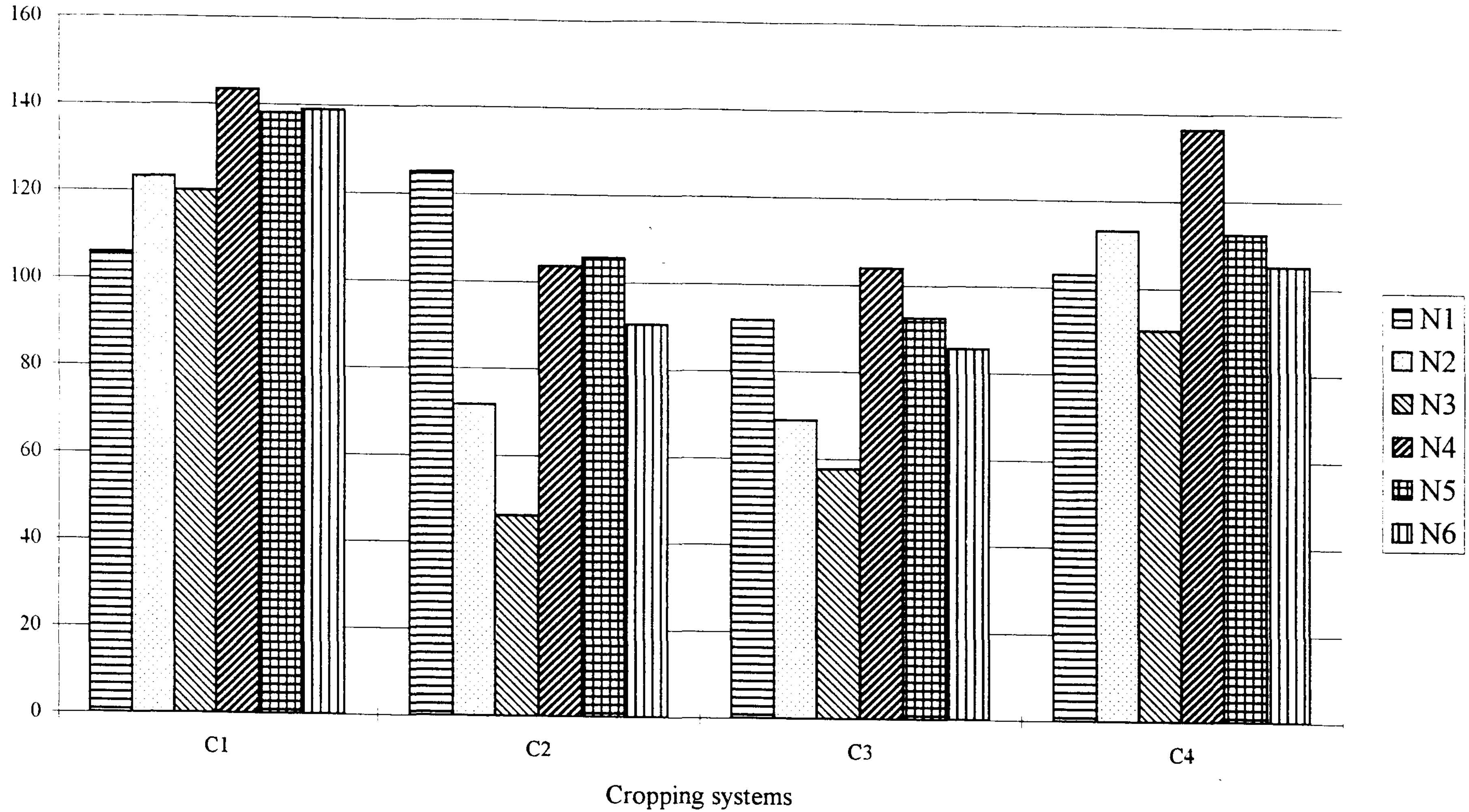


Fig.14a Net gain or loss in the available potassium content of the soil (kg ha^{-1}) - 1994 - '95

Table No. 57b Balance sheet of available potassium in the soil as influenced by cropping systems and nutrient management (kg ha^{-1}) - 1995-'96

(a) Addition and removal of potassium (kg ha^{-1}) - 1995-'96

Cropping systems	Addition of potassium (kg ha^{-1})							Removal of potassium (kg ha^{-1})					
	Sources	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
C1	Soil contribution	25.71	60.10	66.89	72.65	92.20	92.70	183.24	241.09	243.45	252.17	262.52	269.21
	Manures and fertilisers	56.70	109.20	127.80	127.80	151.40	151.40						
	Total	82.41	169.30	194.69	200.45	243.60	244.10						
C2	Soil contribution	33.23	68.17	57.48	68.63	83.04	77.07	254.40	261.71	268.10	291.80	303.27	300.32
	Manures and fertilisers	56.70	140.70	159.30	159.30	182.90	182.90						
	Total	89.93	208.87	216.78	227.93	265.94	259.97						
C3	Soil contribution	31.23	47.13	50.70	50.63	51.71	54.03	210.27	232.94	246.80	294.87	291.91	281.27
	Manures and fertilisers	56.70	122.50	141.10	141.10	164.70	164.70						
	Total	87.93	169.63	191.80	191.73	216.41	218.73						
C4	Soil contribution	21.33	56.71	44.24	64.05	50.60	48.13	256.54	255.91	262.33	281.18	291.64	286.74
	Manures and fertilisers	68.70	119.00	137.60	137.60	161.20	161.20						
	Total	90.03	175.71	181.84	201.65	211.80	209.33						

(b) Net gain or loss in the available potassium content of the soil (kg ha^{-1}) - 1995-'96

Cropping systems	Computed balance of K (kg ha^{-1})						Actual balance of K (kg ha^{-1})						Net gain or loss (kg ha^{-1})						Mean loss or gain (kg ha^{-1})
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	
C1	-100.83	-71.79	-48.76	-51.72	-18.92	-25.11	24.96	41.59	60.72	54.29	58.62	58.29	+125.79	+113.38	+109.48	+106.01	+77.54	+83.40	+102.60
C2	-164.47	-52.84	-51.32	-63.87	-37.33	-40.35	29.45	51.51	47.36	54.72	69.52	66.16	+193.92	+104.35	+98.68	+118.59	+106.85	+106.51	+121.15
C3	-122.34	-63.31	-55.00	-103.14	-75.50	-62.54	29.51	43.55	47.25	46.21	47.26	52.07	+151.85	+106.86	+102.25	+149.35	+122.76	+114.61	+124.61
C4	-166.51	-80.20	-80.49	-79.53	-79.84	-77.41	22.93	47.16	40.69	55.64	44.54	42.11	+189.44	+127.36	+121.18	+135.17	+124.38	+119.52	+136.18

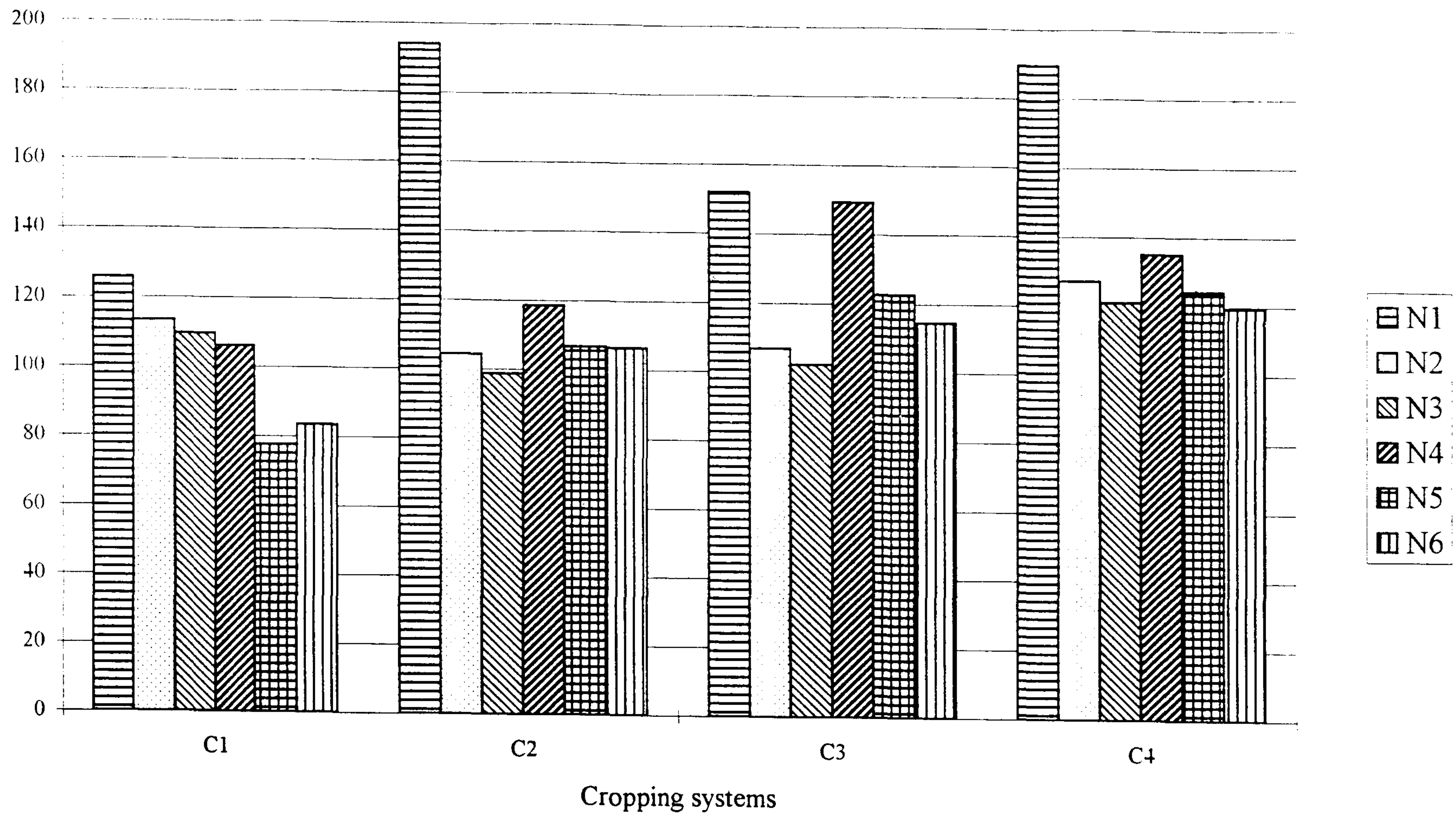


Fig.14b Net gain or loss of available potassium content of the soil (kg ha^{-1}) - 1995 - '96

even after intensive cropping although greater quantity of potassium was removed by the crops than added by fertilisation. Similar results were reported by Sasidhar (1978) and Deka and Singh (1984).

4.12 Economics of component crops in the cropping systems

4.12.1 First crop rice

4.12.1.1 Net returns (Rs. ha^{-1})

Tables 59a and 59b present the results on net returns of first crop rice under different nutrient management in different cropping systems.

The nutrient management alone were observed to have significant influence on the net returns during the first year. However both cropping systems and nutrient levels influenced the returns during the second year. The interaction effect of the treatments was significant during the second year. N_5 recorded the highest net returns during the first year. It was on a par with N_6, N_4 and N_2. The perusal of data on net returns recorded during the second year showed that the cropping system rice-rice-groundnut (C_2) recorded the maximum net returns for first crop rice. Among the various nutrient levels N_5 recorded the maximum value for net return and was observed to be on a par with N_6. Considering the effect of nutrient levels over the cropping systems, it was observed that.

Table No. 58 Effect of cropping systems and nutrient management on the gross returns (Rs. ha^{-1})

Table No. 58a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	17038.80	21021.50	20799.80	24404.30	25908.80	28755.10	22988.10
C2	18300.10	20420.80	20495.50	23098.40	24602.70	28363.00	22546.80
C3	16319.90	20200.60	20153.30	24173.60	26130.70	28099.60	22513.00
C4	18242.10	20035.50	20151.40	24263.10	25013.30	28797.50	22750.50
Mean	17475.30	20419.60	20400.00	23984.90	25413.90	28503.80	

SEm C - 604.105 N - 383.422 CN - 565.716

CD - N - 1155.514 -

Table No. 58b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	11931.90	15678.10	17521.80	19792.70	22612.30	24998.80	18755.90
C2	20546.30	20536.70	22244.60	23313.10	26171.10	29103.30	23652.50
C3	17777.30	17705.10	21939.40	25158.80	27592.70	29472.40	23274.30
C4	19022.80	18677.90	20698.40	24149.50	25785.30	29120.20	22907.40
Mean	17319.60	18147.00	20601.10	23103.50	25540.40	28173.70	

SEm C - 621.908 N - 365.137 CN - 595.998

CD C - 1989.451 N - 1100.409 CN - 1698.381

Table No. 59 Net returns (Rs. ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 59a First crop rice (1994-'95)

Cropping systems	N1	N2	N3	N4	N5	N6	Mean
	Nutrient management						
C1	1831.70	4691.70	3580.50	4569.10	5548.30	4869.30	4180.80
C2	3092.80	4091.00	3276.20	3263.30	4242.10	4477.20	3740.40
C3	1112.80	3870.80	2934.00	4338.40	5770.10	4213.80	3706.60
C4	3034.80	3705.70	2932.10	4427.90	4652.70	4911.70	3944.10
Mean	2268.00	4089.80	3180.70	4149.70	5053.30	4618.00	

SEm C - 604.108 N - 383.342 CN - 565.717

CD C - - N - 1155.514

Table No. 59b First crop rice (1995-'96)

Cropping systems	N1	N2	N3	N4	N5	N6	Mean
	Nutrient management						
C1	-3275.50	-651.80	302.40	-42.50	2251.70	1113.00	-50.40
C2	5339.00	4147.80	5025.30	3477.90	5810.60	5217.50	4836.40
C3	2569.90	1375.30	4720.10	5323.60	7232.10	5586.60	4467.90
C4	3815.50	2338.10	3479.10	4314.30	5424.80	5234.40	4101.00
Mean	2112.20	1802.40	3381.70	3268.30	5179.80	4287.90	

SEm C - 601.019 N - 364.102 CN - 596.554

CD C - 1992.630 N - 1097.291 CN - 1699.964

Table No. 60 Effect of cropping systems and nutrient management on the benefit cost ratio of rice

Table No. 60a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.14	1.27	1.21	1.23	1.27	1.20	1.22
C2	1.21	1.25	1.19	1.15	1.21	1.19	1.20
C3	1.07	1.24	1.17	1.22	1.28	1.18	1.19
C4	1.20	1.23	1.17	1.22	1.23	1.20	1.21
Mean	1.15	1.25	1.18	1.21	1.25	1.19	

SEm C - 0.035 N - 0.025 CN - 0.036

CD - - -

Table No. 60b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.78	0.96	1.02	1.00	1.11	1.05	0.99
C2	1.35	1.25	1.29	1.18	1.29	1.22	1.26
C3	1.16	1.14	1.27	1.27	1.36	1.23	1.24
C4	1.25	1.14	1.20	1.22	1.27	1.22	1.22
Mean	1.14	1.12	1.20	1.17	1.26	1.18	

SEm C - 0.036 N - 0.024 CN - 0.039

CD C - 0.115 N - 0.073 CN - 0.111

irrespective of cropping system, N_5 generated the highest returns. The reason for this is clearly evident from the data on cost of cultivation (Table 69) and gross returns (Tables 58a and 58b).

4.12.1.2 Benefit cost ratio (BCR)

Tables 60a and 60b present the results on the influence of cropping systems and nutrient management on the benefit cost ratio of first crop rice.

The effect of the treatments, cropping systems and nutrient management and their interaction were significant only during the second year. Rice-rice-groundnut (C_2) recorded the maximum BCR (1.26). It was on a par with C_3 and C_4. Among the various nutrient levels N_5 recorded significantly high BCR for first crop rice.

The perusal of data on the influence of nutrient levels over the cropping systems showed that N_5 recorded the maximum BCR in C_1, C_3 and C_4.

4.12.2 Second crop rice

4.12.2.1 Net returns (Rs. ha^{-1})

The results on the net returns of second crop rice as influenced by cropping systems and nutrient management are presented in Tables 62a and 62b.

Table No. 61 Effect of cropping systems and nutrient management on the gross returns (Rs. ha^{-1})

Table No. 61a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	20393.90	27998.40	31704.30	33450.40	34292.60	33942.20	30297.00
C2	19381.30	27210.20	28418.50	31692.10	36842.90	36066.60	29935.30
C3	17081.00	25964.40	26419.50	32317.30	35562.10	34808.70	28692.20
C4	18935.60	28211.90	29590.40	33180.90	36656.60	35859.80	30405.90
Mean	18948.00	27346.30	29033.20	33660.20	35838.60	35169.30	

SEm C - 586.764 N - 636.229 CN - 863.170

CD - N - 1917.396 CN - 2459.724

Table No. 61b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	20759.30	32977.10	33319.40	33795.70	35571.20	37319.50	32290.40
C2	24010.90	32334.30	32985.30	38083.70	38595.10	38433.70	34073.80
C3	21832.90	29827.30	30333.40	38200.90	37792.20	37120.90	32517.90
C4	21581.80	31488.00	31722.70	35687.80	37260.60	37106.80	32474.60
Mean	22046.20	31656.60	32090.20	36442.00	37304.80	37495.20	

SEm C - 519.574 N - 352.872 CN - 749.860

CD - N - 1063.445 CN - 2136.831

Table No. 62 Net returns (Rs. ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 62a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2131.60	2926.60	4550.20	3645.00	3329.00	2878.50	3243.50
C2	1118.80	2138.40	1264.40	1886.60	5879.30	5003.00	2881.80
C3	-1181.40	892.60	-734.60	2511.90	4598.40	3745.00	1638.70
C4	673.30	3140.10	2436.30	3375.50	5692.90	4796.10	3352.40
Mean	685.60	2274.50	1879.10	2854.80	4874.90	4105.70	

SEm C - 586.722 N - 636.289 CN - 863.149

CD - N - 1917.395 CN - 2459.663

Table No. 62b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2496.90	7905.30	6165.30	3990.30	4607.60	6255.90	5236.90
C2	5748.60	7262.50	5831.20	8278.30	7631.40	7370.00	7020.30
C3	3570.50	4755.60	3179.30	8395.50	6828.60	6057.20	5465.40
C4	3319.40	6416.20	4568.60	5882.40	6296.90	6043.10	5421.10
Mean	3783.90	6584.90	4936.10	6636.60	6341.10	6431.60	

SEm C - 519.546 N - 352.884 CN - 749.823

CD - N - 1063.482 CN - 2136.726

Nutrient management showed significant influence on the net returns of second crop rice during both the years. N_5 and N_4 recorded the maximum net returns during 1994-'95 (Rs. 4874.90 ha^{-1}) and during 1995-'96 (Rs.6636.60 ha^{-1}) respectively. However N_4 was on a par with N_5, N_2 and N_6 during the second year. N_5 and N_6 were at par during the first year.

The influence of nutrient management over the cropping systems was significant during the first year and second year. In C_1, considerable difference was not observed among the different treatments, during both the years. In C_2, N_5 recorded the maximum net returns during the first year and was on a par with N_6. During the second year, the treatments N_2, N_4, N_5 and N_6 were at par with N_4 giving the maximum net returns. In C_3, the treatment N_5 generated the maximum net returns during the first year which was at par with N_4 and N_6. The treatment N_4 recorded the maximum net returns during the second year and was on a par with N_5. In C_4, the maximum net returns was generated by N_5 during the first year and N_5 in turn was at par with N_6 and N_4. During the second year N_2 recorded the maximum net returns and was on a par with N_3, N_4, N_5 and N_6.

4.12.2.2 Benefit cost ratio (BCR)

Tables 63a and 63b present the results on the effect of cropping systems and nutrient management on the benefit cost ratio of second crop rice.

Table No. 63 Effect of cropping systems and nutrient management on the benefit cost ratio of rice

Table No. 63a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.12	1.12	1.17	1.12	1.11	1.09	1.12
C2	1.06	1.09	1.05	1.06	1.19	1.16	1.10
C3	0.94	1.04	0.98	1.08	1.15	1.12	1.05
C4	1.04	1.13	1.09	1.12	1.18	1.15	1.12
Mean	1.04	1.09	1.07	1.10	1.16	1.13	

SEm C - 0.025 N - 0.029 CN - 0.038

CD - - -

Table No. 63b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.14	1.32	1.23	1.14	1.15	1.20	1.19
C2	1.31	1.29	1.21	1.28	1.25	1.24	1.26
C3	1.20	1.19	1.12	1.28	1.22	1.20	1.20
C4	1.18	1.26	1.17	1.20	1.21	1.19	1.20
Mean	1.21	1.26	1.18	1.22	1.20	1.21	

SEm C - 0.022 N - 0.014 CN - 0.033

CD - N - 0.041 CN - 0.093

Cropping systems did not have any significant influence on the BCR of second crop rice during both the years. Nutrient management significantly influenced the BCR during the second year. The influence of nutrient management over cropping systems was also observed to be significant during the second year.

N_2 recorded the highest BCR and was observed to be on a par with N_4. When the treatment interaction was considered, considerable difference was not observed among the treatment combinations.

4.12.3 Third crop season

4.12.3.1 Net returns (Rs. ha^{-1})

The results on the influence of cropping systems and nutrient management the net returns of the third season (summer) crops recorded are presented in Tables 65a and 65b.

Cropping systems and nutrient management exerted significant influence on the net returns from the summer crops. The effect of nutrient management over the cropping systems was significant only during the second year.

While bhindi of the C_4 system recorded the maximum net returns during the first year, groundnut of the C_2 system recorded the maximum net returns during the second year.

Table No. 64 Effect of cropping systems and nutrient management on the gross returns (Rs. ha^{-1})

Table No. 64a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	7869.70	11399.90	11475.30	13839.60	14799.90	14939.00	12387.30
C2	13769.20	11393.50	15925.30	15790.00	20782.10	20874.90	17255.80
C3	9414.40	15214.50	16334.90	17644.70	18202.70	17929.90	15790.20
C4	21824.90	26724.60	26980.30	28761.60	28966.50	29686.10	27157.30
Mean	13219.50	17433.20	17678.90	19009.00	20687.80	20857.60	

SEm C - 820.652 N - 503.776 CN - 565.717

CD C - 2625.226 N - 1518.223 CN - 1612.091

Table No. 64b Third crop season (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	7556.70	11157.00	11885.00	13470.40	14070.80	13987.80	12021.30
C2	15743.80	19387.80	19960.00	21457.00	26204.50	26420.00	21528.90
C3	8369.80	14237.90	14579.60	14788.40	15289.00	15086.60	13725.20
C4	22451.40	26608.30	27770.20	27390.20	27587.80	27591.60	26566.60
Mean	13530.40	17847.70	18548.70	19276.50	20788.00	20771.50	

SEm C - 829.015 N - 554.341 CN - 935.480

CD C - 2651.977 N - 1670.611 CN - 2665.780

Table No. 65 Net returns (Rs. ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 65a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	-1160.30	688.30	763.60	3127.90	4088.30	4227.90	1996.00
C2	2579.20	3197.70	2729.50	2594.20	7586.20	7679.10	4394.30
C3	1039.40	1462.90	2483.20	3893.00	4451.10	4178.30	2934.70
C4	5210.90	8303.50	8559.10	10340.40	10545.30	11264.90	9037.30
Mean	1917.30	3413.10	3658.80	4988.90	6667.70	6837.60	

SEm C - 856.763 N - 483.039 CN - 756.649

CD C - 2740.742 N - 1455.730

Table No. 65b Third crop season (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	-1473.30	445.30	1173.40	2758.70	3359.10	3276.20	1589.90
C2	4553.80	6191.90	6764.20	8261.10	13008.70	13244.20	8667.30
C3	-0.30	486.30	828.00	1036.80	1537.40	1335.00	870.50
C4	5337.40	8187.10	9349.00	8969.00	9166.60	9170.40	8366.30
Mean	2104.40	3827.60	4528.60	5256.40	6768.00	6751.50	

SEm C - 829.022 N - 554.366 CN - 935.455

CD C - 2652.000 N - 1670.687 CN - 2665.709

Furthermore, C_2 and C_4 were on a par during the second year. Among the various nutrient levels N_6 generated the maximum net returns and was on a par with N_5 during the first year and on a par with N_5 and N_4 during the second year.

The perusal of data on the effect of nutrient management on the croppting systems showed that in C_1, the treatment N_6 recorded the maximum net returns and was on a par with N_8, N_4 and N_3. In C_2, the treatments N_6 and N_5 were at par with N_6 recording the maximum net returns. In C_3, although N_5 was observed to generate the maximum net returns, it was on a par with N_6, N_4, N_3 and N_2. Similarly the treatment N_6 recorded the maximum net returns in C_4 and was observed to be at par with N_5, N_4, N_3 and N_2.

4.12.3.2 Benefit cost ratio (BCR)

The results on the benefit cost ratio of the third season (summer) crops as influenced by cropping systems and nutrient management are presented in Tables 66a and 66b.

Cropping systems and nutrient management were observed to exert a significant influence on the BCR of the summer crops. Furthermore, the influence of nutrient management over cropping systems was also observed to be significant during both the years.

C_2 (groundnut) recorded the maximum BCR of 1.54 and 1.64 during the first year and second year respectively. C_4

Table No. 66 Effect of cropping systems and nutrient management on the benefit cost ratio of summer crops

Table No. 66a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.87	1.07	1.07	1.29	1.38	1.39	1.18
C2	1.23	1.46	1.42	1.41	1.86	1.87	1.54
C3	1.13	1.11	1.19	1.28	1.32	1.31	1.22
C4	1.28	1.45	1.46	1.56	1.57	1.61	1.49
Mean	1.13	1.27	1.29	1.39	1.53	1.54	

SEm C - 0.048 N - 0.037 CN - 0.056

CD C - 0.152 N - 0.112 CN - 0.159

Table No. 66b Third crop season (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.84	1.04	1.11	1.26	1.31	1.31	1.14
C2	1.23	1.47	1.51	1.63	1.98	2.00	1.64
C3	1.00	1.02	1.06	1.08	1.11	1.10	1.06
C4	1.32	1.45	1.51	1.49	1.50	1.50	1.50
Mean	1.09	1.24	1.30	1.36	1.48	1.48	

SEm C - 0.051 N - 0.037 CN - 0.075

CD C - 0.164 N - 0.112 CN - 0.213

(bhindi) ranked second in terms of BCR. Considering the effect of the nutrient levels, N_6 and N_5 recorded almost similar BCR during both the years.

The perusal of data on the effect of nutrient management on the cropping systems showed that the treatments N_6 and N_5 recorded almost similar BCR in all the cropping systems. During the first year N_6, N_5 and N_4 were at par in C_1; N_6 and N_5 were at par in C_2, N_6, N_5, N_4 and N_3 were at par in C_3 and in C_4, the treatments N_6, N_5, N_4, N_3 and N_2 were at par. During the second year, considerable difference was not observed among the effects of different nutrient levels on the BCR of the cropping systems, C_1 (sesamum), C_3 (cowpea) and C_4 (bhindi). In the case of C_2 (groundnut) the treatments N_6 and N_5 were at par and were observed to record significantly higher BCR.

4.13 Return per rupee invested on manures, fertilisers and biofertilisers (Rs.)

4.13.1 First crop rice

Tables 67a and 67b present the results on the influence of cropping systems and nutrient management on the return per rupee invested on manures, fertilisers and biofertilisers for first crop rice.

Cropping systems and nutrient management showed significant influence the return per rupee invested on manures,

Table No. 67 Effect of cropping systems and nutrient management on the return per rupee invested on manures, fertilisers and biofertilisers

Table No. 67a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.75	2.71	2.34	2.61	2.45	2.42	2.38
C2	2.54	2.49	2.25	2.22	2.14	2.33	2.33
C3	1.57	2.41	2.13	2.54	2.50	2.28	2.24
C4	2.50	2.35	2.15	2.57	2.23	2.77	2.43
Mean	2.09	2.49	2.22	2.49	2.33	2.45	

SEm C - 0.209 N - 0.212 CN - 0.264

CD - - -

Table No. 67b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	-1.08	0.78	1.28	1.25	1.67	1.59	0.92
C2	1.99	1.70	2.81	2.29	2.51	2.49	2.30
C3	1.78	1.50	2.71	2.83	2.84	2.58	2.37
C4	2.01	1.85	2.31	2.54	2.42	2.50	2.27
Mean	1.18	1.46	2.28	2.23	2.36	2.29	

SEm C - 0.153 N - 0.097 CN - 0.215

CD C - 0.491 N - 0.292 CN - 0.614

fertilisers and biofertilisers for first crop rice, during the second year only. C_3 recorded the maximum return per rupee invested. This treatment comprised rice after cowpea. Cowpea was supplied with farmyard manure @ 20t ha^{-1}. The residual effect of this may be the main reason for the higher BCR, in rice following cowpea in the sequence.

The perusal of data on the effect of nutrient management on the return per rupee invested, showed that N_5 recorded the maximum value for the parameter. Furthermore, N_5 was at par with N_6, N_4 and N_3. The treatments N_2 and N_1 were at par. These results are in conformity with those of Gaur and Singh (1982), Mahapatra *et al*. (1985) and Malik and Jaiswal (1993).

The influence of cropping systems x nutrient management was significant during the second year. N_5 recorded the maximum return per rupee invested on manures, fertilisers and biofertilisers for first crop rice in C_1 cropping system. However it was on a par with N_6, N_4 and N_3. Similar results were recorded in the C_3 cropping system also.

N_3 recorded the maximum return per rupee invested and was on a par with N_5, N_4 and N_6 in the system C_2. N_4 recorded the maximum value for this parameter in C_4.

Irrespective of the cropping system, it was observed that substituting a part of the chemical nitrogen applied, with bio-organic sources resulted in higher net returns. Similar results have been reported by Padmaja *et al*. (1993) and Puste *et al*. (1996).

4.13.2 Second crop rice

Tables 68a and 68b present the results on the influence of cropping systems and nutrient management on second crop rice with regard to the return per rupee invested on manures, fertilisers and biofertilisers.

Cropping systems showed no significant influence. On the other hand, nutrient management influenced the return per rupee invested on manures, fertilisers and biofertilisers significantly, both during the first year and second year. While N_5 recorded the maximum value during the first year, N_2 recorded the same during the second year. N_5, N_4, N_3, N_2 and N_6 were at par during the first year. N_2 and N_4 were at par during the second year. When we consider the effect of the treatments on the physico-chemical properties also. N_4 and N_5 are more suitable. However, it is to be noted here that the selection of a treatment depends upon the cost factor involved.

In the cropping system C_1, although N_2 recorded higher returns it was on a par with N_3. In C_2, the treatments N_4, N_2, N_3 and N_5 were at par with N_4 recording the maximum returns. In C_3, the maximum returns was recorded by N_4 and this treatment was significantly different from all the

Table No. 68 Effect of cropping systems and nutrient management on the return per rupee invested on manures, fertilisers and biofertilisers

Table No. 68a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.87	2.12	2.81	2.59	1.82	1.36	2.10
C2	1.33	1.82	1.65	1.81	2.72	1.88	1.87
C3	0.28	1.34	0.94	2.02	2.38	1.57	1.42
C4	1.26	2.21	2.06	2.30	2.67	1.83	2.05
Mean	1.19	1.87	1.86	2.18	2.40	1.66	

SEm C - 0.244 N - 0.246 CN - 0.354

CD - N - 0.742 CN - -

Table No. 68b Second crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.96	4.03	3.38	2.51	2.38	2.20	2.74
C2	3.13	3.78	3.26	3.92	3.18	2.48	3.29
C3	2.16	2.83	2.33	3.96	2.96	2.15	2.73
C4	2.12	3.46	2.82	3.13	2.82	2.15	2.75
Mean	2.34	3.53	2.95	3.38	2.83	2.24	

SEm C - 0.175 N - 0.122 CN - 0.260

CD - N - 0.367 CN - 0.741

others. In C_4, inspite of the treatment N_2 recording the maximum returns, it was on a par with N_4, N_5 and N_3.

4.14 Economics of cropping systems

4.14.1 Net returns of cropping systems (Rs. ha^{-1})

Results on the net returns of cropping systems as influenced by cropping systems and nutrient management during 1994-'95 and 1995-'96 are presented in Tables 70a and 70b respectively.

Cropping systems and nutrient management significantly influenced the net returns during the first year and second year. Their interaction effect was significant only during the second year.

Rice-rice-bhindi (C_4) recorded the maximum net returns during the first year. Rice-rice-groundnut (C_2) recorded the maximum net returns during the second year. However, C_2 and C_4 were on a par during the second year. Rao and Willey (1980) and Gupta and Rai (1990) reported that legumes offer special advantage to farmers and reduce the probability of low income.

Among the different nutrient management levels, N_6 generated the maximum net returns during both the years. While N_6 and N_5 were at par during the first year, N_6, N_5 and N_4 were at par during the second year.

Table No. 69 Cost of cultivation (Rs. ha^{-1})

Cropping systems	Nutrient management					
	N1	N2	N3	N4	N5	N6
Rice	15207.30	16329.80	17219.30	19835.10	20360.50	23885.80
Rice	18262.40	25071.80	27154.10	29805.40	30963.60	33163.70
Sesamum	9030.00	10711.70	10711.70	10711.70	10711.00	10711.70
Total	42499.70	52113.30	55085.10	60352.20	62035.80	67761.10
Rice	15207.30	16329.80	17219.30	19835.10	20360.50	23885.80
Rice	18262.40	25071.80	27154.10	29805.40	30963.60	33163.70
Groundnut	11190.00	13195.90	13195.90	13195.90	13195.90	13195.90
Total	44659.70	54597.50	57569.30	62836.40	64520.00	70245.30
Rice	15207.30	16329.80	17219.30	19835.10	20360.50	23885.80
Rice	18262.40	25071.80	27154.10	29805.40	30963.60	33163.70
Cowpea	8370.00	13751.60	13751.60	13751.60	13751.60	13751.60
Total	41839.70	55153.20	58125.00	63392.10	65075.70	70801.00
Rice	15207.30	16329.80	17219.30	19835.10	20360.50	23885.70
Rice	18262.40	25071.80	27154.10	29805.40	30963.60	33163.70
Bhindi	17114.00	18421.20	18421.20	18421.20	18421.20	18421.20
Total	50583.70	59822.80	62794.60	68061.70	69745.30	75470.60

Table No. 70 Net returns (Rs. ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 70a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	2802.90	8306.60	8894.30	11342.10	12965.50	11975.80	9381.20
C2	6790.80	9427.00	7270.10	7744.10	17707.60	17159.30	11016.50
C3	970.60	6226.30	4782.60	10743.30	14819.70	12137.10	8280.00
C4	8918.90	15149.30	13927.50	18143.80	20891.00	20972.70	16333.90
Mean	4870.80	9777.30	8718.63	11993.30	16596.00	15561.20	

SEm C - 1364.351 N - 1196.022 CN - 1332.015

CD C - 4364.490 N - 3604.438

Table No. 70a 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	-2251.80	7698.80	7641.10	6706.50	10218.40	10645.40	6776.30
C2	15641.40	17602.20	17620.60	20017.40	26450.70	25811.70	20524.00
C3	6140.20	6617.10	8727.30	14755.90	15598.10	12978.80	10802.90
C4	12472.30	16941.40	17396.70	19165.70	20888.30	20447.90	17885.40
Mean	8000.50	12214.90	12846.50	15161.40	18288.90	17470.90	

SEm C - 1215.373 N - 1092.333 CN - 1300.870

CD C - 3887.916 N - 3291.951 CN - 3707.011

N_6 recorded the maximum net returns in the rice-rice-sesamum (C_1) system. N_6 and N_5 were on a par.

The rice-rice-groundnut (C_2) system generated the maximum net returns with N_5, which was at par with N_6.

The maximum net returns for the cropping system, rice-rice-cowpea (C_3) was recorded by N_5. It was observed to be at par with N_4 and N_6.

Net returns generated in the rice-rice-bhindi (C_4) system was maximum with the treatment N_5. However, N_5 was on a par with N_6, N_4, N_3 and N_2.

4.14.2 Benefit cost ratio of cropping systems

Tables 71a and 71b and Fig. 15 present the results on the benefit cost ratio (BCR) of the cropping systems as a whole as influenced by cropping systems and nutrient management during 1994-'95 and 1995-'96 respectively.

The perusal of the data on the BCR exhibited significant influence for cropping systems and nutrient management, both during the first year and second year. The effect of nutrient management over cropping systems was observed to be significant only during the second year.

Rice-rice-groundnut (C_2) recorded the highest BCR during the first year (1.28) and during the second year (1.39). C_2 and C_4 (rice-rice-bhindi) were at par during the first year.

Table No. 71 Benefit cost ratio as influenced by cropping systems and nutrient management

Table No. 71a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	1.04	1.15	1.15	1.22	1.25	1.23	1.17
C2	1.17	1.27	1.22	1.21	1.42	1.41	1.28
C3	1.04	1.13	1.11	1.19	1.25	1.20	1.15
C4	1.17	1.27	1.24	1.30	1.33	1.32	1.27
Mean	1.11	1.20	1.18	1.23	1.31	1.29	

SEm C - 0.024 N - 0.025 CN - 0.026

CD C - 0.076 N - 0.075

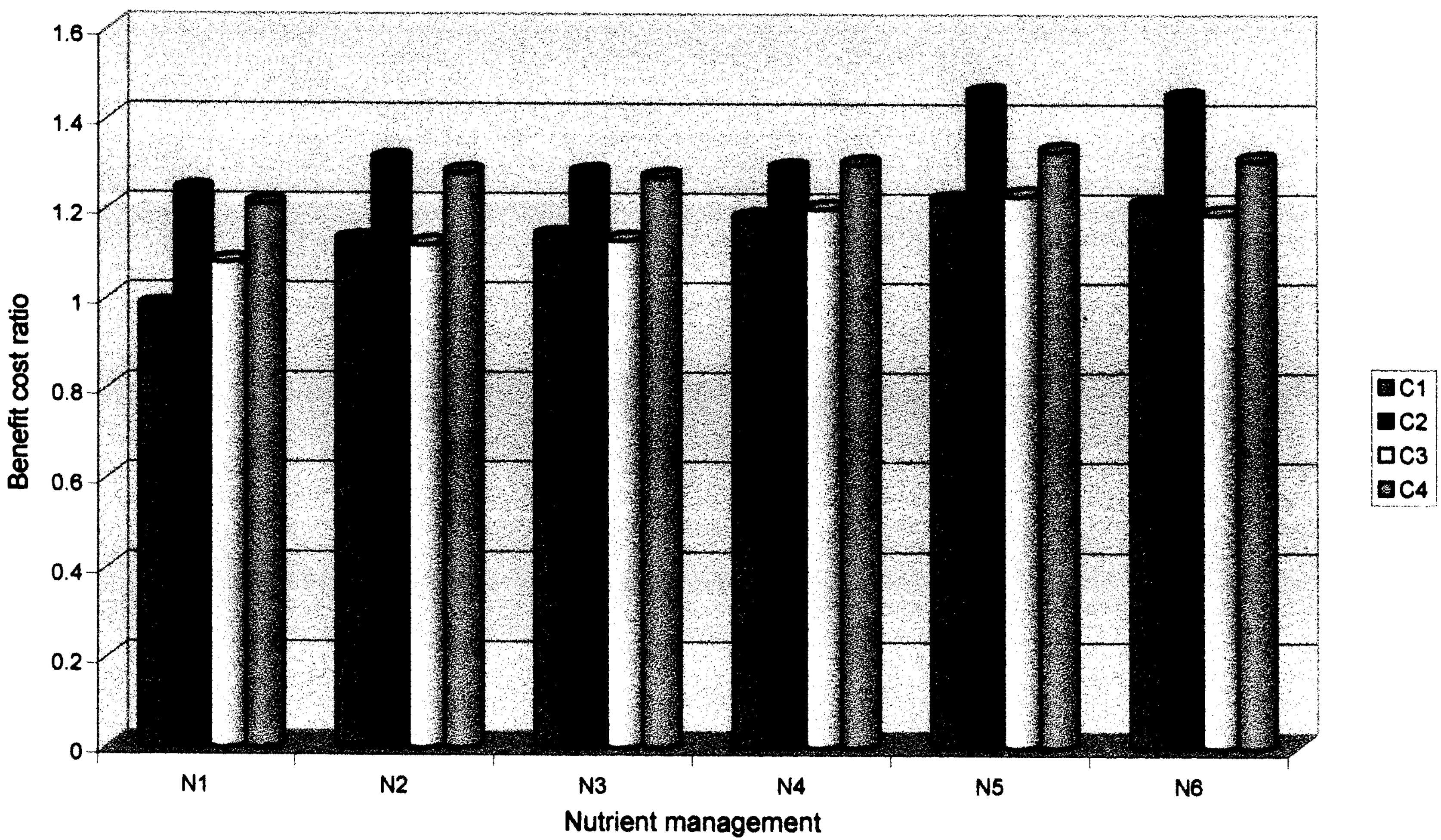
Table No. 71b 1995-'96

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	0.92	1.10	1.12	1.13	1.19	1.18	1.11
C2	1.30	1.34	1.34	1.36	1.50	1.49	1.39
C3	1.12	1.11	1.15	1.21	1.23	1.18	1.17
C4	1.25	1.28	1.29	1.30	1.32	1.30	1.29
Mean	1.15	1.21	1.22	1.25	1.31	1.29	

SEm C - 0.021 N - 0.021 CN - 0.027

CD C - 0.066 N - 0.066 CN - 0.078

Fig.15 Benefit cost ratio of cropping systems
(Mean over two years)



The nutrient level N_5 recorded the highest BCR of 1.29 each during the first year and second year respectively. While N_5 and N_6 were at par during the first year, N_5, N_6 and N_4 were at par during the second year.

In rice-rice-sesamum (C_1), N_5 recorded the maximum BCR. N_5, N_6, N_4 and N_3 were at par.

The treatment N_5 recorded the highest BCR in rice-rice-groundnut (C_2) system, and was on a par with N_6.

The highest BCR for rice-rice-cowpea system was recorded by the treatment N_5. However, it was at par with N_6 and N_4.

Although the treatment N_5 recorded the highest BCR in the rice-rice-bhindi (C_4) system, considerable difference in BCR was not observed between N_6 and the other treatments.

4.15 Cost and return analysis

The results on the cost and return analysis for the different cropping systems over the different nutrient management levels are presented in Tables 72a and 72b and graphically in Fig. 18a and 18b.

In the rice-rice-sesamum (C_1) cropping system, N_2 (package of practices recommendations) recorded the highest marginal benefit cost ratio (MBCR) of 1.57 during the first

Table No. 72a. Cost and return analysis of cropping systems (1994-'95)

Cropping systems		Nitrient management					
		N1	N2	N3	N4	N5	N6
C1	Added cost	-	9613.60	12585.40	17852.20	19536.10	25261.40
	Added returns	-	15117.60	18676.00	26391.00	29699.00	32334.00
	MBCR	-	1.57	1.48	1.51	1.52	1.28
C2	Added cost	-	9937.80	12909.60	18176.70	19860.30	25585.60
	Added returns	-	12574.00	13389.00	19130.00	30777.00	33854.00
	MBCR	-	1.27	1.04	1.05	1.55	1.32
C3	Added cost	-	13313.50	16285.30	21552.40	23236.00	28961.30
	Added returns	-	18565.00	20093.00	31321.00	37070.00	38023.00
	MBCR	-	1.39	1.23	1.45	1.60	1.31
C4	Added cost	-	9239.10	12210.90	17478.00	19161.60	24886.90
	Added returns	-	15969.00	17719.00	27203.00	31634.00	35340.00
	MBCR	-	1.73	1.45	1.56	1.65	1.42

Table No. 72b Cost and return analysis of cropping systems 1995-'96

Cropping systems		Nutrient management					
		N1	N2	N3	N4	N5	N6
C1	Added cost	-	9613.60	12585.40	17852.20	19536.10	25261.40
	Added returns	-	19564.00	21728.00	26811.00	32007.00	36058.00
	MBCR	-	2.04	1.73	1.50	1.64	1.43
C2	Added cost	-	9937.80	12909.60	18176.70	19860.30	25585.60
	Added returns	-	12230.00	14891.00	22553.00	30670.00	33656.00
	MBCR	-	1.23	1.15	1.24	1.54	1.32
C3	Added cost	-	13313.50	16285.30	21552.40	23236.00	28961.30
	Added returns	-	13541.00	18623.00	29918.00	32444.00	33450.00
	MBCR	-	1.02	1.14	1.39	1.40	1.15
C4	Added cost	-	9239.10	12120.90	17478.00	19161.60	24886.90
	Added returns	-	13709.00	16514.00	24172.00	25078.00	30763.00
	MBCR	-	1.48	1.35	1.38	1.31	1.24

year and 2.04 during the second year. N_5 and N_3 ranked second during the first year and second year respectively. N_6 recorded the least MBCR during both the years.

The MBCR of the rice-rice-groundnut (C_2) system was observed to be the highest at the nutrient level N_5 during both the years (1.55 and 1.54). N_3 recorded the least value on both occasions.

The maximum MBCR was recorded by the treatment N_5, in the rice-rice-cowpea (C_3) system during the first year (1.60) and during the second year (1.40).

The package of practices recommendations (N_2) recorded the highest value for the MBCR in the rice-rice-bhindi (C_4) system during the first year (1.73) and during the second year (1.48).

A general observation was that the inclusion of legumes (cowpea and groundnut) recorded the maximum MBCR at N_5. This may be attributed to the favourable influence of legume crops, which permitted the integrated nutrient management (N_5 substituting the one-fourth recommended nitrogen by farmyard manure and vermicompost) in the first crop rice and second crop rice. The higher yields recorded by the first crop rice and second crop rice raised after groundnut and cowpea together with the benefits of the integrated nutrient management level at N_5 may have contributed to the high MBCR.

4.16 Energy budgetting of cropping systems

4.16.1 Net output of energy (MJ ha^{-1})

4.16.1.1 First crop rice

The results on the net output of energy as influenced by cropping systems and nutrient management during 1994-'95 and 1995-'96 are presented in Tables 75a and 75b respectively.

Cropping systems were observed to influence the net output of energy of first crop rice significantly during the second year. Nutrient management exhibited significant effect on the net output of energy during both the years. The interaction effect was significant during the second year.

C_2 recorded the maximum net energy output and was at par with C_3 and C_4. The total biomass production was maximum in C_2. This may be the reason for the higher net energy output from C_2.

N_6 recorded the maximum net energy output during both the years. N_6 and N_5 were observed to be at par during the first year.

The perusal of data on the effect of nutrient management over the cropping systems (interaction) showed that N_6 generated the maximum net energy in all the cropping systems. In C_3, the treatmemts N_6 and N_5 were at par. Higher the total biomass produced, higher was the net energy recorded.

Table No. 73 Input of energy (MJ ha^{-1}) for the different cropping systems

Cropping systems	Nutrient management					
	N1	N2	N3	N4	N5	N6
Rice	9467	12270	12710	13619	12489	13398
Rice	11256	13741	14122	15031	13931	14840
Sesamum	4191	7678	7678	7678	7678	7678
Total	24914	33689	34510	36328	34098	35916
Rice	9467	12270	12710	13619	12489	13398
Rice	11256	13741	14122	15031	13931	14840
Groundnut	6885	18593	18593	18593	18593	18593
Total	27608	44604	45425	47243	45013	46831
Rice	9467	12270	12710	13619	12489	17398
Rice	11256	13741	14122	14031	13931	14840
Cowpea	4245	16490	16490	16490	16490	16490
Total	24968	42501	43322	45140	42910	44728
Rice	9467	12270	12710	13619	12489	13398
Rice	11256	13741	14122	15031	13931	14840
Bhindi	8194	11834	11834	11834	11834	11834
Total	28917	37845	38666	40484	38254	40072

Table No. 74 Gross output of engery (MJ ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 74a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	73944.3	76968.6	77893.0	91006.1	94903.8	103788.7	86417.4
C2	81820.3	77130.2	76658.2	76658.2	87373.7	90114.1	84378.0
C3	73082.3	75734.6	74939.1	91104.1	95812.8	100211.7	85147.4
C4	81891.7	75153.5	74932.3	91567.9	91167.8	102841.7	86259.1
Mean	77684.7	76246.7	76105.7	90262.9	92999.8	100003.3	

SEm C - 1806.251 N - 2228.818 CN - 3475.226

CD - N - 6716.964

Table No. 74b First crop rice (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	51657.3	61965.7	65504.5	73701.9	84024.9	91754.5	71434.8
C2	91374.3	76818.7	82302.8	85725.4	95503.3	103551.6	89212.7
C3	77825.0	65793.6	81333.2	92756.1	102350.1	104864.3	87487.0
C4	84997.3	70770.2	78728.2	88249.2	94054.2	101019.5	86925.9
Mean	76463.3	68837.0	76967.2	85249.2	94054.2	101019.5	

SEm C - 2450.767 N - 1440.306 CN - 2270.894

CD C - 7839.881 N - 4340.641 CN - 6471.299

Table No. 75 Net output of engery (MJ ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 75a First crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	64477.0	64698.8	65183.0	77387.3	82415.0	90390.5	74091.9
C2	70353.5	64860.3	63948.5	73754.5	77625.5	79773.3	72052.6
C3	63615.5	63464.8	62229.0	77485.0	83324.0	86813.8	72822.0
C4	72424.8	62883.3	62222.5	77949.0	78678.5	89443.8	73933.6
Mean	68217.7	63976.8	63395.80	76643.9	80510.8	86605.3	

SEm	C - 1805.915	N - 2228.512	CN - 3475.252
CD	-	N - 6716.041	-

Table No. 75b First crop rice (1995-96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	42190.5	49695.8	52794.8	60083.3	71536.0	78356.5	59109.4
C2	77321.8	64548.8	69593.0	72106.5	83014.5	90153.5	76123.0
C3	68358.3	53523.5	68623.3	79137.0	89861.3	91466.3	75161.6
C4	75530.3	58500.5	66018.3	75194.3	81849.3	90509.8	74600.4
Mean	65850.2	56567.1	64257.3	71630.3	81565.3	87621.5	

SEm	C - 2135.680	N - 1420.166	CN - 2114.994
CD	C - 6831.932	N - 4279.938	CN - 6026.970

4.16.1.2 **Second crop rice**

The results on the influence of cropping systems and nutrient management on the net output of energy of the second crop rice, during 1994-'95 and 1995-'96 are presented in Tables 77a and 77b respectively.

The different cropping systems had no significant influence on the net energy output of the second crop rice. However, the effect of nutrient levels and the effect of cropping systems x nutrient management were significant during both the years.

Among the different nutrient management levels, N_5 recorded the maximum net energy output during both the years. N_5 was observed to be on a par with N_6 during the first year and with N_6 and N_4 during the second year.

In C_1, the highest net energy output for the second crop rice was recorded by N_6, during the first year and during the second year.

The net energy output of the second crop rice in the C_2 cropping system was maximum with the treatment N_5 and during the first year and N_4 during the second year. N_4, N_5 and N_6 were at par during both the years.

The treatments N_5 and N_4 recorded the highest net energy output for second crop rice in the C_3 cropping system,

Table No. 76 Gross output of engery (MJ ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 76a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	94988.1	126276.2	143086.1	148181.2	148528.0	159079.0	136689.8
C2	90492.9	122241.0	128492.5	145461.3	159679.3	151838.6	133034.3
C3	80099.8	110463.2	113683.2	143142.5	154155.4	147098.8	124773.8
C4	88239.1	127347.9	133632.5	146833.0	158904.6	151051.6	134334.8
Mean	88455.0	121582.1	129723.6	145904.5	155316.9	152267.0	

SEm C - 3377.593 N - 3335.377 CN - 4849.156

CD - N - 10051.790

Table No. 76b Second crop rice (1995-96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	103288.0	150318.8	150701.8	152260.8	155044.2	158381.1	144999.1
C2	117480.4	148557.1	150398.4	170463.5	169322.4	165094.1	153552.6
C3	103738.7	138556.0	138904.0	173912.6	167466.3	160411.6	147164.7
C4	100727.7	144061.1	143993.2	158890.1	163211.4	158114.4	144833.0
Mean	106308.7	145373.0	145999.4	163881.7	163761.1	160500.3	

SEm C - 2534.391 N - 1879.175 CN - 3784.320

CD - N - 5663.249 CN - 10783.950

Table No. 77 Net output of engery (MJ ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 77a Second crop rice (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	83732.0	112535.0	128964.3	133150.0	134599.5	144239.0	122870.0
C2	56224.5	108500.3	114370.3	130430.3	145748.5	136998.5	123712.0
C3	68846.3	96722.5	99561.3	128111.5	140224.5	132258.5	110954.1
C4	76983.0	113607.0	119510.5	131802.0	144973.5	136211.5	120514.6
Mean	83946.4	107841.2	115601.6	130873.4	141386.5	137426.9	

SEm C - 3355.510 N - 3048.443 CN - 4807.986

CD - N - 9187.059 CN - 13701.030

Table No. 77b Second crop rice (1995-96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	92032.3	136577.8	136580.0	137229.8	141113.0	143540.8	131178.9
C2	79237.0	134816.0	136276.3	155432.5	155391.8	150254.3	135234.6
C3	92482.8	124814.5	124781.8	158881.5	153535.3	145571.8	133344.6
C4	89471.8	130319.8	129871.3	143859.0	149280.3	143274.5	131012.8
Mean	88305.9	131632.0	131877.3	148850.7	149830.1	145660.3	

SEm C - 2508.037 N - 2228.818 CN - 3860.049

CD - N - 6716.964 CN - 10999.750

during the first year and second year respectively. While N_5, N_6 and N_4 were at par during the first year, N_4 and N_5 and N_5 and N_6 were at par during the second year.

The second crop rice of the cropping system C_3 recorded the maximum net energy output with the treatment N_5 during both the years. N_4, N_5 and N_6 were on a par during the first year and during the second year.

Irrespective of the cropping system, the tretment N_1 recorded the least net energy output. These results are a clear indication of the superiority of integrated nutrient management practices over the conventional practices in improving the energy output of cropping systems.

4.16.1.3 Third crop season

Tables 79a and 79b present the results on the net output of energy by the third season (summer) crops as influenced by cropping systems and nutrient management during 1994-'95 and 1995-'96 respectively.

Cropping systems, nutrient management and their interaction influenced the net energy generated by the third season (summer) crops significantly during both the years.

The perusal of data on the effect of cropping systems showed that C_2 (groundnut) recorded the maximum net output of

Table No. 78 Gross output of engery (MJ ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 78a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	24033.7	27107.5	27647.9	30899.5	32437.4	34884.5	29501.8
C2	54572.7	64974.1	63145.8	62651.7	82367.4	82653.5	68394.2
C3	15092.2	21338.5	22977.4	24807.4	25575.6	25172.6	22493.9
C4	49779.4	59776.1	62471.3	64677.7	64860.3	68062.4	61602.8
Mean	3586940	43299.0	44058.1	45759.1	51310.2	52693.2	

SEm C - 1638.175 N - 1047.237 CN - 2040.230

CD C - 5242.166 N - 3156.045 CN - 5813.922

Table No. 78b Third crop season (1995-'96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	24249.5	26513.5	27939.0	31175.9	32013.5	33517.8	29234.9
C2	52670.2	62864.3	64719.8	69573.7	84967.5	84881.6	69946.2
C3	13262.3	21488.0	23034.1	24887.3	25765.3	25408.9	22307.6
C4	44660.6	59899.4	61734.6	61431.4	61581.1	61348.1	58442.5
Mean	33710.6	42691.3	44356.9	46767.1	51081.9	51289.1	

SEm C - 1980.825 N - 1368.032 CN - 2596.031

CD C - 6336.560 N - 4291.367 CN - 7397.755

Table No. 79 Net output of engery (MJ ha^{-1}) as influenced by cropping systems and nutrient management

Table No. 79a Third crop season (1994-'95)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	19830.3	19429.5	19969.8	23221.5	24759.0	27206.5	22402.8
C2	47687.5	46381.3	44552.8	44058.8	63774.3	64060.5	51752.5
C3	10847.3	4848.5	6487.5	8317.3	9085.8	8682.3	8044.8
C4	41585.0	47941.8	50627.5	52843.5	32110.3	37661.3	50375.4
Mean	29987.5	29650.3	30409.4	32110.3	37661.3	39044.4	

SEm C - 1639.015 N - 1047.351 CN - 2040.353

CD C - 5343.128 N - 3156.389 CN - 5814.271

Table No. 79b Third crop season (1995-96)

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	20058.3	18835.5	20261.0	23498.0	24335.5	25839.8	22138.0
C2	45785.0	44271.3	46126.5	50980.3	66374.3	66288.8	53304.3
C3	9017.3	4998.0	6543.8	8397.3	9275.3	8919.0	7858.4
C4	36466.8	48065.5	49900.8	49957.5	49746.8	49514.0	47215.2
Mean	27831.8	29042.6	30708.0	33118.3	37432.9	37640.4	

SEm C - 1980.806 N - 1423.970 CN - 2595.900

CD C - 6336.499 N - 4291.403 CN - 7397.380

energy, followed by C_4 (bhindi). C_2 and C_4 were observed to be at par. Pillai (1993) has reported high values for net output of energy in groundnut. The least net energy output was recorded by C_3 (cowpea). This is due to the very high energy input for cowpea (Table 73) compared to the energy output, owing to the large quantities of farmyard manure applied (20 t ha^{-1}) to cowpea. The same trend was observed during the second year also.

Among the various nutrient management levels tested, N_6 recorded the maximum net energy output during both the years. N_6 and N_5 were at par.

N_6 recorded the maximum net energy output for C_1 (sesamum) during both the years. While N_6 and N_5 were at par during the first year, significant difference was not observed among the different nutrient levels during the second year.

The net energy output of C_2 (groundnut) was observed to be maximum with N_6 during the first year and with N_5 during the second year. However N_6 and N_5 were at par during both the years.

In C_3 (cowpea), N_1 recorded the maximum net energy output during both the years. However significant difference was not observed between N_1 and the other treatments. The total energy input in the treatments N_2 to N_6 was much higher than that in N_1. This may be the reason for the higher net energy output inspite of the lower total dry matter production in N_1.

The treatments N_6 and N_5 generated the maximum net energy in C_4 (bhindi) during 1994-'95 and 1995-'96 respectively. While N_6, N_5, N_4 and N_3 were at par during the first year, the treatments N_6, N_5, N_4, N_3 and N_2 were at par during the second year.

4.16.2 Energy ratio of cropping systems

The results on the energy ratio as influenced by cropping systems and nutrient management are presented in Tables 80a and 80b and graphically in Fig. 19a and 19b.

Energy ratio was observed to be influenced significantly by the cropping systems, nutrient management and by their interaction during the first year and during the second year.

Rice-rice-sesaumum (C_1) and rice-rice-bhindi (C_4) recorded the highest energy ratios of 6.6 each during the first year. Rice-rice-bhindi (C_4) recorded the highest energy ratio of 6.8 during the second year. C_4 and C_1 and C_1 and C_2 (rice-rice-groundnut) were on a par during the second year.

The treatment, N_1 (farmers' practice) was observed to record the highest energy ratio of 6.8 each during the first

Table No. 80 Effect of cropping systems and nutrient management on the energy ratio

Table No. 80a 1994-'95

Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	6.7	5.8	6.1	6.4	7.1	7.3	6.6
C2	8.2	4.9	4.9	5.2	6.4	6.0	5.9
C3	5.7	3.9	3.9	4.7	5.4	5.1	4.8
C4	6.6	5.9	6.0	6.5	7.2	7.0	6.6
Mean	6.8	5.1	5.2	5.7	6.5	6.4	

SEm C - 0.123 N - 0.160 CN - 0.172

CD C - 0.395 N - 0.482 CN - 0.490

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Cropping systems	Nutrient management						Mean
	N1	N2	N3	N4	N5	N6	
C1	6.2	6.1	6.1	6.1	7.0	6.9	6.4
C2	7.3	5.4	5.6	5.9	6.8	6.5	6.3
C3	6.8	4.3	4.6	5.5	5.9	5.5	5.4
C4	7.0	6.3	6.4	6.6	7.3	7.1	6.8
Mean	6.8	5.5	5.6	6.0	6.7	6.5	

SEm C - 0.111 N - 0.132 CN - 0.145

CD C - 0.356 N - 0.399 CN - 0.428

year and during the second year. N_2 (package of practices recommendations) recorded the least energy ratio of 5.1 during the first year and 5.5 during the second year. Both the years observed the treatments N_1, N_5 and N_6 to be on a par. In general, farmers' practices involve minimum input of energy and have been observed to be the most efficient energy user (Freedman, 1980). This may be the reason for the higher energy ratio recorded by N_1 and the least by N_2. On the other hand, the higher energy ratios in the other treatments may be attributed to the influence of the integrated use of organic and inorganic fertilisers which has been reported to result in higher energy use efficiency in rice based cropping systems (Baishya and Sharma, 1990).

SUMMARY

SUMMARY

A field experiment entitled "Integrated nutrient management for rice based cropping systems of Onattukara tract" was laid out at the Rice Research Station, Kayamkulam starting from the first crop season of 1994 for a period of two years with the objectives of identifying the most suitable rice based cropping system for the Onattukara tract, studying the impact of integrated nutrient management on the physico-chemical properties of the soil, assessing the most efficient nutrient management practice, working out the nutrient balance sheet of the soil and economics of the different treatments. The experiment was laid out in a strip plot design with four replications. Four cropping systems (C_1 - rice-rice-sesamum, C_2 - rice-rice-groundnut, C_3 - rice-rice-cowpea, C_4 - rice-rice-bhindi) and six levels of nutrient management (N_1 - farmers' practice, N_2 - package of practices recommendations, N_3 - three-fourth recommended nitrogen as chemical + one-fourth as farmyard manure, N_4 - three-fourth recommended nitrogen as chemical + one-fourth as farmyard manure + *Azospirillum*, N_5 - three-fourth recommended nitrogen as chemical + one-eighth as farmyard manure + one-eighth as vermicompost, N_6 - three-fourth recommended nitrogen as chemical + one-eighth as farmyard manure + one-eighth as vermicompost + *Azospirillum*) were the

treatments. In the case of the summer crops all the plots except those receiving farmers' practice were treated as per the KAU package of practices recommendations. The salient findings of this study are summarised below.

In rice-rice-sesamum, the first crop rice recorded the maximum grain yield (3346 kg ha^{-1}) and straw yield (3887 kg ha^{-1}) at N_6. The second crop rice also observed the treatment N_6 to record the maximum grain yield (3693 kg ha^{-1}) and straw yield (7700 kg ha^{-1}). In the case of sesamum the treatment N_4, N_5 and N_6 recorded more or less similar higher yields suggesting the possibility of residual effect.

The total dry matter production of the system was observed to be the maximum (20350 kg ha^{-1}) at N_6. The total uptake of nitrogen, phosphorus and potassium was also maximum at N_6.

The treatment N_6 recorded the maximum net returns (Rs.10645/- ha^{-1}) for the rice-rice-sesamum system and was at par with N_5. BCR was observed to be the maximum (1.19) with N_5.

The energy ratio was observed to be maximum with N_6 (7.3) during the first year and with N_5 (7.0) during the second year. Both the years observed the treatments N_5 and N_6 to be on a par.

In rice-rice-groundnut the first crop rice recorded the highest grain yield at N_6 (3638 kg ha^{-1}). Although N_1 recorded the highest straw yield it was at the expense of the grain. Thus N_6 may be considered to be optimum for maximum straw yield. In the case of second crop rice, N_6 recorded the highest grain yield (3823 kg ha^{-1}) and N_5 recorded the highest straw yield (8778 kg ha^{-1}). Groundnut was not benefitted from residual effects of the treatments applied to rice, and thus the package recommendations was required for groundnut. Grain yield of rice following groundnut was observed to be higher.

The total dry matter production of the system observed to be the maximum at N_6 (23684 kg ha^{-1}). The uptake of nitrogen and phosphorus was maximum at N_6 and that of potassium was observed to be maximum at N_5.

The treatment N_5 recorded the maximum net returns (Rs.22079/- ha^{-1}) as well as the highest BCR (1.46) in the rice-rice-groundnut cropping system.

The energy ratio was observed to be maximum at N_1 (7.8) followed by N_5 (6.6). The higher energy ratio at N_1 is due to the low energy input while that at N_5 is due to the higher energy output.

The first crop rice of the rice-rice-cowpea cropping system recorded the highest grain yield (3661 kg ha^{-1}) at N_6.

Although N_1 recorded the highest straw yield it was at the expense of grain yield. Thus while considering the straw:grain ratio N_6 may be considered to be more suitable for higher straw yield (3898 kg ha^{-1}). The maximum grain yield for second crop rice (3663 kg ha^{-1}) and straw yield (8785 kg ha^{-1}) were recorded by the treatments N_6 and N_4 respectively. Package recommendation was essential for high yield of cowpea.

The total dry matter production was maximum (21463 kg ha^{-1}) with the treatment N_5. The total nutrient uptake was also observed to be maximum at N_5.

Rice-rice-cowpea system recorded the maximum net returns (Rs.15209/- ha^{-1}) at N_5. BCR was also observed to be the highest (1.24) at N_5.

A study on the energetics of the cropping system showed that the treatment N_1 recorded the highest energy ratio (6.3). However this was due to the lower energy input and not due to the higher output. Thus the energy ratio recorded by N_5 (5.7) may be considered as optimum.

In the rice-rice-bhindi cropping system, first crop rice recorded the maximum grain yield (3686 kg ha^{-1}) at N_6. Considering a favourable straw : grain ratio N_6 was observed to the highest straw yield (3911 kg ha^{-1}). The treatment N_6 recorded the maximum grain yield (3765 kg ha^{-1}) and N_5 recorded the maximum straw yield (8586 kg ha^{-1}) for the second crop rice. The package recommendations was observed to be essential to produce higher fruit yield in bhindi indicating the absence of residual effect.

The total dry matter production of the system was observed to be maximum (24179 kg ha^{-1}) at N_6. The total uptake of nitrogen and phosphorus was observed to be the maximum at N_6.

The treatment N_5 recorded the maximum net returns (Rs.20890/- ha^{-1}) for the rice-rice-bhindi cropping system. The BCR was also observed to be the maximum (1.33) at N_5

The study on the energetics of the cropping system indicated the energy ratio to be maximum (7.3) at N_5.

When the different cropping system were compared, rice-rice-bhindi recorded the highest production efficiency (34.22 kg ha^{-1} day^{-1}) followed by rice-rice-groundnut (19.30 kg ha^{-1} day^{-1}). The least production efficiency was for rice-rice-sesamum (16.88 kg ha^{-1} day^{-1}). The total dry matter production also followed the same trend with rice-rice-bhindi (21631 kg ha^{-1}) ranking first and rice-rice-groundnut (20827 kg ha^{-1}) ranking second. The rice-rice-cowpea cropping system (18484 kg ha^{-1}) ranked last.

The physico-chemical properties of the soil were studied before and after the experiment after the first year and after the second year.

There was only a small reduction in the bulk density of the soil due to the various cropping systems. The maximum reduction in bulk density was observed after rice-rice-cowpea. The reduction was to the tune of 0.004 g cc^{-1} during the first year and 0.014 g cc^{-1} during the second year. Integrated use of organics, inorganics and or biofertilisers was observed to lower the bulk density.

Cropping systems were observed to influence the particle density of the soil significantly. Particle density was observed to decrease after the rice-rice-cowpea cropping system.

Water holding capacity of the soil was influenced significantly by the different cropping systems and levels of nutrient. Rice-rice-cowpea could increase the water holding capacity of the soil slightly (by 0.36 per cent). Integrated nutrient management was observed to have a positive influence on the water holding capacity of the soil.

Cropping systems in general were observed to improve the soil structure. Inclusion of groundnut and cowpea was observed to have the maximum positive influence on aggregation. Application of farmyard manure and vermicompost were observed to improve the percentage of water stable aggregates.

The soil pH was observed to decrease after all the cropping systems except rice-rice-groundnut. Application of organics in conjunction with inorganics was observed to have a buffering effect on the soil pH as is indicated by the negligible variation in pH over the initial pH.

The organic carbon status of the soil was observed to increase after all the cropping systems, the maximum being after the cropping system, rice-rice-cowpea. The treatments N_2 to N_6 were observed to increase the organic carbon content of the soil, the maximum being at N_6.

Rice-rice-cowpea recorded significantly higher total soil nitrogen contents during both the years. Integrated nutrient management improved the total nitrogen status of the soil.

The effect of cropping systems, nutrient levels and their interaction was observed to be significant with regard to the available nitrogen content of the soil. Rice-rice-cowpea recorded the highest available nitrogen content in the soil followed by rice-rice-bhindi. Among the various nutrient levels N_2 recorded the highest content of available nitrogen. The available nitrogen content of the soil decreased progressively from N_2 to N_6.

In general, there was an increase in the available phosphorus content of the soil after all the cropping systems.

The least increase was observed after rice-rice-sesamum. All the other systems were more or less similar in improving the available phosphorus content of the soil. Integrated nutrient management was observed to improve the available phosphorus status of soil.

Nutrient management alone was observed to have significant influence on the available potassium content of the soil. N_5 recorded the maximum available potassium. In general, organic matter irrespective of source improved the soil available potassium status.

The balance sheet of available nitrogen indicated a loss in the cropping systems, rice-rice-sesamum and rice-rice-bhindi. However there was gain in nitrogen in the cropping systems in which legumes like groundnut and cowpea were included, the maximum gain being from the cropping system rice-rice-groundnut during both the years.

The balance sheet of available phosphorus of the soil showed a loss in all the cropping systems. In general the loss was maximum from the crop sequence rice-rice-cowpea and the minimum loss was from the crop sequence rice-rice-sesamum.

The balance sheet of available potassium showed good gains in all the cropping systems, during both the years. Maximum gain in available potassium was observed in the cropping system, rice-rice-bhindi.

The rice-rice-bhindi cropping system proved to be the most remunerative with an average net returns of Rs.34219/- ha^{-1} followed by rice-rice-groundnut with an average net returns of Rs.15770/- ha^{-1}. Rice-rice-sesamum was the least remunerative (Rs.8078/- ha^{-1}). With regard to the benefit cost ratio, rice-rice-groundnut ranked first (1.34), rice-rice-bhindi ranked second (1.28), rice-rice-cowpea ranked third (1.16) and rice-rice-sesamum ranked fourth (1.14). The treatment N_5 recorded the maximum BCR in all the cropping systems.

When the marginal benefit cost ratio for the effect of nutrient management over the individual cropping systems was worked out, the package of practices recommendations was observed to record the highest MBCR of 1.81 for rice-rice-sesamum and 1.61 for rice-rice-bhindi cropping systems. However the treatment N_5 recorded the maximum MBCR for rice-rice-groundnut (1.55) and rice-rice-cowpea (1.50) cropping systems.

The rice-rice-groundnut cropping system was assessed to be the best system for the Onattukara tract based on the higher production efficiency, benefit cost ratio and soil sustainability compared to the other cropping systems studied. This system yielded best by the application of three-fourth recommended dose of nitrogen as chemical + one-eighth as farmyard manure + one-eighth as vermicompost, to the first crop and second crop of rice, followed by the package of practices recommendations for the third crop of groundnut.

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* Originals not seen

APPENDICES

APPENDIX - Ia

Mean monthly meteorological data during the cropping period

(April 1994 to April 1995)

Year	Month	Rainfall (mm)	Temperature (°C) Maximum	Temperature (°C) Minimum	Relative humidity (%)
1994	APRIL	111.4	33.4	24.0	75.26
	MAY	392.8	32.0	23.8	78.64
	JUNE	365.4	30.6	23.4	77.42
	JULY	737.4	29.9	22.7	85.26
	AUGUST	262.0	30.4	23.4	76.73
	SEPTEMBER	123.4	31.3	23.5	75.24
	OCTOBER	768.4	30.9	23.1	86.94
	NOVEMBER	110.6	32.4	22.9	71.95
	DECEMBER	NIl	33.7	20.2	70.34
	JANUARY	24.2	33.6	21.4	71.63
	FEBRUARY	4.4	33.9	22.4	70.22
	MARCH	96.1	34.1	23.4	73.11
	APRIL	301.5	33.9	23.8	80.25

APPENDIX - Ib

Mean monthly meteorological data during the cropping period

(May 1995 to May 1996)

Year	Month	Rainfall (mm)	Temperature (°C)		Relative humidity (%)
			Maximum	Minimum	
1995	MAY	191.7	32.7	25.0	76.84
	JUNE	455.3	31.1	24.2	84.77
	JULY	372.4	30.3	23.5	82.16
	AUGUST	317.3	30.2	23.5	80.11
	SEPTEMBER	221.1	31.1	23.5	80.16
	OCTOBER	170.7	31.6	23.7	78.26
	NOVEMBER	142.3	31.5	22.5	79.00
	DECEMBER	1.0	33.6	19.3	70.20
	JANUARY	30.3	33.4	19.9	73.11
	FEBRUARY	NIL	33.9	21.3	70.02
	MARCH	21.0	34.1	23.0	71.26
	APRIL	101.8	33.3	24.3	75.64
	MAY	50.8	34.3	24.8	74.25

Source: Meteorological Observatory, Central Plantation Crops Research Institute, Kayamkulam

APPENDIX - II

Mean monthly meteorological data during the past ten years

(1984 to 1993)

Month	Rainfall (mm)	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum	
JANUARY	10.7	31.9	19.9	70.46
FEBRUARY	13.9	32.5	22.0	71.17
MARCH	34.4	30.1	23.1	71.96
APRIL	106.8	33.5	24.4	74.15
MAY	281.8	32.8	24.1	77.00
JUNE	567.1	27.7	22.9	83.67
JULY	444.8	30.1	22.7	84.63
AUGUST	235.7	29.3	22.4	82.17
SEPTEMBER	432.1	31.1	22.3	79.85
OCTOBER	280.0	30.7	22.4	79.63
NOVEMBER	132.7	31.5	21.4	79.00
DECEMBER	33.1	29.0	20.4	71.90

APPENDIX - III

Basic data used for calculating the cost of cultivation and net returns (in Rs. ha^{-1}) are furnished below.

A. Cost of labour

1. Hire charge of tiller	-	Rs. 80 hr^{-1}
2. Man labourer	-	Rs. 80 day^{-1}
3. Woman labourer	-	Rs. 80 day^{-1}

B. Cost of manures, fertilisers and soil amendments

1. Farmyard manure	-	Rs. 199 t^{-1}
2. Poultry manure	-	Re. 1 kg^{-1}
3. Vermicompost	-	Rs. 3 kg^{-1}
4. Nitrogen	-	Rs.10.45 kg^{-1}
5. Phosphorus	-	Rs.20.04 kg^{-1}
6. Potassium	-	Rs. 9.70 kg^{-1}
7. Lime	-	Re. 1 kg^{-1}

C. Cost of biofertilisers

1. *Azospirillum*	-	Rs.50 kg^{-1}
2. *Rhizobium*	-	Rs.50 kg^{-1}

D. Cost of seeds -

1. Paddy	-	Rs. 8 kg^{-1}
2. Sesamum	-	Rs.40 kg^{-1}
3. Groundnut	-	Rs.30 kg^{-1}
4. Cowpea	-	Rs.50 kg^{-1}
5. Bhindi	-	Rs.400 kg^{-1}

E. Cost of economic produce

1.	Paddy grains	-	Rs. 6 kg^{-1}
2.	Paddy straw	-	Rs.1.75 kg^{-1}
3.	Sesamum grains	-	Rs.32 kg^{-1}
4.	Groundnut pods	-	Rs.25 kg^{-1}
5.	Cowpea grains	-	Rs.25 kg^{-1}
6.	Bhindi fruits	-	Rs.4 kg^{-1}

APPENDIX - IV

Basic data used for calculating the energetics of cropping systems (in MJ ha^{-1}) are furnished below.

A. Energey equivalent of inputs

1.	Tiller	-	253.24 MJ $hour^{-1}$
2.	Man labourer	-	1.96 MJ $manhour^{-1}$
3.	Woman labourer	-	1.57 MJ $womanhour^{-1}$
4.	Farmyard manure	-	0.3 MJ kg^{-1}
5.	Poultry manure	-	1.32 MJ kg^{-1}
6.	Vermicompost	-	0.97 MJ kg^{-1}
7.	Nitrogen	-	60.60 MJ kg^{-1}
8.	Phosphorus	-	4.85 MJ kg^{-1}
9.	Potassium	-	5.49 MJ kg^{-1}
10.	Lime	-	10 MJ kg^{-1}
11.	*Azospirillum*	-	909 MJ ha^{-1}
12.	*Rhizobium*	-	2424 MJ ha^{-1}
13.	P.P. chemicals requiring dilution	-	120 MJ l^{-1}
14.	Paddy seeds	-	14.7 MJ kg^{-1}
15.	Sesamum seeds	-	25 MJ ha^{-1}
16.	Groundnut pods	-	25 MJ ha^{-1}
17.	Cowpea seeds	-	14.7 MJ kg^{-1}
18.	Bhindi seeds	-	2.4 MJ kg^{-1}

B. Energy equivalents of produce

1.	Paddy grains	-	14.7 MJ kg^{-1} dry weight
2.	Paddy straw	-	12.5 MJ kg^{-1} dry weight
3.	Sesamum grains	-	25 MJ kg^{-1} dry weight
4.	Sesamum haulm	-	18 MJ kg^{-1} dry weight
5.	Groundnut pods	-	25 MJ kg^{-1} dry weight
6.	Groundnut haulm	-	18 MJ kg^{-1} dry weight
7.	Cowpea grains	-	14.7 MJ kg^{-1} dry weight
8.	Cowpea haulm	-	12.5 MJ kg^{-1} dry weight
9.	Bhindi fruits	-	1.9 MJ kg^{-1} fresh weight
10.	Bhindi bhusa	-	18 MJ kg^{-1} dry weight

Note: Energy equivalents of *Azospirillum* and *Rhizobium* have been computed based on the assumption that on an average they fix 15 kg and 40 kg nitrogen per hectare respectively.

INTEGRATED NUTRIENT MANAGEMENT FOR RICE BASED CROPPING SYSTEMS OF ONATTUKARA TRACT

BY

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ABSTRACT

An investigation was carried out at the Rice Research Station, Kayamkulam to identify the most suitable rice based cropping system for the Onattukara tract and to evolve a suitable ecologically and economically viable integrated nutrient management practice for the system. The experiment was laid out in a 4x6 factorial strip plot design and was carried out for two consecutive years extending from April, 1994 to May, 1996.

The treatments consisted of four cropping systems (rice-rice-sesamum, rice-rice-groundnut, rice-rice-cowpea and rice-rice-bhindi) and six nutrient management levels (N_1 - farmers' practice, N_2 - Package of practices recommendations, N_3 - three-fourth recommended N as chemical + one-fourth as FYM, N_4 - three-fourth recommended N as chemical + one-fourth as FYM + *Azospirillum*, N_5 - three-fourth recommended N as chemical + one-eighth as FYM + one-eighth as vermicompost and N_6 - three fourth recommended N as chemical + one - eighth as FYM + one - eighth as vermicompost + *Azospirillum*). During the third crop season the treatments N_2 to N_6 was package of practices recommendations (for the respective crops) while N_1 was farmers' practice itself.

Among the different nutrient management levels tested, the treatment wherein one-fourth recommended N was

substituted with FYM and vermicompost along with *Azospirillum* recorded the maximum grain yield for first crop rice and second crop rice (irrespective of cropping system). The same treatment also supported a better straw yield by maintaining a favourable grain : straw ratio.

In rice-rice-sesamum, the production efficiency was highest when one-fourth recommended nitrogen was supplied through farmyard manure and vermicompost along with *Azospirillum*. The BCR was maximum when the same treatment was applied without *Azospirillum*. In rice-rice-groundnut, rice-rice cowpea and rice-rice-bhindi, the same trend followed.

Rice-rice-bhindi cropping system recorded the maximum production efficiency followed by rice-rice-groundnut during both the years, and rice-rice-sesamum recorded the minimum value.

The overall mean returns was maximum with the cropping system, rice-rice-groundnut. It was followed closely by the rice-rice-bhindi cropping system. While rice-rice-cowpea recorded the minimum economic returns during the first year, rice-rice-sesamum recorded the same during the second year.

Studies on the physico-chemical properties of the soil showed that the cropping system, rice-rice-sesamum resulted in a slight increase in bulk density, water holding capacity and water stable aggregates. The organic carbon, total nitrogen and available phosphorus content of the soil increased, while the soil pH, available nitrogen and available potassium contents decreased. The cropping system, rice-rice-groundnut resulted in an increase in bulk density, water holding capacity, water stable aggregates, organic carbon, soil pH, total nitrogen and available phosphorus and a decrease in the available nitrogen and available potassium contents. While there was an increase in the water holding capacity, water stable aggregates, organic carbon, total nitrogen, available nitrogen and available phosphorus there was a slight decrease in bulk density and soil pH in the cropping system, rice-rice-cowpea. The rice-rice-bhindi cropping system resulted in a decrease in the bulk density and soil pH and available potassium and an increase in the water holding capacity, water stable aggregates, organic carbon, total nitrogen, available nitrogen and available phosphorus.

The balance sheet of nitrogen showed a positive balance in the cropping systems rice-rice-groundnut and rice-rice-cowpea and a negative balance in the other two systems. All the cropping systems tested resulted in a negative balance for available phosphorus and a positive balance for available potassium.

The cropping system, rice-rice-groundnut was observed to be the most efficient one, followed by rice-rice-bhindi based on the productive efficiency, benefit cost ratio and soil sustainability. The marginal benefit cost ratio for the different nutrient management practices showed that the treatment comprising three fourth recommended dose of N as chemical + one-eighth as FYM + one-eighth as vermicompost (for first and second crop rice) and package of practices recommendations for groundnut (third crop) was the most economic. However, for the rice-rice-bhindi cropping system, the package of practices recommendations was observed to be more economical.