PROSPECTS OF ORGANIC FARMING IN RICE-BASED CROPPING SYSTEM

By

MALLU SRINIVASA REDDY
M.Sc. (Ag.)

THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRICULTURAL SCIENCES
(AGRONOMY)

DEPARTMENT OF AGRONOMY
SRI VENKATESWARA AGRICULTURAL COLLEGE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
TIRUPATI - 517 502 (A.P)

JUNE, 2002

CERTIFICATE

Mr. M.SRINIVASA REDDY has satisfactorily prosecuted the course of research and that the thesis entitled **"PROSPECTS OF ORGANIC FARMING IN RICE-BASED CROPPING SYSTEM "** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

Date :

Place :

Major Advisor
Dr. D.SRINIVASULU REDDY
Professor and Head
Department of Agronomy
S.V.Agricultural College
Tirupati – 517 502

CERTIFICATE

This is to certify that the thesis entitled **"PROSPECTS OF ORGANIC FARMING IN RICE-BASED CROPPING SYSTEM "** submitted in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in Agronomy to the Acharya N.G.Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr M.SRINIVASA REDDY** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted by the student for the award of any other degree or diploma. The published part has been fully acknowledged. All assistant and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

(Dr. D.SRINIVASULU REDDY)
Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee:

Chairman : **(Dr. D.SRINIVASULU REDDY)**
Professor and Head
Department of Agronomy
S.V. Agricultural College,
Tirupati – 517 502

Member : **(Dr. K. RAMKUMAR REDDY)**
Principal Scientist (Agronomy)
Regional Agricultural Research Station
Tirupati – 517 502

Member : **(Dr. P.V.REDDY)**
Principal Scientist (Plant Physiology)
Regional Agricultural Research Station
Tirupati – 517 502

Member : **(Dr. N.RAMAVATHARAM)**
Professor and Head
Department of Soil Science & Agril. Chemistry
S.V. Agricultural College,
Tirupati – 517 502

Member : **(Dr. P.MAHESWARA REDDY)**
Associate Professor
Department of Agronomy
S.V. Agricultural College,
Tirupati – 517 502

CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF APPENDICES

LIST OF PLATES

DECLARATION

I, **M.SRINIVASA REDDY** here by declare that the thesis entitled **"PROSPECTS OF ORGANIC FARMING IN RICE-BASED CROPPING SYSTEM "** submitted to Acharya N.G.Ranga Agricultural University, Hyderabad for the award of degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) in AGRONOMY** is the result of original research work done by me. It is further declared that the material contained in this thesis or any part thereof has not been published earlier elsewhere in any manner.

M.Srinivasa Reddy

Date : 10-06-2002

M.SRINIVASA REDDY

ACKNOWLEDGEMENTS

*It is by the greatness of **my parents**, I was able to bring to light this humble piece of work, for which I am eternally indebted.*

*With immense pleasure and deep respect and regard, I express my heartfelt gratitude to **Dr.D.Srinivasulu Reddy**, Professor and Head, Department of Agronomy, S.V.Agricultural College, Tirupati and Chairman of the Advisory committee not only for his matured guidance throughout the investigation but also for his sustained interest he has evinced in my presentation of this thesis.*

*I express my deep sense of gratitude to the other members of my advisory committee, **Dr.P.V.Reddy**, Principal Scientist (Plant Physiology), **Dr.K.Ramkumar Reddy**, Principal Scientist (Agronomy), Regional Agricultural Research Station, Tirupati, **Dr.N.Ramavatharam**, Professor and Head (Soil Science and Agricultural Chemistry) and **Dr. P.Maheswara Reddy**, Associate Professor (Agronomy), S.V. Agricultural College, Tirupati.*

I deem it my privilege in expressing my deep sense of gratitude and sincere thanks to Dr.S.Rami Reddy (Retired Professor and University Head, Department of Agronomy, SVAC, Tirupati), for his kind help and co-operation in pursuing the Ph.D Programme.

I extend my sincere thanks to Dr. C.Raghava Reddy, Sri M.Reddappa Reddy, Dr. D.S.Koteswara Rao, Dr.V.Sridhar, Dr. G.Prabhakar Reddy, Dr. G.Karunasagar, and Mrs. V.Chandrika. Mrs. V.Sumathi and Miss. A.V.Nagavani, faculty members, Department of Agronomy, S.V.Agricultural College, Tirupati, Scientists of RARS, Tirupati and Dr.G.Krishna Reddy, Farm Superintendent, Mr.P.Parthasarathy Farm Manager, S.V. Agricultural College Farm, Tirupati and Dr. K.Gopal, Scientist, AICRP on Citrus for their help during my research work.

My sincere thanks due to Dr.M.Ananda Rao, (Retired ADR, RARS, Tirupati), for his kind help during the prosecution of the research work.

I sincerely acknowledge the help and guidance extended by Dr. V.Siva Reddy, Dr. M.Nedunzhiyam, Dr. P.V.N.Prasad. Dr. A.V.Ramana and Dr. P.Sujathamma, my senior Ph. D. Scholars.

I am in dearth of words to express my sincere and heartfelt thanks to my colleagues Mrs.U.Veneetha, Mrs. Bhargavi and Mr.D.Sampath Kumar for their kind co-operation and help.

It is not right unless I extend my profound thanks to my beloved and eternal friends R.V., Dev, Bhaskar (Agro & Phy) Varam, Raja (Phy), Sreekanth. Subbu. M.R.Y.Reddy, Sai (MBA), K.K. Sanath, Devandra (town), Vasu, Rajasekhar Chaitanya, Vinod, Sai (Juniors), Krishna Reddy, Obul Reddy, H.P., Seenu (Ento) Basu, Palani, Sarathi, Ramakrishna (Andaman, Ento & Ext), V.Ramudu and SS Reddy (Ento), Sivanandan, Tarak, RSP, Lakshman, Madhav, Pradeep (Vetty), Sriharsha, Bala, Seenu (RASS) and all those who directly and indirectly helped me. My special thanks to Keerthi Ashok Ram Reddy and Bharathi my admirers who have developed great inspiration and challenging spirit in me.

I am extremely grateful to my loving brother ***Sreenath,*** *brother-in-law* ***B.J.Reddy,*** *my sister* ***Nagamani*** *and their children* ***Vasanth*** *and* ***Devi*** *for their love and affection towards me, which has been the source of unaccountable moral support during the period of the present mission.*

I am grateful to Acharya N.G.Ranga Agricultural University, Hyderabad for providing me with the opportunity and financial assistance for prosecuting my Doctoral Programme.

I am very much thankful to Mr.E.Ashok and his employees of ***Sri Rudhvic Xerox & DTP, Tirupati*** *for neat and speedy execution of thesis work.*

I am indeed indebted to ***Lord Shri Venkateswara*** *for his grace and fruitful blessings on me.*

M.Srinivasa Reddy

(M. SRINIVASA REDDY)

ABSTRACT

Author : **M.SRINIVASA REDDY**

Title of the thesis : **PROSPECTS OF ORGANIC FARMING IN RICE-BASED CROPPING SYSTEM**

Submitted for the award of degree : Ph.D.

Faculty : AGRICULTURE

Department : AGRONOMY

Major advisor : **Dr.D.SRINIVASULU REDDY**

University : Acharya N.G. Ranga Agricultural University

Year of submission : **2002**

Field experiments were conducted during two consecutive years (2000 and 2001) on sandy loam soils of wet land block of S.V. Agricultural College Farm (ANGRAU), Tirupati (Southern Agro-climatic Zone of A.P.) to study the **"Prospects of organic farming in rice-based cropping system".** The investigations were conducted for two seasons, with rice during *kharif* and groundnut during *rabi* and laid out in randomized block design replicated thrice. The same layout was followed during both the years of study. The treatments consisted of twelve N management practices (no N, *Azospirillum* alone, GM N_{100}, GLM N_{100}, FYM N_{100}, F N_{100}, GM N_{50} + F N_{50}, GLM N_{50} + F N_{50}, FYM N_{50} + F N_{50}, GM N_{50} + F N_{50} + *Azo.*, GLM N_{50} + F N_{50} + *Azo.* and FYM N_{50} + F N_{50} + *Azo.*) applied to *kharif* rice and groundnut was raised to find out the residual effect of the treatments applied to *kharif* rice. The test variety of rice was NLR-145 and that of groundnut was K-134.

The results indicated that different N management practices to rice noticeably altered the growth parameters, yield attributes, yield and nutrient uptake of rice as well as the post harvest fertility status of soil. The growth attributes viz., plant height, total tiller m^{-2}, LAI and dry matter production were highest with GM N_{100} at active tillering and with GLM N_{50} + F N_{50} + *Azo.*, at panicle initiation, while at flowering and at harvest the highest stature of the growth parameters was associated with FN_{100}.

Yield attributes of rice viz., panicles m^{-2}, number of grains panicle^{-1}, filled grains panicle^{-1} and 1000-grain weight were highest with supply of 100 per cent N through fertilizer, which were comparable with all the recommended N application treatments, except the two exclusive organic sources of N supply viz. GM N_{100} and FYM N_{100}.

Grain and straw yield of rice was significantly higher with the application of 100 per cent N through fertilizer, which was in parity with all the integrated N management practices of GLM N_{50} + F N_{50} + *Azo.*, GM N_{50} + F N_{50} + *Azo.*, GLM N_{50} + F N_{50}, GM N_{50} + F N_{50}, FYM N_{50} + F N_{50} + *Azo.*, and FYM N_{50} + F N_{50}.

Quality parameters of rice viz., whole grain per cent, milling per cent, protein content and amylose content of rice kernels were highest with conjunctive use of GLM N_{50}+F N_{50}+*Azo.*, while the highest broken grain percentage was recorded with no N application.

Nitrogen, phosphorus and potassium uptake of rice was the highest with GM N_{100} at active tillering and with GLM N_{50} + F N_{50} + *Azo.* at panicle initiation, while at flowering and harvest the highest N, P and K uptake was registered with supply of 100 per cent N through fertilizer.

The highest organic carbon, available nitrogen and available potassium content of soil (post harvest) were noticed with application of 100 per cent N through FYM, which was however, comparable with all the N application treatments, except F N_{100}, *Azospirillum* alone and control. The available soil phosphorus status did not vary to a statistically traceable extent.

The highest gross returns, net returns and BC ratio of rice were recorded with application of 100 per cent N through fertilizer (T_6).

Supply of 100 per cent N through FYM to preceding rice has recorded the highest stature of growth parameters viz., plant height, LAI and dry matter production and yield attributes viz., number of pods plant^{-1}, hundred-pod weight, and hundred-kernel weight of *rabi* groundnut.

The highest pod and haulm yield of groundnut were recorded with FYM N_{100} imposed to preceding rice, which were however statistically similar to FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3).

At 30 and 60 DAS, the nodule dry weight was highest with FYM N_{100} applied to *kharif* rice, while at 90 DAS and at harvest the nodule dry weight was not significantly influenced by different N management practices imposed to preceding rice.

The highest N, P and K uptake at all the stages of groundnut were recorded with application of FYM N_{100} to preceding rice.

The highest post harvest soil organic carbon, available nitrogen and potassium content after groundnut were noticed with the application of FYM N_{100} to preceding rice, which was however, comparable with all the recommended N application treatments, except 100 percent N through fertilizer. The post harvest soil available phosphorus status did not show any significant variation.

The highest gross and net returns as well as BC ratio of groundnut were recorded with FYM N_{100}, which were statistically similar with FYM N_{50} + F N_{50}, FYM N_{50} + F N_{50} + *Azo.*, GLM N_{100}, GM N_{100}, GLM N_{50} + F N_{50}, and GLM N_{50} + F N_{50} + *Azo.* imposed to *kharif* rice.

The highest total dry matter production of the cropping system as a whole was recorded with application of GLM N_{50}+F N_{50}+*Azo*, while the highest rice-grain equivalent (economic) yield of the cropping system was noticed with FYM N_{50} + F N_{50}.

The highest gross returns of the cropping system were recorded with FYM N_{50}+F N_{50} and the highest net returns were with F N_{100} during the first year and with FYM N_{50} + F N_{50} during the second year, while the highest BC ratio were registered with the application of 100 per cent N through fertilizer.

The soil organic carbon content tended to increase with each crop of rice and groundnut of the cropping system. The available nitrogen, phosphorus and potassium content of the soil tended to increase with the raising of rice crop and decrease marginally with the raising of groundnut crop.

The nitrogen balance in the cropping system was negative with the treatments of no N (T_1), *Azospirillum* alone (T_2) and 100 per cent N through fertilizer (T_6) imposed to rice crop. All other treatments recorded positive balance of soil available nitrogen in the cropping system, indicating a net gain of soil available nitrogen

In conclusion, it is inferred from the investigations that rice-groundnut cropping system can be sustained with any package of integration of 50 per cent N each through fertilizer and any of the organic sources, not only in terms of higher productivity and economic returns, but also in terms of sustaining the soil fertility status at a fairly high level. Even though application of entire recommended N through fertilizer could meet the N requirement of rice, it would not sustain the soil fertility status and its residual effect was meagre for economical production of groundnut in rice-groundnut cropping system. Impact of *Azospirillum* was marginal, but considering its cost, it can be included for application to rice in rice-based cropping system. Supply of N through exclusive organic sources could not have met the timely crop demand of N requirement and also the cost of production was higher with exclusive organic farming, compared to integrated farming or inorganic farming. However, organic farming may gain importance in future if the lower yields and higher cost of cultivation are compensated with premium pricing of organically produced rice and groundnut, which of course, depends on consumer preference and purchasing power.

ABBREVIATIONS AND ACRONYMS

%	-	Per cent
@	-	At the rate of
°C	-	Degree celcius
BGA	-	Blue green algae
CD	-	Critical difference
Cm	-	Centimetre
DAS	-	Days after sowing
DAT	-	Days after transplanting
dSm^{-1}	-	Deci seimen per metre
et.al.	-	and others
F N	-	Fertilizer nitrogen
Fig	-	Figure
FYM	-	Farm yard manure
g	-	Gram
GLM	-	Green leaf manure
GM	-	Green manure
ha	-	Hectare
K	-	Potassium
kg ha^{-1}	-	Kilogram per hectare
kg	-	Kilogram
LAI	-	Leaf area index
m	-	Metre
m.ha	-	Million hectares
m.t	-	Million tonnes
mg	-	Milligram
mm day^{-1}	-	Millimetre per day
mm	-	Millimetre
N	-	Nitrogen
NHI	-	Nitrogen harvest index
NS	-	Not significant
NUE	-	Nitrogen use efficiency
P	-	Phosphorus
PU	-	Prilled urea
RH	-	Relative humidity
Rs ha^{-1}	-	Rupees per hectare
Rs kg^{-1}	-	Rupees per kilogram
SEm	-	Standard error of mean
t ha^{-1}	-	Tonnes per hectare
viz.	-	Namely

Introduction

CHAPTER - I

INTRODUCTION

"Exploitive agriculture offers great possibilities if carried out in a scientific way, but poses great dangers if carried out with only an immediate profit motive. The emerging exploitive farming community in India should become aware of this. Intensive cultivation of land without conservation of soil fertility would lead, ultimately, to the springing of deserts"—Prof. M.S.Swaminathan.

The green revolution is one of the biggest success stories of India cited globally, which enabled the country to convert the nightmarish "begging bowl" status to that of "self-sufficiency". It also brought about an element of the resilience in agriculture to ward-off the threat of famines. The green revolution obviously assured the food production of a little over 200 million tonnes by the dawn of the current millennium.

All this had obviously been possible as a result of the adoption of good quality seeds, enhanced use of fertilizers and plant protection practices besides assured irrigation. Since, production for market is the only aim of the green revolution, factors like crop rotation, crop diversity, soil health, environmental degradation etc. have been ignored. The seed chemical paradigm of green revolution has reached a plateau and the situation has worsened when the productivity of miracle seeds leveled off since 1990. Hence, there is a need to revise the production and management practices towards sustainability in agricultural production.

The heavy dose of fertilizer application to meet the nutritional demands of the modern varieties of crops has depleted the soil in such a way that to get a unit quantity of output more and more quantity of fertilizers are needed to be applied, every time the land is ploughed. Also, the heavy dependence on high analytical fertilizers had resulted in a plethora of environmental problems like declining productivity, impoverishment of soil fertility including deficiency of several micronutrients and environmental pollution, with the result of which, modern agriculture became lack of wholesome in its approach.

The success of future agriculture depends upon the sustainability of production systems in the years to come. Arresting the decline of soil organic matter is the most potent weapon in fighting against abated soil degradation and imperiled sustainability of agriculture in tropical regions, and particularly those under arid, semi arid and sub humid climate. Thus, shift from market orientation to sustainability can be done by shift from inorganic to organic. Hence, to keep the ball rolling, organic farming should be initiated. The thought-provoking statement of Summer and Farina (1986), "crops do not respond to fertilizer application *per se*, but rather the soils respond to that application" would clearly spell out that crop sustainability is in turn linked to the soil sustainability.

Organic farming is a holistic management system, which promotes and improves the health of the agro system and emphasizes the management practices involving substantial rely upon crop rotation, crop residues, animal manures, green manures, off-farm wastes and biological nitrogen fixation. These components in addition to reducing the cost of production, also ensures clean environment.

There is a great potential for organic resources to supply plant nutrients including micronutrients in the state of Andhra Pradesh. According to the available information, total nutrient potential (N + P_2O_5+ K_2O) from crop residues, dung and other organic materials during 1998-99 was 2.53 million tonnes. The nutrients removed by the crops during the corresponding period was 1.373 million tonnes (nitrogen, 0.476 million tonnes, phosphorus, 0.217 million tonnes and potassium, 0.680 million tonnes) and thus, the state has possible balance of nutrients even if all the available organic resources alone are utilized.

Rice-groundnut cropping system is the predominant cropping system of the state. Rice occupies the largest area in the state followed by groundnut and these two crops in order, accounts for the maximum removal of nitrogen, phosphorus and potassium. The system is often considered as a market insurance, since the price commanded by the latter can buffer the lower returns due to glut of high production. Reports of stagnation in the productivity of these crops with the lowering of the soil organic carbon and possible deterioration of soil ecosystem have raised doubts on the sustainability of this important production system.

Nitrogen is considered as the key to the yield potential of modern rice. In India, about 67 per cent of rice soils are estimated to be deficient in nitrogen. Of late, due to decrease in fertilizer subsidies, the prices have been increasing. So, the current trend is to explore the feasibility of supplementing mineral fertilizers with organics. Also, legumes with their adaptability to different crop-based cropping patterns and their ability to fix nitrogen, may offer opportunities to increase and sustain productivity in rice-based cropping systems.

Organic manures and biofertilizers have been proved to be viable components of nitrogen management, which can supplement and successfully replace costly fertilizer nitrogen. The possibilities and prospects of exclusive organic farming *vis-à-vis* exclusive chemical farming and integrated nutrient management in the cropping systems has not been researched adequately, though such research has been conducted to a limited extent in respect of individual crops. Especially, research efforts in this direction have not been initiated in the Southern Agro-climatic Zone of Andhra Pradesh.

In the light of the above context, the present study was planned and investigations were carried out for two successive *kharif* and *rabi* seasons of 2000 and 2001, with the following objectives:

1. To study the response of low land rice to organic manuring *vis-à-vis* biological and inorganic sources as well as integration of different sources.
2. To estimate the influence of different nitrogen management practices on the grain quality of rice.
3. To investigate the residual effect of different nitrogen management practices to rice crop on succeeding groundnut crop.
4. To evaluate the soil fertility dynamics in rice-groundnut cropping system with different nitrogen management practices.
5. To assess the economics of different nitrogen management practices in rice-groundnut cropping system.

Review of Literature

CHAPTER – II

REVIEW OF LITERATURE

Introduction of high yielding varieties and intensive cultivation with excess and imbalance use of chemical fertilizers showed reduction in the soil fertility status and crop yields by 38 per cent of rice and 19 per cent of wheat (Singh *et al*., 2001). Excess and imbalance use of chemical fertilizers may also reduce the availability of micronutrients and yield. Also the concerns about the increased cost and reduced availability of fossil fuels, deflating human nutrition and environmental degradation have prompted agricultural scientists to re-evaluate our current agricultural practices and investigate alternative production methods. Organic farming seems to be an alternative, which may not be acceptable on short-term basis, but may be viable on long-term basis. Undoubtedly, human survival depends on agricultural production being increased and the earth's environment being sustained.

The available state of knowledge on various aspects of different organic sources and their integration with fertilizers for lowland rice and their residual effect on the succeeding crop of groundnut is briefly reviewed in this chapter.

2.1 EFFECT OF ORGANICS ON LOWLAND RICE PRODUCTION

The main natural source of N is soil organic matter, which is being replenished by various atmospheric N fixers (IRRI, 1974).

Organic manuring has been known to increase the biological N fixation in lowland soils, due to the increased population of heterotropic N fixers. Further, the reduced conditions in lowland soils with the application of organic manures were found favoured the nitrogenase activity in the soil (Kimura *et al*., 1979).

Organic manures play a direct role in supplying macro and micronutrients and indirectly by improving the physico-chemical and biological properties of the soils, besides supplying nutrients to the current crop and quite often leave substantial residual effect on succeeding crops in the cropping systems (Maskina and Meelu, 1984).

In lowland rice cultivation, crop growth depends much on the mineralized N from soil organic matter (Kai *et al.*, 1984).

Application of organic materials influenced the growth of rice crop directly by providing nutrients (Palaniappan and Balasubramanian, 1991) and stimulating the microbial activity (Kukreja *et al.*, 1991).

The uptake of soil N was up to 63 per cent between planting to necknode initiation, 45 per cent between necknode initiation to late stage of spikelet initiation and 50 per cent between late stage of spikelet initiation to heading (Wada *et al.*, 1986). Nitrogen uptake was up to 80 per cent during the period from panicle primordial initiation to heading (Kitada *et al.*, 1991), whereas the soil N alone contributed to the entire uptake of N from spikelet filling stage to maturity (Wada *et al.*, 1986; Kitada *et al.*, 1991).

The significance of native soil N was apparent from the fact that 60 to 80 per cent of N (Manguiat *et al.*, 1994; Ponnamperuma and Detruck, 1993) absorbed by the lowland rice crop was derived from native soil N pool.

Nitrogen in soils is mostly present in organic form in organic matter and in most of the soils, it is 59-95 per cent (Srivastava and Singh, 1996).

Saravana Pandian and Rani Perumal (2000) reported that N levels and organics have significantly influenced the soil organic carbon content. The negative balance of organic carbon was registered with fertilizer N alone as well as with the combination of *Azospirillum*. The conjoint application of N with green manure and FYM has resulted in the build up of the soil organic carbon content.

Efficiency of green manuring with dhaincha or mungbean after one picking proved almost at par with or without the prilled urea (Singh *et al.*, 2001).

Masthana Reddy *et al.* (2001) did not notice any significant difference in grain yield of rice with farmyard manure or glyricidia green leaf manure.

2.2 EFFECT OF GREEN MANURE ON LOWLAND RICE

Green manuring has been known to favourably alter the availability of plant nutrients including the micronutrients (FAO, 1977).

Among the various ways to add organic materials to the soil, green manures appear to be a practical proposition (Mulongoy and Akobundu, 1985).

The N from green manure had a higher agronomic efficiency than that of the N from inorganic fertilizers (Morris *et al.*, 1986).

The green manure contains two fractions, one of which undergoes faster decomposition and releases N for the current crop, while the other mineralizes at a slower rate. Enhanced level of organic carbon might be due to the late fractions (Bouldin, 1987).

Ramasamy *et al.* (1988) reported that *Sesbania aculeata* (dhaincha) contained 3.2 per cent N, 0.31 per cent P and 1.1 per cent K.

Sesbania species are well adapted for use as a green manure in rice fields because of their ability to grow under varied climatic, soil and stress conditions (Garrity and Flinn, 1988).

In the tropics, *Sesbania* species especially *Sesbania aculeata* (dhaincha) is used as green manure in rice based cropping systems (Abrol and Palaniappan, 1988).

About eight weeks old dhaincha plants have been found to contain 3 per cent N in addition to K, Ca, Mg, P, S and micronutrients and about 33 kg N, 1 kg P, 14 kg K, 14 kg Ca, 16 kg Mg and 2 kg S are added to the soil if a tonne of dhaincha dry matter is applied (Bhuiyan *et al.*, 1988). Besides being a deep-rooted crop, dhaincha absorbs nutrients from the subsoil enriching the rice plough layer upon incorporation.

Padhmanaban (1990) reported that among the organic manures, green manure was the cheapest one. Legume-rhizobium symbiosis in most of the green manure crops is highly advantageous because, it supplies approximately 80-90 per cent of the total N requirement.

Siddeswaran (1992) noticed that mineralization of green manures ensured a continuous supply of NH_4^+-N, which was preferred and readily absorbed by the lowland rice crop, resulting in better growth.

Singh (1994) noticed that a good crop of *Sesbania aculeata* accumulates about 20 to 25 tonnes of biomass ha^{-1}, which could in turn supply about 175 to 200 kg N ha^{-1}.

In 45 days, the contribution of N through *Sesbania aculeata* was 116 kg ha^{-1} (Ghai *et al.*, 1988), 105 kg ha^{-1} (Chandrasekaran, 1989) and 53 to 103 kg ha^{-1} (Panda *et al.*, 1994).

Application of *Sesbania* sp. appeared to stimulate the release of soil N, thus showing a positive added N interaction effect (Seneviratna and Kulasooriya, 1994).

Green manuring with *Sesbania rostrata* increased both availability in soil and accumulation in plant of Fe, Mn and Cu due to the development of intense reduced condition, complex formations and greater nutrient binding capacity (Bhattacharyya and Mandal, 1996).

2.2.1 Growth Characters

The slow and steady supply of N by *Sesbania aculeata,* increased the soil fertility status and also improved the organic carbon status of the soil (Bhajan Singh and Brar, 1985) and in turn influenced the growth of rice.

Constant N supply due to slow release from the incorporated green manure would match with the absorption pattern of rice resulting in improved crop performance (Westcott and Mikkelson, 1987).

Chandrasekaran (1989) reported that green manuring increased the plant height, number of tillers, LAI and dry matter production.

Green manuring with *Sesbania aculeata* increased the growth, yield parameters, nutrient uptake and yield of rice (Padmavathy, 1992).

Incorporation of green manures resulted in promoting the growth of rice crop by increasing the plant height (Raju *et al.*, 1987; Srinivasulu Reddy, 1988; Budhar *et al.*, 1991 and Saravanapandian and Raniperumal, 1994) and tiller production (Ramasamy, 1990; Kolambe and Patel, 1994).

Application of N through green manures increased the leaf area index and dry matter production (Vaiyapuri *et al.*, 1995) CGR, NAR and RGR of rice (Matiwade and Sheelavantar, 1994). Vigorous plants with more number of tillers and broader leaves could be the possible reasons for increased LAI of rice recorded with green manure and *Azospirillum* combination (Nagaraju *et al.*, 1995).

Mahapatra and Sharma (1995) noted that green manuring with *Sesbania aculeata* increased the growth characters of rice.

Green manures raised during pre-season rice recorded higher values of growth parameters and yield of succeeding rice than pre-season fallow (Solaiappan *et al.*, 1996 and Subbalakshmi Lokanadhan *et al.*, 1999).

Application of green manure (*Sesbania aculeata* at 6.25 t ha^{-1}) along with *Azospirillum* recorded significantly shorter period for flowering and highest number of productive tillers m^{-2}, filled grains panicle^{-1}, panicle length and grain yield (Shanmugam and Veeraputhran, 2000).

2.2.2 Yield Attributes

Green manuring with *Sesbania rostrata* has resulted in significant increase in length of panicle, filled grains panicle^{-1} and 1000-grain weight in comparison with recommended dose of N through chemical fertilizer (Matiwade and Sheelavantar, 1994).

Saravanapandian and Raniperumal (1994) reported that productive tillers m^{-2}, filled grains panicle^{-1} and 1000-grain weight were perceptibly increased by green manuring with *Sesbania rostrata*.

Solaiappan *et al.* (1996) observed that green manure incorporated plots recorded higher values of number of grains panicle^{-1} and 1000-grain weight of rice.

Longer panicles (Reddy, 1985), more number of filled grains panicle^{-1} (Vaiyapuri *et al.*, 1998), increase in number of panicles unit area^{-1} (Budhar *et al.*, 1991) and a moderate increase in thousand grain weight of rice (Nachimuthu, 1985) were registered with green manuring practice.

Green manuring has significantly increased the number of panicles hill^{-1}, length and weight of panicles, number of filled grains panicle^{-1} and thousand-grain weight of rice (Thakur *et al.*, 1999).

Green manures promoted the supply of assimilates to sink, thus increasing the length of panicle with more number of spikelets and filled grains and thousand grain weight (Thiagarajan, 1991; Thakur *et al.*, 1999).

2.2.3 Yield

Roy *et al.* (1988) reported that incorporation of *Sesbania aculeata* at 5 t ha^{-1} increased grain yield of rice by 34 per cent over control.

According to Chandrasekaran (1989) the marked increase in grain yield of rice due to green manuring could be attributed to the enrichment of soil fertility resulting from N fixation by rhizobial nodule as well as their green matter addition.

Yield response of rice to green manuring in India ranged from 0.65 to 3.1 t ha^{-1} in high yielding varieties (Yadvinder Singh *et al.*, 1991).

Grain and straw yields of rice were significantly increased, when *Sesbania rostrata* was incorporated as green manure prior to rice (Halepyati and Sheelavantar, 1992).

Manguiat *et al.* (1992) reported that green manure alone improved the grain yield of rice crop by about 18 q ha^{-1} over that of control.

Matiwade and Sheelavantar (1994) stated that green manuring with *Sesbania rostrata* alone resulted in higher grain yield of rice (52.07 q ha^{-1}) than that realized with application of 100 per cent fertilizer N (50.53 q ha^{-1}).

Pandey *et al.* (1995) reported that green manure was capable of producing and sustaining more than 6 t ha^{-1} of rice yield, which was equal to 100 kg inorganic N ha^{-1}.

Thakur *et al.* (1995) proved that seed and straw yield of rice increased significantly due to green manuring with *Sesbania aculeata*.

Green manure has not only increased the grain yield but also enhanced the sustainability of soil due to higher residual recoveries of nutrients (Deka Medhi and De Datta, 1996).

Green manuring with *Sesbania aculeata* gave higher rice yield, which was at par with 20 t ha^{-1} of FYM (Misra *et al.*, 1996)

Green manuring with *Sesbania aculeata* gave the highest yield of rice as reported by Paturde and Patankar (1998).

Reducing the recommended fertilizer dose to half along with sunhemp (*Crotalaria juncea* L.) green manuring recorded comparable yield of rice with that of recommended N P K (Subhash Chandra *et al*., 2001).

2.2.4 Nutrient Uptake

Tiwari *et al.* (1980) observed that the nutrient content of rice plant at tillering stage has increased from 1.58 to 1.88 per cent of N. 0.45 to 0.69 per cent of P and 2.73 to 3.48 per cent of K due to green manuring.

The green manures undergo slow decomposition and the mineralization may help in the release of N to meet the requirement of rice crop at the critical stages (Meelu *et al*., 1986).

Organic acids produced during decomposition of green manures solubilises insoluble P and increases P uptake (Ventura *et al*.. 1987).

The N uptake in grain and straw increased significantly by the application of green manure (Ghai *et al*., 1988). Antil *et al.* (1989) recorded highest uptake of N when rice crop was green manured with dhaincha.

Budhar *et al.* (1991) recorded increased uptake of N P K with *Sesbania rostrata* as green manure to rice crop. Higher N and P uptake by rice was noticed with incorporation of *Sesbania rostrata* applied with 50 per cent phosphorus and no nitrogen (Halepyati and Sheelavantar, 1992).

Green manuring enhanced the uptake of N (Hundal and Thind, 1993), P (Siddeswaran, 1992) and K (Sreedevi and Thangamuthu, 1991).

Bindra and Thakur (1995) observed that green manuring with *Sesbania aculeata* increased N, P and K uptake by rice.

Nitrogen uptake in grain and straw were increased significantly by the application of green manures (Deka Medhi and Medhi, 2000).

2.2.5 Soil Fertility Status

Application of green manure influenced the availability of P and other elements through better mobilization (Muneendra Naidu, 1981).

Organic acids produced during decomposition of green manure besides solubilizing the insoluble P (Ventura *et al*, 1987), adds substantial quantities of other nutrients viz., Ca, Mg, S, Cu, Fe and Mn in soil after incorporation of green manure (Ponnamperuma, 1984).

In water logged soils, green manures increased the availability of P through the mechanism of reduction, chelation and favourable changes in soil pH (Hundal *et al.*, 1987).

Green manuring with N fixing legume crop contributed to a substantial part of the N requirement of rice and supplied organic matter to rice soils (Bouldin, 1988).

Mahapatra *et al.* (1991) observed steep increase in organic carbon and total N status of the soil following green manuring with dhaincha.

Significant raise in the total N status of the soil due to incorporation of *Sesbania rostrata* was noticed by Halepyati and Sheelavantar (1992).

Green manuring with *Sesbania aculeata* resulted in significantly higher soil organic carbon content, available N, P and K than when French bean was used as green manure (Thakur *et al.*, 1995).

Mahapatra and Sharma (1995) reported that inoculation of *Sesbania aculeata* increased the available soil N after harvesting of rice.

Green manuring with *Sesbania rostrata* improved the soil organic carbon, available N and K (Somasundaram *et al.*, 1996)

Application of *Sesbania aculeata* has enriched the soil organic carbon (Sriramachandrasekaran *et al.*, 1996).

None of the inorganic fertilizer treatments was capable of maintaining soil fertility except green manuring with 100 or 50 per cent of N P K (Subhash Chandra *et al.*, 2001).

2.2.6 Equivalence of Fertilizer

Application of green manure reduced denitrification, volatilization and leaching losses of N and thus reduced the total N loss by 19 to 46 per cent (Mu and Quian, 1983).

Sixty days old *Sesbania aculeata* and *Sesbania rostrata* incorporated prior to planting of rice contributed fertilizer N equivalent to 60 kg ha^{-1} (Furoc *et al.*, 1985). Meelu and Morris (1986) concluded that green manuring could contribute fertilizer N equivalent to 50 to 100 kg ha^{-1}.

The magnitude of leaching, denitrification and NH_3 volatization losses may be lower for green manure-N than for fertilizer-N, especially in the presence of a rice crop, because of relatively slower rate of N release from plant materials (Nagarajah, 1988).

Saravanan *et al.* (1988) found higher NUE of 21.5 kg grain kg^{-1} N with conjunctive use of green manure and prilled urea than prilled urea alone (17.1)

The cumulative volatilization loss of nitrogen was higher (13% of the applied amount), when N was applied in the form of urea alone as basal dressing and it was lower (6%) when it was applied in combination with dhaincha on 1:1 basis (Santra *et al.*, 1988).

Maskina *et al.* (1989) reported that eight weeks old *Sesbania aculeata* and *Crotalaria juncea* can contribute N equivalents of 90 to 100 kg ha^{-1} respectively.

Integrated use of organic and inorganic nitrogen lowered the agronomic efficiency, physiological efficiency but enhanced the apparent N recovery and nitrogen harvest index (Siddeswaran, 1992).

In a laboratory study, it was observed that soil amended with green manure alone was not having any NH_3 volatization (Khind *et al.*, 1989; Rekhi and Bajwa, 1994).

The average N loss in flooded soils from applied green manures was considerably lower (14%) than that of split applied urea (35%) thus resulting in less pollution to the environment (Becker *et al.*, 1994).

Application of green manure along with urea may reduce NH_3 losses from urea lowering pH in the flood water (De Datta, 1995).

Combined application of green manures and prilled urea is the most efficient fertilization method with relatively low N losses due to volatilization and leaching compared to prilled urea alone (Das *et al.*, 1995).

Green manuring has significantly reduced both leaching and gaseous loss of fertilizer as confirmed from ^{15}N studies and remained most efficient under drought prevailing at the rice vegetative stage (Bhattacharyya and Mandal, 1997).

2.2.7 Mineralization of Green Manures

Bouldin (1988) proposed a simple two-component model to describe the N mineralization pattern of green manures. The organic material was treated as if there were two distinct components, one that decomposed rapidly the other that decomposed slowly.

The fate and availability of N from green manures depended upon the magnitude and extent of its decomposition and associated N mineralization process (Palm *et al.*, 1988).

Laboratory studies (Beri *et al.*, 1989a) have shown that under submerged conditions obtained in rice paddies, about 80 per cent total N and 40 per cent of total C in dhaincha was released in about 10 days. To prevent the loss of this released N, it is recommended to transplant rice immediately after incorporation of green manure and not to wait for 2-3 weeks as recommended under upland conditions.

Following incorporation of dhaincha, the accumulation of soil ammonia reached its peak at 7 to 20 days after rice transplanting and then gradually declined (Beri *et al.*, 1989b).

Release of NH_4^+ -N from green manure was initially rapid, but slowed down markedly with in a short time (Lin and Wen, 1990).

Bhandari *et al.* (1992) observed that *Sesbania aculeata* released the major part of N (25-80 %) with in 40 days after incorporation.

During mineralization of green manures the release of NH_4^+ -N reached its peak at 10 days (Becker *et al.*, 1991) and at 20 days (Tiwari *et al.*, 1995; Pushpavalli *et al.*, 1994) after incorporation into the soil.

2.3 EFFECT OF NEEM LEAF MANURE (GREEN LEAF MANURE) ON RICE CROP

Several green leaf manures viz., neem, pongamia, calotropis, glyricidia, Tephrosia, Cassia, Thespesia and Ipomea are being used by traditional rice growers in Southern parts of India to supplement the fertilizer N.

2.3.1 Growth Characters

Santhi and Palaniappan (1987) reported that leaf area index was highest with incorporation of fresh neem leaf @ 5 t ha^{-1}.

Budhar *et al.* (1991) reported a marked increase in plant height, tiller number and leaf area index with neem leaf manuring.

Krishna Murthy and Mathan (1995) observed that there was no significant difference in plant height of rice due to different green leaf manures including neem leaf.

Neem leaf manuring resulted in taller plants, more number of tillers, larger leaf area index and higher quantity of dry matter accumulation than all other sources of nitrogen (Subba Reddy, 1997).

Growth components of rice like plant height, number of tillers, leaf area index and dry matter accumulation were found superior with neem leaf manuring to fertilizer nitrogen (Vasanth Kumar, 1996; Upendra Rao, 1998).

2.3.2 Yield Attributes

Budhar *et al.* (1991) found that number of filled grains per panicle was more with neem leaf manuring.

Krishna Murthy and Mathan (1995) observed increased panicle length with neem leaf manuring.

Yield components of rice viz., panicles m^{-2}, panicle length and number of filled grains $panicle^{-1}$ were significantly higher with neem leaf manuring than other green manures (Vasanth Kumar, 1996).

Velayudham *et al.* (1996) reported elevated level of yield structure of rice with neem leaf manuring. Neem leaf manuring has manifested better yield structure with larger number of panicles m^{-2}, longer panicles, more number of filled grains with higher grain weight than all other sources of N (Subba Reddy, 1997).

Beneficial effect of neem leaf manuring on different yield components like number of panicles, filled grains, spikelet sterility and grain weight was observed by Upendra Rao (1998).

2.3.3 Yield

Santhi and Palaniappan (1987) reported that grain and straw yields were highest with incorporation of fresh neem leaf at 5 t ha^{-1}. Alkaloids in neem products reduced the activity of nitrifying organisms. Incorporation of fresh leaves into soil before transplanting improved rice yields over application of dried neem leaves, neem cake and urea.

Green leaf manuring with 6.25 t ha^{-1} of fresh neem leaf has given 17 7 and 2.19 per cent more grain and straw yield over unfertilized plot. Green leaf manuring with 6.25 t ha^{-1} of fresh neem leaf alone produced 4.1 t ha^{-1} of grain where as 100-50-50 N.P K fertilized plot has given 5.1 t ha^{-1} (Subramaniyam and Ranga Rajan, 1990).

Neem leaf manuring resulted in production of 44 and 76 per cent more grain and straw yield respectively over no nitrogen (Alam and Azmi, 1990).

Highest grain yield of 3416 kg ha^{-1} was obtained with neem leaf manuring, which was significantly higher than Calotropis (Krishna Murthy and Mathan, 1995).

Velayudham *et al.* (1996) reported that organic wastes including neem leaf, increased the grain and straw yield of rice significantly. The increase in grain yield over control was 18 per cent with neem leaf at 5 t ha^{-1}.

Grain yield of rice was significantly higher with neem leaf manuring, which was in parity with Pongamia, sunhemp and glyricidia manuring. Neem leaf manuring was found to be beneficial in economizing nearly 50 per cent of the fertilizer nitrogen (Vasanth Kumar, 1996).

Subba Reddy (1997) recorded distinctly higher grain yield with neem leaf manuring as compared to prilled urea and neem cake coated urea.

2.3.4 Harvest Index

Alam and Azmi (1990) found distinct superiority of neem leaf manuring in improving harvest index of rice.

Harvest index of rice was higher with neem leaf manuring followed by pongamia than other green manures (Vasanth Kumar, 1996).

In contrast to afore cited results, Budhar *et al.* (1991), Krishnamurthy and Mathan (1995) and Velayudham *et al.* (1996) did not notice any influence of neem leaf manuring on harvest index.

Harvest index of rice was improved by neem leaf manuring as well as different neem products added to urea (Subba Reddy, 1997).

2.3.5 Nitrogen Uptake

Santhi and Palaniappan (1987) reported that N recovery and response to N was highest with incorporation of fresh neem leaf at 5.5 t ha^{-1}.

Nitrogen uptake by rice was higher with pongamia and neem leaf manuring than with other green manures as well as fertilizer N (Vasanth Kumar, 1996).

Subba Reddy (1997) proved the superiority of neem leaf manuring over both neem cake coated urea and prilled urea with respect to nitrogen uptake at different stages of crop growth.

Upendra Rao (1998) reported that nitrogen uptake with neem leaf manuring at 10 t ha^{-1} was equally effective as that with 50 kg N ha^{-1} supplied through fertilizer.

2.3.6 Soil Fertility Dynamics

Budhar *et al.* (1991) observed improvement in post harvest soil nutrient (N, P and K) status with neem leaf manuring.

Vasanth Kumar (1996) revealed that neem leaf manuring at 12.5 t ha^{-1} was found to be superior with regard to organic carbon and available nitrogen and almost equivalent with respect to soil available P and K status with 120 kg N ha^{-1} as fertilizers.

Neem leaf manuring distinctly proved its beneficial effect in improving the post harvest soil fertility status over fertilizer nitrogen (Subba Reddy, 1997).

Superiority of neem leaf manuring in improving the different soil fertility parameters like organic carbon and available N, P and K status of soil over fertilizer nitrogen was also noticed by Upendra Rao (1998).

2.3.7 Economics

Vasanth Kumar (1996) observed that neem leaf manuring at 12.5 t ha^{-1} could save 80 kg N ha^{-1}, gave net profit and benefit cost ratio equivalent to those with 120 kg N ha^{-1} through fertilizers.

Neem leaf manuring gave net profit and benefit cost ratio comparable to those with 50 kg N ha^{-1} through fertilizer (Upendra Rao, 1998).

2.4 FARM YARD MANURE (FYM)

2.4.1 Growth Characters

Tripathi *et al.* (1990) found that the application of graded levels (0, 5, 10 and 15 t ha^{-1}) of FYM increased the dry matter production of rice at various stags of crop growth. However, maximum response was found up to 15 t ha^{-1}.

Budhar *et al.* (1991) reported that relatively less number of tillers hill^{-1} were observed with the application of FYM at 5 t ha^{-1} compared to poultry manure.

Rajput and Warsi (1991) concluded that the application of FYM with and without inorganic N significantly increased tillers hill^{-1}.

Bal *et al.* (1993) observed that the plant height and dry matter production were significantly increased with application of FYM at 5 t ha^{-1} compared to control but, it was on par with glyricidia leaf manure at 5 t ha^{-1}.

Singh *et al.* (1996) found that the plant height of rice was not significantly increased due to application of FYM (0 to 20 t ha^{-1}).

Ramakrishna Reddy (1996) noticed that the growth parameters like plant height, number of tillers m^{-2} and dry matter production of rice were higher with FYM application compared to neem cake @ 120 kg N ha^{-1}.

2.4.2 Yield Attributes

Basal incorporation of FYM at 5 t ha^{-1} did not differ in producing filled grains panicle^{-1} and test weight of rice grains compared to poultry manure (Budhar *et al.*, 1991).

Bal *et al.* (1993) noticed that the number of panicles hill^{-1}, panicle length, number of filled grains panicle^{-1} and 1000-grain weight were significantly higher with application of FYM at 5 t ha^{-1} compared to control and it was inferior to glyricidia leaf manure applied at the same rate.

Ramakrishna Reddy (1996) observed that the productive tillers m^{-2}, filled grains panicle^{-1} and 1000-grain weight were perceptibly increased by FYM application at 120 kg N ha^{-1} compared to neem cake.

Singh *et al.* (1996) found that the panicle length and grains panicle^{-1} were significantly increased with increasing level of FYM from 0 to 20 t ha^{-1} but the increase was not significant beyond 10 t ha^{-1}.

2.4.3 Yield

Many researchers have reported that the increase in grain yield of rice due to incorporation of FYM at 10 t ha^{-1} (Maskina *et al.*, 1985) 12 t ha^{-1} (Purushothaman *et al.*, 1990) and 20 t ha^{-1} (Tandon, 1991).

Grain and straw yields were significantly higher with FYM at 5 t ha^{-1} compared to control but it was inferior to application of glyricidia at 5 t ha^{-1} (Bal *et al.*, 1993).

Radha Madhav *et al.* (1996) revealed that the highest harvest index was obtained with application of FYM at 25 t ha^{-1}.

Dubey and Verma (1999) observed that the grain and straw yields were significantly higher with 100 per cent N supplied through FYM compared to control and it was on par with 100 per cent N through either poultry manure or glyricidia leaf manure.

Application of FYM @ 10 t ha^{-1} and blue green algae (BGA) inoculation either alone or in combination, increased the economic yield. The average increase in grain yield due to BGA was 0.24 t ha^{-1} (7.5%) while combined use of FYM and BGA showed the increase of 0.60 t ha^{-1} (19.2%) (Dixit and Gupta, 2000).

2.4.4 Soil Fertility Dynamics

Application of FYM or compost at 25 t ha^{-1} increased available potassium content of soil (Udayasoorian *et al.*, 1989).

Budhar *et al.* (1991) reported that there was higher amount of residual N in plots treated with FYM or poultry manure or biogas slurry at 5 t ha^{-1}.

Yadvinder Singh *et al.* (1995) noticed that fertilizer N equivalent of FYM in rice ranged from 42 to 52 per cent of the total N applied and the apparent N recovery was 20 per cent from FYM as compared with 35 to 46 per cent in urea.

Radha Madhav *et al.* (1999) revealed the available nitrogen and phosphorus status of soil after harvest of rice were significantly more with incorporation of FYM at 120 kg N ha^{-1} compared to other organic sources like glyricidia and Ipomea leaf manures.

Dubey and Verma (1999) recorded higher soil organic carbon and available N with 100 per cent N applied through FYM compared to control, but it was on par with 100 per cent N through either poultry manure or glyricidia leaf manure.

Application of 12 t of FYM ha^{-1} can save 40 kg N ha^{-1} to rice and also provide residual effect equivalent to 30 kg each of N and P ha^{-1} on succeeding wheat crop (FAO, 1980).

Substitution of FYM to the fertilizer nitrogen @ 25 kg ha^{-1} (5 tonnes ha^{-1} of FYM) has significantly increased the organic carbon content of the soil from 0.19 to 0.21 per cent (Saran Ram *et al.*, 2000).

2.4.5 Economics

Rajput and Warsi (1992) reported that the application of FYM at 10 t ha^{-1} could save 50 kg N ha^{-1} and gave maximum yield of rice.

Ramakrishna Reddy (1996) obtained higher net returns and benefit cost ratio with 50 per cent substitution of fertilizer N through FYM or Ipomoea compared to neem cake, but it was on par with 100 per cent N supplied through urea.

Dubey and Verma (1999) realized higher net returns and benefit cost ratio with 50 per cent N each through FYM and urea compared to 100 per cent N through FYM alone.

2.5 EFFECT OF AZOSPIRILLUM ON RICE CROP

Inoculation of *Azospirillum* increased the fertilizer use efficiency of the applied inorganic N (Heulin *et al.*, 1991).

Saravanapandian and Raniperumal (1994) reported that *Azospirillum* along with 150 kg N ha^{-1} recorded higher grain yield of 5.6 t ha^{-1}.

The benefit cost ratio (4.52) was maximum for the treatment applied with 50 per cent N as inorganic plus 25 per cent N each through *Sesbania aculeata* and *Azospirillum* (Balasubramanian and Veerabadran, 1997).

Gopalaswamy and Raj (1997) reported that without N fertilizer, application of *Azospirillum* alone augmented the grain yield of rice.

The highest mean grain yield of 45 q ha^{-1} was given by *Azospirillum* + 60 kg N ha^{-1}, compared to 29 q ha^{-1} in untreated control (Singh and Choudhary, 1997).

Rice cv.RP-2365 with *Azospirillum brasilense* recorded highest grain yield by 61 per cent compared to uninoculated control (Sudhir Pradhan *et al.*, 1998).

Incorporation of *Azospirillum* did not show any improvement in the N status of the soil (Saravanapandian and Rani Perumal, 2000).

2.6 EFFECT OF INORGANIC N ON RICE CROP

The applied N to rice suffered losses such as denitrification (Craswell and Viek, 1979), volatization (Broadbent, 1979), leaching and runoff (Koshino, 1975).

The effect of N on yield attributes is primarily a function of assimilates accumulation and in turn, facilitating higher N assimilation with adequate supply of photosynthates to grain (Krishnakumar, 1986).

Nitrogen fertilizer is a substrate for the synthesis of organic N compounds and proteins, which are the constituents of protoplasm and chloroplast. In addition to the nutritional status, N can also be looked as from the hormonal view point. which stimulates meristematic growth and cytokinin biosynthesis (Budhar *et al.*, 1989).

2.6.1 Growth Characters

Narsa Reddy *et al.* (1987) reported that with each successive increment of nitrogen by 40 kg N ha^{-1} up to 120 kg N ha^{-1}, dry matter accumulation increased significantly. Increased level of N from 0 to 150 kg ha^{-1} progressively augmented the dry matter production of rice (Raju *et al.*, 1989).

LAI was found to increase significantly with added levels of N. However, the response was limited up to 80 kg N ha^{-1}, which was in parity with 120 kg N ha^{-1} (Prasad *et al.*, 1994).

Prasad *et al.* (1994) reported that number of tillers showed a significant variation with increasing levels of nitrogen up to 80 kg N ha^{-1}.

Gopal (1994) observed increase in plant height and tillering up to 140 kg N ha^{-1}, while the dry matter production increased significantly only up to 100 kg N ha^{-1}.

Growth attributes viz., biomass accumulation, leaf area index and tillering increased significantly up to 120 kg N ha^{-1} (Raju and Reddy, 1997).

Plant height and dry matter production of rice has significantly increased with each successive increase in nitrogen level from 0 to 150 kg ha^{-1}, beyond which the improvement in these parameters was not noticeable (Hari *et al.*, 1997).

2.6.2 Yield Attributes

Panicle length was increased with increase in N levels up to 60 kg, which was at par with 90 kg ha^{-1} (Rama Subba Reddy *et al.*, 1986).

Madan Mohan Reddy *et al.* (1987) reported that increasing levels of nitrogen increased the spikelet sterility and the reason for higher chaffiness was attributed to the accumulation of more soluble and non-productive nitrogen at higher nitrogen levels.

Singh and Varma (1989) have observed increased grain weight with increasing the dose of N up to 120 kg ha^{-1}.

Yield components like number of productive tillers m^{-2}, filled grains panicle^{-1} and thousand-grain weight was enhanced with increased levels of N application (Duraisamy and Palaniappan, 1989)

Increase in filled grains per panicle was only up to 40 kg N ha^{-1}. At 80 kg N ha^{-1} and 120 kg N ha^{-1}, the change was not striking (Husain and Sharma, 1991).

Nitrogen application increased the panicle number only up to 40 kg N ha^{-1} beyond which the response was not statistically accountable (Husain and Sharma, 1991).

The length of panicle increased only up to 80 kg N ha^{-1}, beyond which there was no response (Prasad *et al.*, 1992). Length of the panicle increased with each successive increment of N levels from 0 to 150 kg N ha^{-1} (Shukla *et al.*, 1993).

Thakur (1993) reported significant increase in 1000-grain weight up to 80 kg N ha^{-1}, beyond which the increase was negligible.

Increase in panicle number with increasing levels of nitrogen has been reported by a number of research workers (Reddy *et al.*, 1987; Thakur, 1993; Pandey and Tripathi, 1994).

Saravanapandian and Raniperumal (1994) observed that the panicle number increased only up to 150 kg N ha^{-1} and further increase did not bring significant changes.

Increasing the level of nitrogen significantly increased the 1000-grain weight (Channabasavanna and Setty, 1994; Syed Nazeer Peeran and Sree Ramulu, 1995).

Increasing the levels of nitrogen significantly increased the spikelet sterility (Syed Nazeer Peeran and Sree Ramulu, 1995).

Shashi Kumar *et al.* (1995) noticed a decrease in the spikelet sterility when nitrogen level was increased from 80 kg N ha^{-1} to 120 kg N ha^{-1}.

Application of nitrogen had a noticeable effect on the number of filled grains per panicle, which increased significantly with increasing levels of nitrogen (Saravanapandian and Reniperumal, 1994; Syed Nazeer Peeran and Sree Ramulu, 1995; Chander and Pandey, 1996; Gupta 1996 and Budhar and Palaniappan, 1997).

Yield components viz., number of panicles m^{-2}, total number of grains, filled grains $panicle^{-1}$ and 1000-grain weight increased consistently even up to 200 kg N ha^{-1} through integrated sources (Budhar and Palaniappan, 1997).

2.6.3 Yield

Increasing N supply from 40 to 80 kg ha^{-1} increased the grain yield of rice, beyond which the enhancement was not-significant up to 120 kg N ha^{-1} (Pandey and Singh, 1987).

Patra *et al.* (1989) reported that the grain yield increase with increased level of N was only up to 60 kg N ha^{-1}.

Shanmugasundaram and Selvakumar (1993) observed that the level of N has significant effect on grain yield. Application of N @ 120 kg ha^{-1} recorded the highest grain yield (5254 kg ha^{-1}), which was however, on par with 160 kg N ha^{-1} (5145 kg ha^{-1}).

Increase in the level of nitrogen increased straw yield up to 120 kg N ha^{-1} which was however in parity with 80 kg N ha^{-1}. Straw yield was increased by 54.3 per cent with 80 kg N ha^{-1} over control (Marazi *et al.*, 1993).

Hari *et al.* (1997) noticed significant increase in grain yield with successive increase in N level from 0 to 150 kg N ha^{-1} and significant increase in straw yield was found even up to 200 kg N ha^{-1}.

2.6.4 Harvest Index

Satyanarayana (1986) and Karunasagar (1989) observed a decrease in harvest index with increased levels of nitrogen application.

Dalal and Dixit (1987) did not find any significant difference in harvest index with increased level of N from 0 to 120 kg ha^{-1}.

De *et al.* (1992) reported that the harvest index was significantly increased with increased levels of nitrogen.

According to Dwivedi (1997), highest harvest index was recorded with 60 kg N ha^{-1}, which was at par with 90 kg N ha^{-1}.

2.6.5 Nutrient Uptake

Increasing the levels of nitrogen from 90 kg to 150 kg ha^{-1} significantly increased the uptake of potassium (Mehta *et al.*, 1983).

The supply of fertilizer N along with other organic sources is known to stimulate the mineralization and then immobilization of organic N and reduces the losses of N (Meelu *et al.*, 1985).

With successive increment in dose of nitrogen by 40 kg ha^{-1} from 0 to 120 kg N ha^{-1} the uptake of phosphorus was found to be significantly increased (Rama Subba Reddy *et al.*, 1986).

Both N content and N uptake increased significantly with increased N levels. The percentage increase in N uptake at 80 kg N ha^{-1} over 40 kg N ha^{-1} in grain was 65 and in straw it was 60 (Singandhupe and Rajuput, 1990).

Sreedevi and Thangamuthu (1991) reported highest uptake of N (63.2 kg ha^{-1}), phosphorous (41.2 kg ha^{-1}) and potassium (168.4 kg ha^{-1}) with 120 kg N ha^{-1}.

Upadhyay and Patel (1992) noticed that enhanced supply of N had significantly increased N uptake by grain and straw, whereas decreased the nitrogen use efficiency.

Nitrogen uptake was higher with 120 kg ha^{-1} applied through inorganic N as urea alone compared with organics alone or combined use of organic and inorganic sources of N on sandy clay loam soils of Bapatla (Hari Prasad, 1993).

A gradual increase in uptake of nitrogen, phosphorus and potassium with increased level of nitrogen application has been reported from several studies (Thakur, 1993; Shukla and Sharma 1994 and Shashi Kumar *et al.*, 1995).

2.7 INTEGRATED NITROGEN MANAGEMENT FOR RICE CROP

Plants absorbs N from three major sources viz., soil, fertilizer and biologically fixed nitrogen. The soil and biologically fixed N are rarely sufficient to meet the N requirements of modern high yielding rice genotypes (Yoshida and Ancajar, 1973). Hence, application of inorganic N becomes imperative.

In view of relatively high cost of fertilizers, better management practices should be advocated to get high yield of rice with reduced quantity of fertilizer. With the adoption of modern technology of intensive cropping with high yielding varieties, there is a considerable demand on the soil for nutrients. However, the native fertility of our soil is poor and cannot sustain high crop yields (Ghosh and Hassan, 1980).

There is no doubt that mineral fertilizers are essential to realize maximum crop yields, but in long term experiments where only mineral fertilizers have been used, crop yield has steadily decreased (FAO, 1982).

A study on the use of organic, biological and chemical fertilizers in rice based cropping systems by Meelu and Morris (1986) revealed that INM was beneficial in maintaining soil organic matter, improving soil fertility and rice yields.

Integrated use of organic and biological sources of N with mineral fertilizer is a possible way, not only for substituting atleast part of N, but also achieving ecologically sound and sustainable agriculture (Swaminathan, 1987a).

The best means of maintaining soil fertility and productivity at a maximum level is through periodic addition of organic manures in conjunction with mineral fertilizers. Combined use of organic manures and fertilizer nitrogen significantly increased the rice yields in comparison with the organic manures or fertilizers alone (Thakur, 1991).

The integrated use of organic manures, biofertilizers and chemical fertilizers not only help to maintain optimum crop yields, but also result in long term soil productivity. The organic source of nutrients could be considered as supplements to chemical fertilizers and not as substitutes (Mishra and Kapoor, 1992 and Hegde and Dwivedi, 1993).

Combination of organics with inorganic fertilizers increased the crop production without impairing soil health. Combined application of organic and inorganic N to rice in equal proportion resulted in higher grain yield than either of the sources applied alone (Rao and Moorthy, 1994; Rajamannar *et al.*, 1995).

Hegde (1996) observed that integrated use of inorganic and organics increased soil organic carbon status but had no marked effect on available P and K content.

Combined use of inorganic fertilizers along with 50 per cent N substitution from various organic sources recorded higher grain values than 25 per cent N substituted treatments (Basumatary and Talukdar, 1997).

Bellaki *et al.* (1998) reported that available major and micronutrients increased significantly with combined application of organic and inorganic sources of nutrients.

Sunhemp, FYM and green gram combined with prilled urea (PU) proved better than PU alone and exerted similar effect on panicles m^{-2}, grain and straw yields of rice (Pandey *et al.*, 2001).

A significant increase in plant height. number of effective panicles, grain weight per panicle, grain and straw yield was observed with integrated treatment combinations over full dose of fertilizer N. Also there was no significant difference among the different combination of integrated treatments (Rajni Rani and Srivastava 2001).

2.8 INTEGRATED USE OF GREEN MANURE AND FERTILIZER NITROGEN ON RICE CROP

Application of green manure along with inorganic N increased the mineralization of soil N, improved the biological activity of soil and reduced the N losses (Hesse, 1984).

Application of N in equal proportion through green manure and inorganic sources hastened the release of ammonical N (Broadbent, 1981), promoted root and plant growth (Cao *et al.*, 1983) and finally improved the yield (Palm *et al.*, 1988).

Bhagat *et al.* (1988) reported that application of 50 per cent nitrogen through green manure (*Sesbania aculeata*) and the rest through urea in three splits produced higher grain and straw yield of 3.5 and 4.0 t ha^{-1}, respectively.

Rice with 60 kg N ha^{-1} and dhaincha green manure at 10 t ha^{-1} had more N uptake than with 60 kg ha^{-1} of inorganic N and equal to that of 120 kg ha^{-1} of inorganic N alone (Maskina *et al.*, 1989).

The growth characteristics and yield attributes were positively influenced by green manuring along with chemical fertilizers (Singh *et al.*, 1990).

Matiwada and Sheelavantar (1994) reported that organic and inorganic fertilizers applied in equal proportions could be used to realize higher and sustained yields in low land rice.

Duhan and Mahendran Singh (1994) reported that combination of chemical fertilizer and green manure yielded better than either of chemical fertilizers alone or green manure alone.

Combined application of 60 kg N ha^{-1} through urea and 20 kg N ha^{-1} through green manuring resulted in increased N uptake by rice. which was comparable with that of 80 kg N ha^{-1} through urea alone. Residual soil fertility in terms of available N increased under green manuring, whereas urea N alone made no impact on fertility build up (Rathore *et al.*, 1995).

Rice yield obtained with green manuring alone was equivalent to split application of 90 kg N ha^{-1}. Combined application of green manure and inorganic N, except for *Sesbania cannabina* + 45 kg N ha^{-1} applied at panicle initiation gave similar yield to that of recommended N at 120 kg ha^{-1} (Mahapatra and Sharma, 1996).

Application of 80 kg N ha^{-1} as green manure a week before transplanting of rice gave the highest grain yield of rice but was comparable to substitution of 50 per cent basal nitrogen through green manuring and with 50 per cent nitrogen through prilled urea (Mahapatra *et al.* 1997).

2.9 INTEGRATED USE OF NEEM LEAF AND FERTILIZER NITROGEN ON RICE CROP

Neem leaf manuring exhibited complementary effect with fertilizer nitrogen in elevating the rice yield (Krishna Murthy and Mathan, 1995).

Combined use of 40 kg N ha^{-1} with neem leaf manuring at 12.5 t ha^{-1} resulted in 10 per cent higher grain yield than with 120 kg N ha^{-1} through fertilizer nitrogen alone (Vasanth Kumar, 1996). Also it was reported that nitrogen uptake by rice crop with neem leaf manuring along with 40 kg fertilizer N ha^{-1} was superior to that with 80 kg N ha^{-1} through fertilizer alone.

Higher net returns and benefit cost ratio were obtained with conjunctive use of neem leaf manure and 40 kg fertilizer N ha^{-1} than those with 120 kg N ha^{-1} through fertilizer alone (Vasanth Kumar, 1996).

Growth characters, yield attributes, yield, harvest index, N uptake, soil nutrient dynamics and economics were the highest with combination of neem leaf along with prilled urea (Vasanth Kumar, 1996; Subba Reddy, 1997 and Upendra Rao, 1998).

Conjunctive use of neem leaf manure and prilled urea has registered an impressive trend on the grain yield. Neem leaf manuring along with 25 kg N ha^{-1} has resulted in higher grain yield than that with 50 kg N ha^{-1} through other sources. At all the levels of N supply ranging from 25 to 100 kg N ha^{-1}, neem leaf manuring displayed distinct superiority over other combinations (Subba Reddy, 1997).

Yield parameters like number of panicles m^{-2}, grains per panicle, sterility percentage and 1000-grain weight resulted due to neem leaf manuring in combination with lower levels of fertilizer nitrogen were found equally effective as those with 50 kg additional nitrogen applied through fertilizer alone (Upendra Rao, 1998).

Upendra Rao (1998) obtained higher net profit and almost equal benefit cost ratio with combined use of 25 kg fertilizer N ha^{-1} and neem leaf manure than with 75 kg N ha^{-1} through fertilizer nitrogen alone. He has also indicated the possibility of saving 50 kg N ha^{-1} of fertilizer N.

Murugaiah (2000) revealed that conjunctive use of inorganic fertilizer and neem leaf to supply 50 per cent N each, would be fruitful in obtaining higher yields of low land rice, with profitable returns, besides improvement in soil fertility status

2.10 INTEGRATED USE OF FARM YARD MANURE AND FERTILIZER NITROGEN ON RICE CROP

Various studies conducted have shown that combined use of FYM @ 12 t ha^{-1} and 60 kg N ha^{-1} (Kulkarni *et al.*, 1983) and application of FYM @ 12 t ha^{-1} in combination with 80 kg N ha^{-1} produced rice grain yield equivalent to that obtained with 120 kg N ha^{-1} (Maskina *et al.*, 1985).

Sharma and Sharma (1994) noticed that an increase in number of panicles m^{-2}, when FYM was applied along with urea. Application of 30 kg N ha^{-1} through FYM along with 90 kg N ha^{-1} as urea resulted in more number of spikelets $panicle^{-1}$ and higher grain yield than other treatmental combinations or when compared with other individual applications.

Powar *et al.* (1995) stated that the treatment using urea and 40 per cent FYM with 100 kg N ha^{-1} applied in three splits gave the highest rice grain yield.

Jana and Ghosh (1996) noticed that the rice grain yield in winter season was the highest with 50 per cent N through fertilizer + 50 per cent N through FYM.

Sarkar and Singh (1997) reported that organic manures alone or in combination with inorganic fertilizers increased the level of organic carbon as well as total N, P_2O_5 and K_2O content of soil. Average grain yield of rice was the highest with the recommended rate of N P K followed by application of 50 per cent N P K + 50 per cent FYM.

Application of 60 kg N as urea + 60 kg N as FYM gave the highest rice grain yield and application of N through organic sources either alone or in combination with inorganic N improved soil fertility status (Roy *et al.*, 1997).

The grain yield of 4.85 t ha^{-1} with urea was not significantly differed from 4.63 t ha^{-1} obtained with 4 per cent fly ash + FYM at 10 t ha^{-1} + 50 per cent of the recommended N P K (Aravinda Kumar *et al.*, 1998).

Dubey and Verma (1999) concluded that integrated use of 50 per cent N P K + 50 per cent FYM was advantageous in sustaining the crop and soil productivity and obtaining higher net returns compared to 100 per cent N P K supplied through either inorganic fertilizers or FYM alone. The FYM treatments were comparable with poultry manure, but were superior to glyricidia leaf manure treatments.

Application of FYM with and without inorganic N significantly increased tillers hill^{-1} and straw yield of rice (Rajput and Warsi, 1992).

Selvam (2000) revealed that conjunctive use of 50 per cent fertilizer N + 25 per cent each through FYM N and green manure N has resulted in higher grain yield and economic returns without impairing the soil fertility.

Incorporation of farm yard manure @ 10-15 t ha^{-1} with recommended N, P and K fertilizer dose to the *kharif* crop in the sequence in long term fertilizer experiment of ICAR has a pronounced effect in enhancing the efficiency of chemical fertilizers (Vats, *et al.*, 2001).

Superimposition of the FYM @ 5 t ha^{-1} over the inorganic fertilizers had a significant effect on the crop yields of rice and wheat, being 4.92 and 7.05 per cent higher compared with the treatment without farm yard manure (Sharma and Bali, 2001).

2.11 QUALITY CHARACTERS OF RICE KERNELS

Juliano (1979) stated that quality in rice encompassed storage, milling and cooking and nutritive quality of grain.

Shanmugasundaran (1987) noted that organic manures enhanced the hardness values of rice grain and also found that cooking time did not differ due to organic manure application.

Gruel loss was lower and elongation ratio of rice was higher due to green manuring (Shukla and Sharma, 1994).

Parida *et al.* (1995) reported that application of nitrogen increased grain yield as well as non-protein N and protein content over control. When P was applied with N, it increased protein, while addition of K to N and P decreased non-protein N and protein contents but further increased yield to 39 q ha^{-1} compared to 34 q ha^{-1} with N+P and 30 q ha^{-1} with N alone. FYM application at 10 t ha^{-1} was beneficial to yield, but it decreased protein content.

Radha (1996) observed that application of organic manures enhanced the crude protein and total ash content in brown rice and the total amylose content in the milled rice, where as N and protein contents of grain and straw were not significantly affected.

All characters except test weight and grain length showed a positive direct effect on grain water uptake, while head rice recovery Vs test weight had negative indirect effects on volume expansion (Singh *et al.*, 1996).

Quality and yield were increased significantly with the application of 80 kg N ha^{-1} as compared to 40 kg N ha^{-1}, where as a further increase in N rate to 120 kg ha^{-1} had no further significant effect (Patel *et al.*, 1997).

Hemalatha (1998) noted that organic manure application enhanced crude protein, amylose content and lowered the gruel loss.

Dixit and Gupta (2000) reported increased quality parameters like hulling percentage, milling percentage, protein and amylose content due to application of FYM at 10 t ha^{-1} and blue green algae inoculation either alone or in combination.

2.12 RESIDUAL EFFECT OF NITROGEN SOURCES APPLIED TO RICE

Nutrients applied through organic and inorganic forms to rice crop are not fully utilized by the crop to which they are applied (Rao and Bhardwaj, 1980).

Green manuring resulted in increased rice yields with significant carry over effect on succeeding wheat crop at Ludhiana, India (Meelu and Rekhi, 1981)

In soils testing low in organic carbon, combined use of organic manure with 60 kg N ha^{-1} through mineral fertilizer gave rice yields comparable with 100 kg fertilizer nitrogen ha^{-1} with negligible residual effect of green manuring on succeeding wheat crop (Mahapatra *et al.*, 1981; IRRI, 1984).

According to Soni and Sikarwar (1983) the rice crop which received part of the nitrogen through FYM left a significant residual effect on succeeding wheat crop resulting in increased grain yield of wheat.

Meelu and Morris (1984) reported that 12 t ha^{-1} FYM and 80 kg N ha^{-1} produced same yield of rice as with 120 kg N ha^{-1}, in addition to this gave wheat crop yield equivalent to 30 kg ha^{-1} each of nitrogen and phosphorus as a residual effect on the succeeding season.

The pod yield of winter groundnut was not found to be significantly affected by the level of fertilizer applied to rice grown in the previous rainy season (Ramaseshaiah *et al.*, 1985).

Although rice responds markedly to the applied nitrogen through mineral fertilizers, the efficiency of applied nitrogen is very low. Use of organic manures in rice, and/or rice-based cropping systems, therefore becomes imperative, not only as partial substitute for the costly fertilizer nitrogen but also to maintain sustained fertility of intensively cultivated soils (Swaminathan, 1987b).

Purushotham *et al.* (1988) noticed residual effect of FYM as well as phosphorus and potassium applied to *kharif* rice on the succeeding *rabi* crop and indicated a possibility of saving phosphorus and potassium in a crop sequence due to FYM application.

According to Kulkarni and Pandey (1988), high yields in rice-based cropping systems could be maintained with 25 to 50 per cent of the nitrogen requirement of rice when supplied through green manures.

Rathore *et al.* (1993) reported significantly higher residual effect of green manure than fertilizer nitrogen alone to rice on the seed yield and nitrogen uptake of chickpea in a rice-chickpea cropping system.

Thimmegowda and Devakumar (1994) studied the residual fertility on yield of groundnut grown in rice fallows and the results revealed that conjunctive use of nutrients partly through organic manure and fertilizers to *kharif* rice exhibited significant residual effect on succeeding groundnut crop by increasing pod yield.

Paulraj and Velayudham (1995) reported the highest seed yield of blackgram succeeding rice due to residual effect of FYM and green manure combination

Sujathamma *et al.* (1996) reported that vermicompost at 50 per cent substitution to fertilizer nitrogen applied to *kharif* rice produced appreciable residual effects on the succeeding groundnut. Number of pods plant^{-1}, pod weight and pod yield as well as haulm yield was highest with this treatment. Application of organic sources of nitrogen to rice exhibited greater residual effect compared to fertilizer nitrogen alone and benefited the succeeding groundnut (Sujathamma *et al.*, 2001a).

Nitrogen applied to the preceding rice at 100 per cent recommended dose through combination of prilled urea and varying organic sources and prilled urea alone, remained almost at par in increasing the seed yield of succeeding lentil (Singh *et al.*, 2001).

Residual N fertility was the highest when sunhemp was applied, followed by FYM, greengram and rice straw. A negative status of N was observed in the control plot (Pandey *et al.*, 2001).

In the first year, the yield between the two organic sources viz., farmyard manure and glyricidia green leaf manure were almost similar, while in the second year farmyard manure application showed higher yield (4.42 t ha^{-1}) than glyricidia green leaf manure (3.87 t ha^{-1}) indicating the residual effect associated with farm yard manure (Masthana Reddy *et al.*, 2001).

2.13 INCLUSION OF ORGANICS IN NUTRIENT MANAGEMENT IN CROPPING SYSTEMS

Rami Reddy *et al.* (1980) revealed that conjunctive use of nutrients partly through organic manures and inorganic fertilizers to *kharif* rice exhibited significant residual effect on the succeeding groundnut crop.

Organic manures play a direct role in supplying macro and micro nutrients and indirectly by improving the physico-chemical and biological properties of the soils, besides supplying nutrients to the current crop and very often leave substantial residual effect on succeeding crops in the cropping system (Maskina and Meelu, 1984).

The continued imbalanced as well as indiscriminate use of fertilizers in the intensive cropping system would result in reduced crop yield. Integrated use of organic manures, biofertilizers and chemical fertilizers not only help to maintain optimum crop yields, but also result in long terms soil productivity. The organic sources of nutrients should be considered as supplements to fertilizers and not as substitutes (Mishra and Kapoor, 1992).

Singh and Yadav (1992) inferred that integrated nutrient supply and management system (INSAM) not only helps to restore and sustain soil fertility and crop productivity but also check the emerging deficiency of secondary and micronutrients. Further, it brings economy and efficiency in fertilizer use and favourably influences the physical, chemical and biological environment of soils

According to Yadav and Alok Kumar (1993) continuous cropping of cereals with adequate N P K fertilizers alone resulted in declining crop productivity and native soil fertility and inclusion of legume crop in the cropping system increased the yield of succeeding crops and built up nitrogen status of the soil. Organic manures also showed their pronounced long-term effect on the physical environment and productivity of the soil. The use of FYM along with chemical fertilizers increased the fertilizer use efficiency (FUE) and sustained the productivity of the system.

An efficient nutrient supply system requires a judicious mix of organic and inorganic nutrient sources for the maximum expression of yield potential of rice (Jose Mathew *et al.*, 1994).

Organic sources applied either alone or in combination with prilled urea increased the grain yield and nutrient uptake in rice as well as succeeding lentil (Singh *et al.*, 2001).

2.14 SOIL FERTILITY VARIATION DUE TO INCLUSION OF ORGANICS IN RICE-BASED CROPPING SYSTEMS

Mani *et al.* (1980) reported that application of FYM, GM and compost in combination with inorganic N P K fertilizer increased the organic matter content of the soil.

Incorporation of crop residues and green manure would increase the soil nutrient pool and reduce the losses of nutrients (Rajendra Prasad 1985, Buresh and De Datta 1991). Incorporation of crop stubbles, green manures and residues in rice-based cropping systems resulted in increased organic matter status of the soil (Choudhary and Bathla, 1985; Rajeswari, 1990).

Thimmegowda (1993) reported that the residual effect of fertility after harvest of *kharif* rice due to the combined effect of organic manures (compost; green leaf manure) and inorganic fertilizers influenced the concentration and uptake of N, P and K to a larger extent compared to inorganic fertilizers alone.

Thimmegowda and Devakumar (1994) revealed that conjunctive use of nutrients partly through organic manures and inorganic fertilizers to *kharif* rice, exhibited significant residual effect on the succeeding groundnut.

According to Rathore *et al.* (1995), residual fertility in terms of increased organic carbon and available phosphorus in plots receiving BGA and FYM with and without fertilizers was observed, where as these sources had no impact on build-up of nitrogen and potassium in the soil.

Organic sources applied to the preceding rice, either alone or in combination with prilled urea did not change the pH, electrical conductivity, organic carbon, available N, P and K content of soil (after harvest of each crop of rice-lentil) significantly (Singh *et al.*, 2001).

Though the rice yields were the highest with 100 per cent recommended dose of nitrogen applied through fertilizer, the highest total and available nitrogen, available phosphorus and potassium content in the soil after rice was recorded with 50 and 25 per cent substitution through organic manures (Sujathamma *et al.*, 2001b).

Materials and Methods

CHAPTER-III

MATERIALS AND METHODS

Field experiments were conducted at the wetland farm of Tirupati campus of Acharya N.G.Ranga Agricultural University, Andhra Pradesh to study the " Prospects of organic farming in rice-based cropping system" for two consecutive years (2000 and 2001). The materials used and the methods employed for the investigation are described here under.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The experiments were carried out in the wetland farm of S.V. Agricultural College, Tirupati, which is geographically situated at 13.5°N latitude, 79.5°E longitude and at an altitude of 182.9 m above the mean sea level in the Southern Agro-climatic Zone (Zone III) of Andhra Pradesh.

3.2 WEATHER DURING THE CROP PERIOD

Weather data during the crop period of rice and groundnut, recorded at S.V. Agricultural College Meteorological Observatory, Tirupati is presented in Table 3.1a &3.1b and depicted in Fig. 3.1a&3.1b.

3.2.1 Rice (*kharif,* 2000)

The weekly mean maximum temperature during the crop period ranged from 29.8 to 36.9°C with an average of 32.6°C. The decennial mean maximum temperature for the corresponding period ranged from 29.6 to 36.2°C with an average of 33.0°C.

Table 3.1a: Standard week wise meteorological data during the cropping system, 2000

Standard week*	Date and month	Temperature (°C)				Mean R.H (%)		Rainfall (mm)		Rainy days		Mean evaporation (mm day^{-1})		Mean sunshine (hrs day^{-1})	
		Maximum		Minimum											
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
23	3-9 June	35.4	-2.7	23.1	-3.7	47.0	-2.5	0.0	-25.2	0.0	-1.3	6.4	-1.8	3.3	-4.1
24	10-16 June	37.3	0.8	27.2	0.7	43.5	-6.7	0.0	-27.4	0.0	-1.0	8.0	-0.6	6.5	0.9
25	17-23 June	34.8	-2.0	25.6	-1.3	51.0	2.5	33.4	27.5	2.0	1.3	6.3	-2.9	4.1	-2.0
26	24-30 June	32.7	-3.7	25.6	-0.8	51.0	1.1	2.6	-9.3	1.0	0.1	4.7	-3.1	3.0	-2.2
27	1-7 July	30.0	-6.2	24.2	-1.3	61.0	6.4	14.3	-12.7	3.0	1.2	2.8	-4.4	1.2	-4.0
28	8-14 July	34.3	-0.8	25.6	-0.1	52.0	-4.2	1.0	-25.5	0.0	-1.0	5.8	-1.3	2.4	-2.4
29	15-21 July	35.8	1.5	25.6	0.3	48.0	-12.0	0.0	-20.3	0.0	-1.7	7.9	2.0	5.8	1.7
30	22-28 July	36.9	2.5	25.4	0.2	41.5	-14.8	0.0	-22.7	0.0	-1.5	7.6	1.1	8.1	3.8
31	29 July – 4 Aug	35.7	0.9	24.5	-0.8	58.5	1.7	68.3	39.8	2.0	0.5	6.8	-0.1	7.3	2.0
32	5-11 Aug	32.2	-1.8	23.6	-1.1	64.5	3.7	56.6	25.1	2.0	0.0	3.7	-2.3	3.5	-1.0
33	12-18 Aug	33.0	-0.5	24.1	-0.9	61.5	1.2	15.6	-12.2	2.0	0.5	4.7	-1.4	5.4	0.6
34	19-25 Aug	30.2	-4.2	24.0	-1.3	65.5	6.8	34.6	10.8	4.0	2.7	5.8	-1.2	6.9	0.9
35	26 Aug – 1 Sep	33.4	-0.6	25.4	0.6	53.0	-5.7	2.4	-13.8	0.0	-1.3	5.8	-0.8	5.6	-0.1
36	2-8 Sep	34.2	0.2	24.4	-0.2	53.0	-7.5	10.4	-17.7	1.0	-0.5	6.4	0.4	7.1	1.4
37	9-15 Sep	35.1	1.1	24.5	-0.1	56.0	-5.3	0.5	-30.6	0.0	-1.7	5.0	-1.0	5.4	-0.2
38	16-22 Sep	32.8	-1.3	23.4	-0.9	73.0	9.2	99.4	80.1	4.0	2.4	3.9	-1.5	6.1	-0.5
39	23-29 Sep	32.4	-0.9	23.8	-0.1	69.5	1.1	55.1	18.6	3.0	0.9	3.6	-1.1	4.7	-1.1
40	30 Sep – 6 Oct	30.8	-1.0	22.2	-1.0	77.5	5.7	123.5	86.8	5.0	2.9	2.0	-2.0	3.8	-1.2
41	7-13 Oct	31.0	-1.2	23.2	0.6	74.5	2.8	49.0	19.5	3.0	1.0	3.2	-0.9	4.9	-1.0
42	14-20 Oct	30.5	-1.3	23.7	1.4	69.0	0.9	2.2	-31.9	0.0	-1.7	2.3	-2.2	1.7	-4.6
43	21-27 Oct	33.9	2.0	18.7	2.0	56.5	-14.8	14.8	-2.5	1.0	0.5	1.8	0.3	9.4	2.4

Contd……

Standard week	Date and month	Temperature (°C)				Mean R.H (%)		Rainfall (mm)		Rainy days		Mean evaporation (mm day^{-1})		Mean sunshine (hrs day^{-1})	
		Maximum		Minimum											
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
44	28 Oct – 3 Nov	32.1	2.0	19.4	-2.1	62.5	-12.1	6.6	-66.9	1.0	-1.6	4.5	0.7	7.2	1.9
45	4-10 Nov	31.2	1.5	20.0	-0.1	66.5	-8.8	13.2	-48.9	1.0	-1.8	4.6	1.3	8.3	3.1
46	11-17 Nov	30.1	0.5	19.8	-0.3	59.0	-12.7	0.0	-58.9	0.0	-2.1	4.7	0.8	6.6	0.6
47	18-24 Nov	29.8	0.1	20.8	0.7	71.0	-2.7	19.8	-9.6	2.0	0.0	3.4	-0.5	5.3	-1.1
48	25 Nov – 1 Dec	28.2	-0.9	19.5	1.0	74.0	4.2	70.2	46.0	1.0	0.2	2.9	-1.2	4.0	-4.0
49	2-8 Dec	27.5	-0.7	18.1	-0.4	72.5	2.5	24.7	-8.9	3.0	1.5	2.9	-0.7	6.8	-0.5
50	9-15 Dec	28.3	0.0	14.6	-3.9	64.5	-8.6	0.0	-41.3	0.0	-1.3	3.9	0.4	9.2	2.6
51	16-22 Dec	28.0	-0.2	15.3	-2.8	66.0	-6.6	0.0	-7.9	0.0	-0.7	3.9	0.0	8.1	0.9
52	23-29 Dec	27.1	-1.5	19.4	2.0	69.5	-0.9	23.6	17.6	2.0	1.7	3.8	-0.3	4.1	-3.9
1	1-7 Jan	28.4	-0.4	19.0	2.0	72.5	4.6	0.0	-2.9	0.0	-0.3	3.2	-1.1	7.0	-1.3
2	8-14 Jan	28.9	0.0	17.3	0.2	68.5	0.8	0.0	-4.2	0.0	-0.3	3.9	-0.3	7.3	-0.8
3	15-21 Jan	28.8	-0.7	15.7	-1.4	67.5	1.2	0.0	-4.3	0.0	-0.4	4.3	0.0	7.6	-0.8
4	22-28 Jan	29.6	-0.5	15.8	-0.1	62.0	-2.0	0.0	0.0	0.0	0.0	4.4	-0.5	5.6	-3.8
5	29 Jan – 4 Feb	31.2	0.2	17.6	1.4	62.5	1.7	0.0	0.0	0.0	0.0	4.2	-1.1	7.3	-2.6
6	5-11 Feb	33.9	2.1	16.6	-0.6	55.0	-4.0	0.0	0.0	0.0	0.0	5.9	0.3	9.4	-0.3
7	12-18 Feb	32.4	-0.3	17.6	-0.6	59.0	1.1	0.0	-0.4	0.0	-0.1	5.5	-0.3	9.2	-0.3
8	19-25 Feb	36.4	2.9	20.9	1.6	48.5	-7.1	0.0	-0.4	0.0	-0.1	6.0	-0.1	9.4	-0.3
9	26 Feb – 4 Mar	35.4	1.9	20.1	1.3	52.0	1.0	0.0	-0.8	0.0	-0.1	5.8	-0.9	9.4	-0.3
10	5-11 Mar	34.9	-0.1	21.3	1.6	35.0	-15.6	0.0	-0.4	0.0	-0.1	5.6	-1.3	7.7	-2.0
11	12-18 Mar	36.1	0.2	20.7	0.1	44.0	5.3	0.0	-1.8	0.0	-0.2	6.3	-0.6	8.5	-1.3
12	19-25 Mar	37.5	0.2	24.7	2.6	52.0	3.6	0.0	-0.3	0.0	-0.2	6.3	-1.2	7.2	-2.3

A- Actual DN- Deviation from decennial mean

Table 3.1b: Standard week wise meteorological data during the cropping system, 2001

Standard week	Date and month	Temperature (°C)				Mean R.H(%)		Rainfall (mm)		Rainy days		Mean evaporation (mm day^{-1})		Mean sunshine (hrs day^{-1})	
		Maximum		Minimum											
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
24	11-17 June	36.0	-0.5	26.2	-0.3	48.5	-1.7	6.0	-21.4	1.0	0.0	6.4	-2.2	3.4	-2.2
25	18-24 June	37.3	0.5	27.5	0.6	45.0	-3.5	7.2	1.2	1.0	0.3	9.4	0.2	5.7	-0.4
26	25 June – 1 July	37.6	1.2	28.5	2.1	43.0	-6.9	0.0	-11.9	0.0	-0.9	10.7	2.9	6.2	1.0
27	2-8 July	36.5	0.3	27.7	2.2	45.5	-9.1	0.0	-27.0	0.0	-1.8	8.9	1.7	3.0	-2.2
28	9-15 July	35.3	0.2	26.4	0.7	51.0	-5.2	52.9	26.4	2.0	1.0	6.9	-0.2	3.2	-1.6
29	16-22 July	34.2	-0.1	25.7	0.4	54.0	-6.0	19.4	-0.9	2.0	0.3	5.4	-0.5	5.2	1.1
30	23-29 July	35.2	0.8	25.3	0.1	53.0	-3.3	41.8	19.1	2.0	0.5	5.7	-0.8	6.4	2.1
31	30 July – 5 Aug	32.9	-1.9	25.4	0.1	58.0	-1.2	4.8	-23.7	1.0	-0.5	5.3	-1.6	4.5	-0.8
32	6-12 Aug	34.1	0.1	26.0	1.3	53.0	-7.8	8.2	-23.3	1.0	-1.0	5.1	-0.9	2.9	-1.6
33	13-19 Aug	34.5	1.0	26.6	1.6	52.0	-8.3	0.0	-27.8	0.0	-1.5	6.4	0.3	3.5	-1.3
34	20-26 Aug	34.7	0.3	25.9	0.6	50.0	-8.7	3.2	-20.6	1.0	-0.1	7.9	0.9	4.3	-1.7
35	27 Aug – 2 Sep	34.6	0.6	25.5	0.7	49.5	-9.2	3.4	-12.8	1.0	-0.3	7.5	0.9	7.1	1.4
36	3-9 Sep	36.4	2.4	26.5	1.9	44.0	-16.5	0.0	-28.1	0.0	-1.5	8.4	2.3	7.8	2.1
37	10-16 Sep	33.9	-0.1	24.3	-0.3	61.5	0.2	31.2	0.1	3.0	1.3	4.3	-1.6	3.8	-1.8
38	17-23 Sep	33.5	-0.6	23.5	-0.8	61.5	-2.3	117.4	98.1	3.0	1.4	4.9	-0.5	5.2	-1.4
39	24-30 Sep	30.5	-2.8	24.0	0.1	75.0	6.6	49.0	12.5	2.0	-0.1	2.2	-2.5	1.8	-4.0
40	1-7 Oct	30.9	-0.9	24.2	1.0	69.5	-2.3	100.1	63.4	2.0	-0.3	3.0	-1.0	3.3	-1.7
41	8-14 Oct	31.0	-1.2	23.6	1.0	75.5	3.8	44.8	15.3	3.0	0.9	1.9	-2.2	3.0	-2.9
42	15-21 Oct	28.8	-3.0	22.4	0.1	80.0	11.9	113.9	79.8	3.0	1.1	2.1	-2.4	3.9	-2.4
43	22-28 Oct	30.7	-1.2	22.6	0.9	71.5	0.2	21.8	4.5	3.0	1.5	2.4	-2.1	5.6	-1.4
44	29 Oct – 4 Nov	30.2	0.1	20.0	-1.5	70.0	-4.6	8.4	-65.1	1.0	-1.7	2.6	-1.2	4.4	-0.9

Contd.

Standard week	Date and month	Temperature (°C)				Mean R.H (%)		Rainfall (mm)		Rainy days		Mean evaporation (mm day^{-1})		Mean sunshine (hrs day^{-1})	
		Maximum		Minimum											
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
45	5-11 Nov	29.2	-0.5	22.3	1.2	74.5	-0.8	16.8	-45.3	2.0	-0.9	1.4	-1.9	1.7	-3.5
46	12-18 Nov	30.2	0.6	21.6	1.5	76.0	4.3	16.3	-42.4	2.0	-0.1	2.4	-1.5	6.0	0.0
47	19-25 Nov	29.5	-0.2	20.1	0.0	75.0	1.3	3.2	-26.2	1.0	-1.1	2.7	-1.2	5.7	-0.7
48	26 Nov – 2 Dec	28.6	-0.5	19.4	0.9	71.5	1.7	5.5	-18.7	1.0	0.0	2.4	-1.7	5.3	-2.7
49	3-9 Dec	28.3	0.1	15.1	-3.4	66.5	-6.5	0.0	-33.6	0.0	-1.5	3.4	-0.2	9.1	2.8
50	10-16 Dec	28.7	0.4	15.2	-3.3	64.5	-8.6	0.0	-41.3	0.0	-1.3	3.9	-0.4	8.2	1.6
51	17-23 Dec	26.2	-2.0	21.3	3.2	75.0	2.4	87.6	79.7	3.0	2.3	2.5	-1.4	1.8	-5.4
52	24-30 Dec	31.2	2.6	18.7	1.3	75.0	4.6	12.9	6.9	2.0	1.5	2.5	-1.6	5.3	-2.7
1	1-7 Jan	27.1	-1.7	19.5	2.5	73.5	5.6	29.4	26.5	1.0	0.7	3.1	-1.2	5.9	-2.4
2	8-14 Jan	26.5	-2.4	16.8	-0.3	72.0	4.3	0.7	3.5	0.0	-0.3	2.9	-1.3	6.1	-2.0
3	15-21 Jan	29.1	-0.4	17.3	0.2	65.0	-1.3	0.0	-4.3	0.0	-0.4	3.0	-1.3	7.7	-0.7
4	22-28 Jan	32.0	1.9	20.7	4.8	60.0	-4.0	0.0	0.0	0.0	0.0	4.2	-0.7	8.3	-1.1
5	29 Jan – 4 Feb	38.8	-2.2	19.6	3.4	68.5	7.7	0.0	0.0	0.0	0.0	3.0	-2.3	5.6	-4.3
6	5-11 Feb	30.0	-1.8	17.8	0.6	66.5	7.5	0.0	0.0	0.0	0.0	4.5	-1.1	7.9	-1.8
7	12-18 Feb	30.9	-1.8	16.3	-1.9	66.0	8.1	0.0	-0.3	0.0	-0.1	4.5	-1.3	8.8	-0.7
8	19-25 Feb	32.2	-1.3	14.3	-5.0	58.0	2.4	0.0	-0.4	0.0	-0.1	5.7	-0.4	9.6	-0.1
9	26 Feb – 4 Mar	34.7	1.2	16.3	-2.5	50.5	-0.5	0.0	-0.8	0.0	-0.1	6.1	-0.6	9.8	-0.1
10	5-11 Mar	34.8	-0.2	19.8	0.1	53.0	2.4	0.0	-0.4	0.0	-0.1	6.2	-0.7	9.3	-0.4
11	12-18 Mar	34.9	-1.0	20.6	0.0	50.0	0.7	0.0	-1.8	0.0	-0.2	6.6	-0.3	9.5	-0.3
12	19-25 Mar	36.7	-0.6	21.0	-1.1	50.5	2.1	0.0	-3.2	0.0	-0.2	6.5	-1.0	8.9	-0.6
13	26 Mar – 1 April	36.7	-0.8	25.7	2.5	53.5	3.0	0.0	-0.9	0.0	-0.1	6.6	-1.0	8.3	-1.0

A- Actual DN- Deviation from decennial mean

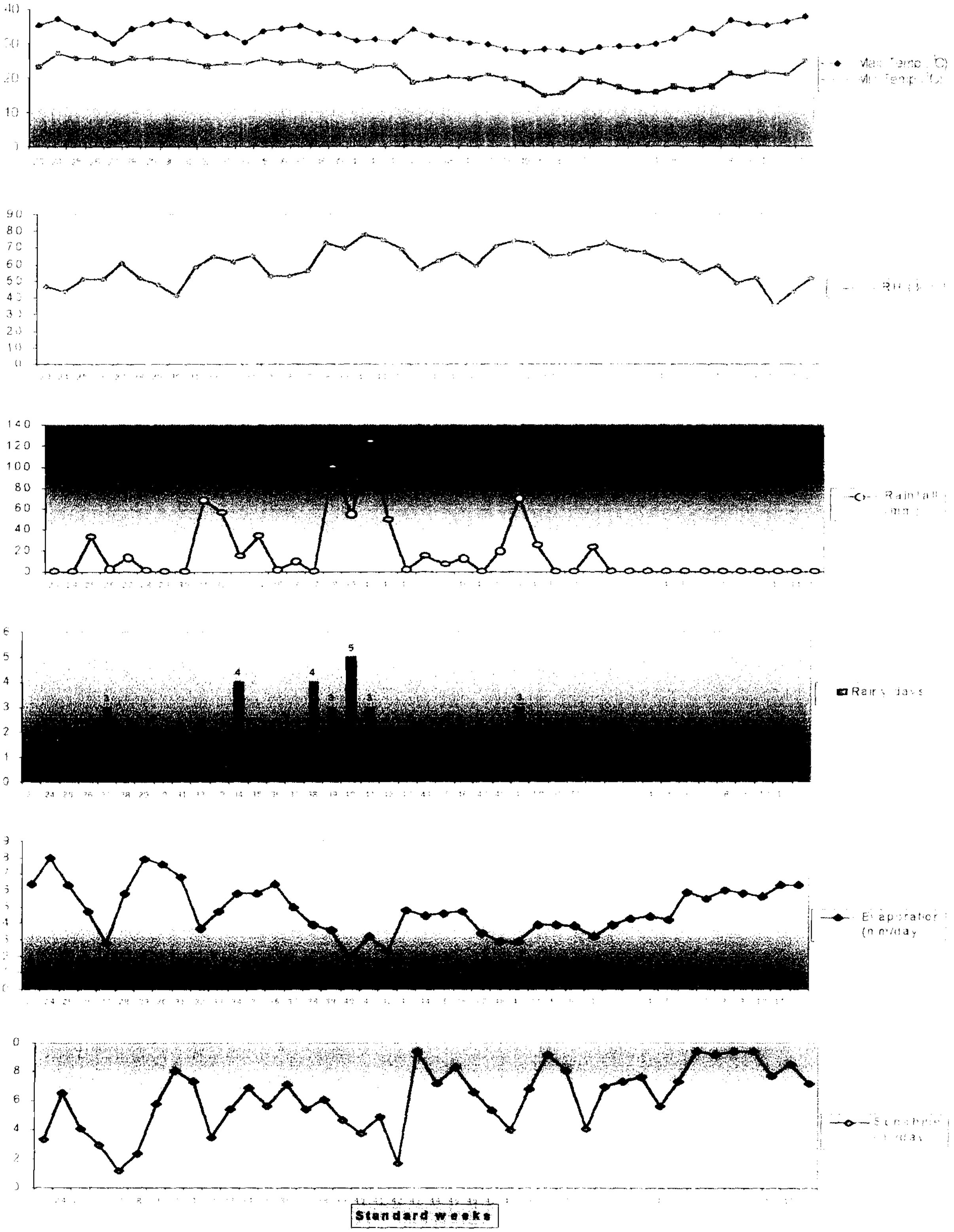


Fig.3.1a: Standard week wise meteorological data graph during the cropping systems (09.6.2000 to 24.3.2001)

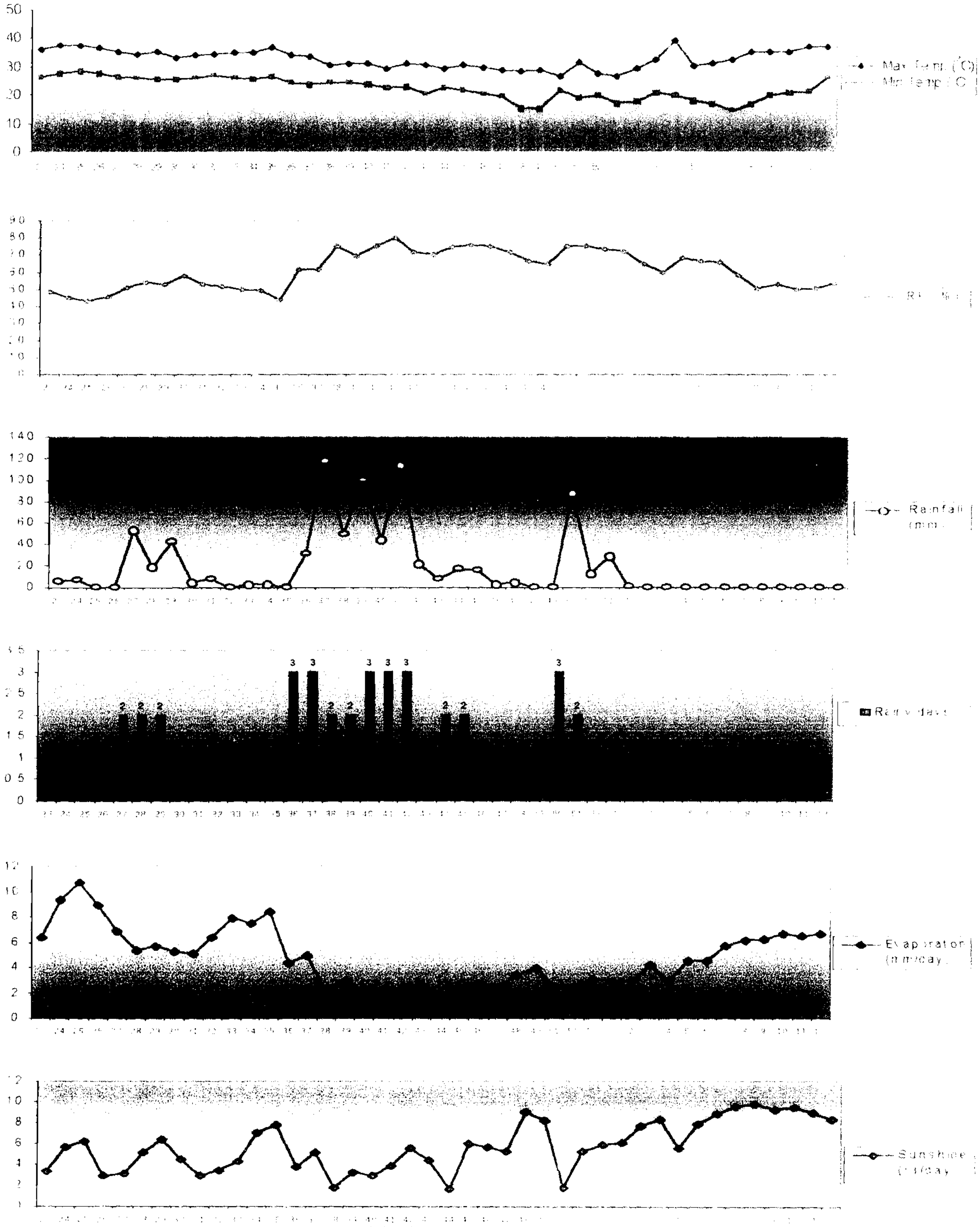


Fig.3.1b: Standard week wise meteorological data graph during the cropping systems (16.6.2001 to 4.4.2002)

The weekly mean minimum temperature during the crop period ranged from 18.7 to 25.6°C with an average of 23.2°C. The decennial mean minimum temperature for the corresponding period ranged from 21.0 to 25.7°C with an average of 23.5°C.

The weekly mean relative humidity during the crop period ranged from 41.5 to 77.5 per cent with an average of 61.6 per cent. The decennial mean relative humidity for the corresponding period ranged from 54.6 to 75.3 per cent with an average of 64.5 per cent.

During the crop period, a total amount of 587.3 mm of rainfall was received in 34 rainy days as against the decennial average of 680.8 mm received in 37 rainy days for the corresponding period.

During the crop period, the evaporation (measured from USWB class A open pan Evaporimeter) ranged from 2.0 to 7.9 mm day^{-1} with an average of 4.7 mm day^{-1}. The decennial mean evaporation for the corresponding period ranged from 3.3 to 7.2 mm day^{-1} with an average of 5.4 mm day^{-1}.

Mean bright sunshine hours day^{-1} during the crop period ranged from 1.2 to 9.4 with an average of 5.6. The decennial mean for the corresponding period ranged from 4.1 to 7.0 with an average of 5.5.

3.2.2 Rice (*kharif*, 2001)

The weekly mean maximum temperature during the crop period ranged from 28.6 to 36.5°C with an average of 32.5°C. The decennial mean maximum temperature for the corresponding period ranged from 29.1 to 36.2°C with an average of 32.8°C.

The weekly mean minimum temperature during the crop period ranged from 19.4 to 27.7°C with an average of 24.1°C. The decennial mean minimum temperature for the corresponding period ranged from 18.5 to 25.7°C with an average of 23.5°C.

The weekly mean relative humidity during the crop period ranged from 44.0 to 80.0 per cent with an average of 62.3 per cent. The decennial mean relative humidity for the corresponding period ranged from 54.2 to 75.1 per cent with an average of 64.7 per cent.

During the crop period, a total amount of 662.1 mm of rainfall was received in 36 rainy days as against the decennial average of 703.6 mm received in 39 rainy days for the corresponding period.

During the crop period, the evaporation (measured from USWB class A open pan Evaporimeter) ranged from 1.4 to 8.9 mm day^{-1} with an average of 4.5 mm day^{-1}. The decennial mean evaporation for the corresponding period ranged from 3.3 to 7.3 mm day^{-1} with an average of 5.3 mm day^{-1}.

Mean bright sunshine hours day^{-1} during the crop period ranged from 1.7 to 7.8 with an average of 4.4. The decennial mean for the corresponding period ranged from 4.1 to 8.0 with an average of 5.6.

3.2.3 Groundnut (*rabi*, 2000)

The weekly mean maximum temperature during the crop period ranged from 27.1 to 37.5°C with an average of 31.5°C. The decennial mean maximum temperature for the corresponding period ranged from 28.2 to 37.3°C with an average of 31.3°C.

The weekly mean minimum temperature during the crop period ranged from 14.6 to 24.7°C with an average of 18.4°C. The decennial mean minimum temperature for the corresponding period ranged from 15.9 to 22.1°C with an average of 18.2°C.

The weekly mean relative humidity during the crop period ranged from 35.0 to 75.5 per cent with an average of 59.6 per cent. The decennial mean relative humidity for the corresponding period ranged from 48.4 to 73.1 per cent with an average of 61.6 per cent.

A total amount of 48.3 mm of rainfall was received in 5 rainy days as against the decennial average of 103.9 mm received in 5.6 rainy days for the corresponding period.

During the crop period the evaporation (measured from USWB class A open pan Evaporimeter) ranged from 2.9 to 6.3 mm day^{-1} with an average of 4.7 mm day^{-1}. The decennial mean evaporation for the corresponding period ranged from 3.6 to 7.5 mm day^{-1} with an average of 5.2 mm day^{-1}.

Mean bright sunshine hours day^{-1} during the crop period ranged from 4.1 to 9.4 with an average of 7.7. The decennial mean for the corresponding period ranged from 6.3 to 9.9 with an average of 8.8.

3.2.4 Groundnut (*rabi,* 2001)

The weekly mean maximum temperature during the crop period ranged from 26.2 to 36.7°C with an average of 31.3°C. The decennial mean maximum temperature for the corresponding period ranged from 28.2 to 37.5°C with an average of 31.9°C.

The weekly mean minimum temperature during the crop period ranged from 14.3 to 25.7°C with an average of 18.8°C. The decennial mean minimum temperature for the corresponding period ranged from 15.9 to 23.2°C with an average of 18.5°C.

The weekly mean relative humidity during the crop period ranged from 50.0 to 75.0 per cent with an average of 62.6 per cent. The decennial mean relative humidity for the corresponding period ranged from 48.3 to 72.7 per cent with an average of 60.3 per cent.

A total amount of 130.6 mm of rainfall was received in 6 rainy days as against the decennial average of 74.4 mm received in 4.4 days for the corresponding period.

During the crop period the evaporation (measured from USWB class A open pan Evaporimeter) ranged from 2.5 to 6.6 mm day^{-1} with an average of 4.5 mm day^{-1}. The decennial mean evaporation for the corresponding period ranged from 3.5 to 7.6 mm day^{-1} with an average of 5.5 mm day^{-1}.

Mean bright sunshine hours day^{-1} during the crop period ranged from 1.8 and 9.8 with an average of 7.6. The decennial mean for the corresponding period ranged from 6.6 to 9.9 with an average of 8.9.

3.3 SOILS

The study during both the years (2000 and 2001) was conducted on the same field (F.No.12 of wetland farm of S.V. Agricultural College, Tirupati). Soil analysis was done initially prior to the start of the experiment and samples were taken immediately after the harvest of rice and groundnut crops of both the years. Soil samples were drawn at random from 0-30 cm depth of the experimental field initially and from the individual plots after the layout of the experiment. The layout was undisturbed till the completion of the experiment.

The results of physico-chemical analysis (Table 3.2) revealed that soil is sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen and medium in available phosphorus and available potassium.

3.4 CROPPING HISTORY OF EXPERIMENTAL FIELD

The details of the crops grown during the preceding years are given below:

Year	*Kharif*	*Rabi*	*Summer*
1996-1997	Fallow	Fallow	Fallow
1997-1998	Groundnut	Groundnut	Fallow
1998-1999	Green gram	Groundnut	Fallow
1999-2000	Fallow	Fallow	Fallow
2000-2001	Rice (present experiment)	Groundnut (present experiment)	
2001-2002	Rice (present experiment)	Groundnut (present experiment)	

3.5 EXPERIMENTAL DETAILS

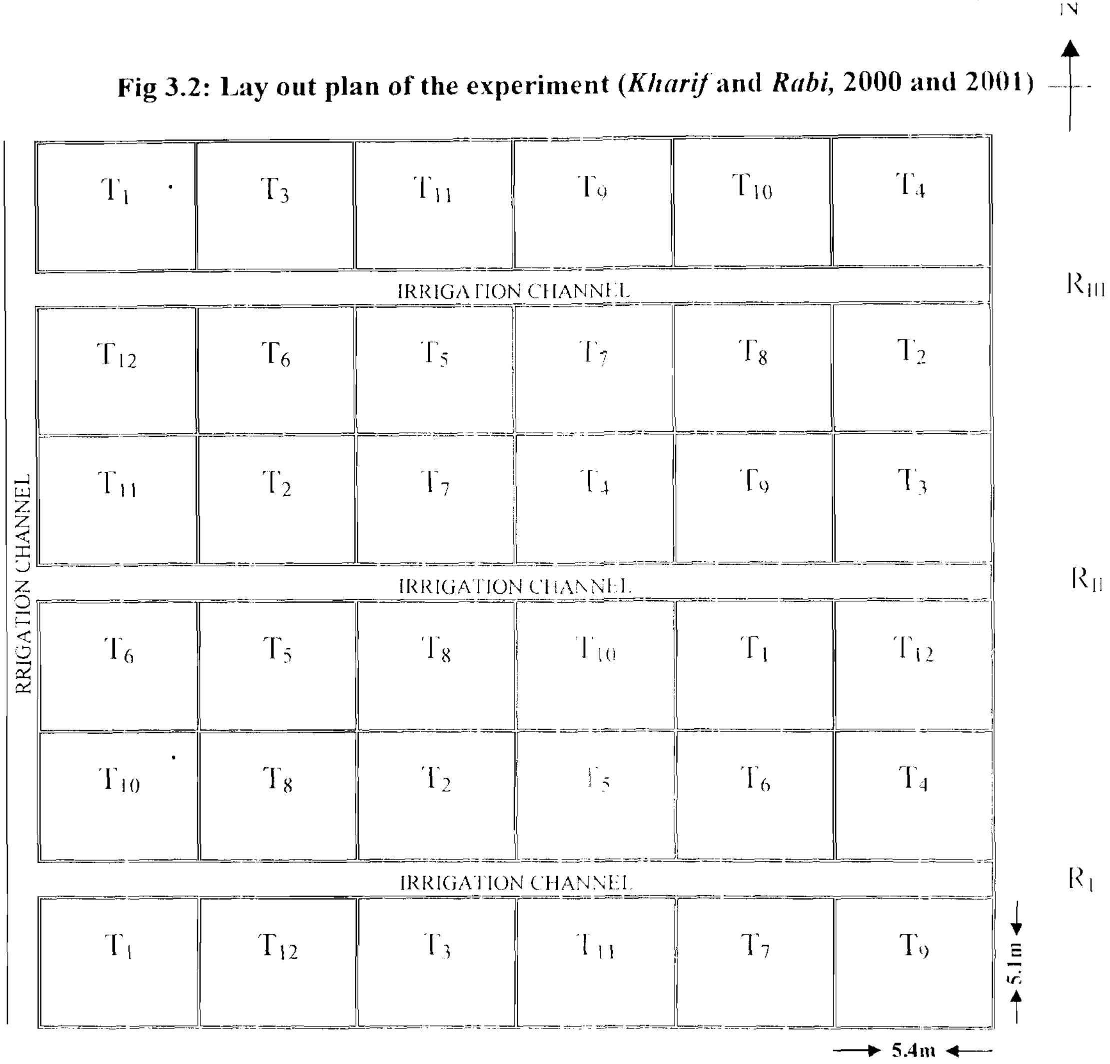
3.5.1 Design and Layout

The experiment was laid out in randomized block design with three replications. The layout plan is given in the Fig. 3.2. The same layout was followed during both the years of study (2000 and 2001).

Table 3.2: Physico-chemical properties of soil of the experimental field

S.No.	Particulars	0-30 cm	Method
I	**Mechanical Analysis**		International pipette method (Piper, 1966)
	Coarse sand (%)	30.9	
	Fine sand (%)	43.9	
	Silt (%)	4.6	
	Clay (%)	20.6	
	Texture	Sandy clay loam	
II	**Chemical analysis**		
	Organic carbon (%)	0.27	Wet digestion method (Walkely and Black, 1934)
	Available nitrogen (kg ha^{-1})	157.5	Alkaline permanganate method (Subbiah and Asija, 1956)
	Available P_2O_5 (kg ha^{-1})	22.0	Olsen's method (Olsen *et al.*, 1954)
	Available K_2O (kg ha^{-1})	190.0	Flame photometry (Jackson, 1973)
	pH (1:2 soil water suspension)	7.5	Glass electrode pH meter (Jackson, 1973)
	EC (dSm^{-1})	0.17	Conductivity bridge (Jackson, 1973)

Fig 3.2: Lay out plan of the experiment (*Kharif* and *Rabi*, 2000 and 2001)



Layout and Design:

	Rice (*kharif,* 2000& 2001)	**Groundnut (*rabi,* 2000& 2001)**
Design	RBD	RBD
Replications.	Three	Three
Gross plot size	5.4 x 5.1 m	5.4 x 5.1 m
Net plot size	4.5 x 4.2 m	4.05 x 4.50 m
Spacing	15 x 15 cm	22.5 x 10 cm

T_1 : N_0

T_2 : *Azo.*

T_3 : GM N_{100}

T_4 : GLM N_{100}

T_5 : FYM N_{100}

T_6 : F N_{100}

T_7 : GM N_{50} + F N_{50}

T_8 : GLM N_{50} + F N_{50}

T_9 : FYM N_{50} + F N_{50}

T_{10} : GM N_{50} + F N_{50}+ *Azo*

T_{11} : GLM N_{50} + F N_{50}+ *Azo.*

T_{12} : FYM N_{50} + F N_{50}+ *Azo.*

3.5.2 Treatments

There were twelve treatments comprising of different nitrogen management practices.

T_1 : Control: No nitrogen source (N_0)

T_2 : *Azospirillum* alone (*Azo.*)

T_3 : 100 per cent recommended nitrogen through dhaincha green manure (GM N_{100})

T_4 : 100 per cent recommended nitrogen through neem leaf manure (GLM N_{100})

T_5 : 100 per cent recommended nitrogen through farm yard manure (FYM N_{100})

T_6 : 100 per cent recommended nitrogen through fertilizer (F N_{100})

T_7 : 50 per cent recommended nitrogen through dhaincha green manure + 50 per cent recommended N through fertilizer (GM N_{50} + F N_{50})

T_8 : 50 per cent recommended nitrogen through neem leaf manure + 50 per cent recommended N through fertilizer (GLM N_{50} + F N_{50})

T_9 : 50 per cent recommended nitrogen through farm yard manure + 50 per cent recommended N through fertilizer (FYM N_{50} + F N_{50})

T_{10} : 50 per cent recommended nitrogen through dhaincha green manure + 50 per cent recommended N through fertilizer + *Azospirillum* (GM N_{50} + F N_{50}+ *Azo.*)

T_{11} : 50 per cent recommended nitrogen through neem leaf manure + 50 per cent recommended N through fertilizer + *Azospirillum* (GLM N_{50} + F N_{50}+ *Azo.*)

T_{12} : 50 per cent recommended nitrogen through farm yard manure + 50 per cent recommended N through fertilizer + *Azospirillum* (FYM N_{50} + F N_{50}+ *Azo.*)

3.6 RICE (*kharif,* 2000 and 2001)

3.6.1 Plot Size

Gross	: 5.4 x 5.1m
Net	: 4.5 x 4.2 m
Spacing	: 15 x 15 cm

3.6.2 Variety

The test variety of rice was NLR-145, a popular rice cultivar released from Agricultural Research Station, Nellore, Andhra Pradesh. It is of medium duration (135 to 140 days), photo insensitive, compact and profuse tillering, suitable for both *kharif* and early *rabi* season. It has a yield potential of 6.0 to 6.5t ha^{-1}.

3.6.3 Cultivation details

3.6.3.1 Nursery. The nursery area was thoroughly puddled and leveled. About 20 kg of foundation seed of the rice variety NLR-145 was soaked in water for 24 hours and incubated for 48 hours to induce germination. The sprouted seeds were broadcasted uniformly over well-prepared seedbed and nursery was irrigated whenever necessary. The seed was not given any chemical treatment prior to soaking and similarly the nursery bed was also not fertilized as done conventionally.

3.6.3.2 Main field preparation. Primary and secondary tillage operations were carried out to get a good tilth for sowing of the green manure (dhaincha). The experimental field was laid out in three replications having twelve treatments as shown in Fig.3.2. Green manure (dhaincha) seed was sown in accordance with the treatments and the crop was irrigated thrice to ensure required biomass production with in the stipulated time period. At 45 days after sowing of green manure, during the 1^{st} year of experimentation the entire field was puddled using power tiller leaving the green manured plots and the green manured plots were puddled separately by *in situ* incorporation of the dhaincha plants. Micro leveling of individual plots was carried out latter. However, adequate care was taken to avoid difference of water levels in the individual plots. Calculated quantities of organic manures were incorporated in the laid out plots to supply prescribed quantity of N as per the treatments.

During the second year of experimentation (2001), puddling was done for individual plots using country plough and the green manure (dhaincha) was incorporated *in situ* and the plots were puddled separately as done during the previous season. Leveling was done to the individual plots and the inter plot soil movement was avoided.

3.6.3.3 Manures and fertilizers. The recommended dose of fertilizers was 80 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}. The N content in different organic materials was determined and the amount of these materials required for substituting a specified amount of N as per the treatment was calculated (Appendix A&B). These materials were incorporated into the soil 10 days prior to transplanting of rice. As per the treatments, fertilizer nitrogen in the form of urea was applied in three split doses of 50 per cent as basal, 25 per cent at active tillering and 25 per cent at panicle initiation. A uniform dose of 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied to rice in the form of single super phosphate and muriate of potash before transplanting. Recommended dose of *Azospirillum* @ 2.5 kg ha^{-1} was thoroughly mixed with FYM and sand in the ratio of 1:10:20 and applied to the treatmental plots just before transplanting.

3.6.3.4 Transplanting. Thirty days old seedlings were transplanted with a spacing of 15 x 15 cm, using two seedlings $hill^{-1}$, during both the years of study.

3.6.3.5 Irrigation. A thin film of 2-3cm water was maintained at the time of planting and thereafter water level of 5±2 cm was maintained during the entire crop growing period up to completion of grain filling stage, except at the time of top dressing. The water from the field was with drawn after completion of grain filling.

3.6.3.6 Weed control. Hand weedings were undertaken at 25 and 40 days after transplanting to keep the weeds under check.

3.6.3.7 Plant protection. Absolutely no inorganic chemicals were used during the entire period of experimentation including for the seed treatment. However, the crop was sprayed with neem seed oil and extract from custard apple leaves and seeds by making required dilutions, as and when necessary. Also extract obtained by soaking de-oiled neem cake for a period of a month in closed container was used as a repellent.

3.6.3.8 Harvesting and threshing. The crop was harvested, when the grain and straw turned yellow. The border rows were harvested first and latter net plots were harvested separately. The harvested sheaves were allowed to dry for two days in the plots itself and then threshed by using pedal operated thresher for separation of grain. Grain was sun dried on an open threshing floor to a moisture level of 14 per cent. Straw was allowed to sun dry to a constant weight in the plots itself. Grain and straw yields were recorded treatment wise and expressed as kg ha^{-1}.

3.6.4 Biometric Observations

Five plants from each net plot were chosen by random sampling and tagged, which were used for recording plant height and tiller number at different stages of crop growth as given below.

3.6.4.1 Growth parameters

3.6.4.1.1 Plant height. Plant height was measured from the base of the plant to the tip of the longest leaf stretched and expressed in cm. Plant height was measured at active tillering, panicle initiation and flowering.

3.6.4.1.2 Tiller Number. Total number of tillers hill^{-1} were counted at active tillering, panicle initiation, flowering and at harvest and expressed as tillers m^{-2}.

3.6.4.1.3 Leaf area index. Leaf area index was worked out at active tillering, panicle initiation and flowering stages. Leaf area from five destructively sampled plants from border rows leaving the extreme rows, was measured as per the method suggested by Palaniswamy and Gomez (1974) using the formulae as given below:

Leaf area $= L \times W \times K$

Where,

L = length of the third leaf from the top (cm)

W = maximum width of the same leaf (cm)

K = constant factor (0.75)

From this, LAI was computed taking into account the area occupied by each hill and number of leaves in the hill.

3.6.4.1.4 Dry matter production. Five plants at random from the border rows leaving the extreme rows were destructively sampled at active tillering, panicle initiation, flowering and at harvest. These samples were air-dried and then oven dried at 60°C to a constant weight and expressed as kg ha^{-1}.

3.6.4.1.5 Days to 50 per cent flowering. Number of days taken for flowering of 50 per cent plant population was recorded and presented as days to 50 per cent flowering.

3.6.4.1.6 Spad chlorophyll meter readings. Readings by the Spad chlorophyll meter were recorded at different stages of crop growth from the 3rd leaf of ten randomly selected plants and the average readings are expressed as Spad chlorophyll meter readings.

3.6.4.2 Yield attributes and yield. The following yield components were measured at harvest from the five tagged plants.

3.6.4.2.1 Productive tillers (Panicles m^{-2}). The number of ear bearing tillers were counted from tagged plants, averaged to compute productive tillers $hill^{-1}$ and expressed as panicles m^{-2}.

3.6.4.2.2 Panicle length. The length of panicle from the last node to the tip was recorded from randomly selected ten panicles and the mean length expressed in cm.

3.6.4.2.3 Total number of grains $panicle^{-1}$. Total number of grains from ten randomly selected panicles were counted, averaged and expressed as number of grains $panicle^{-1}$.

3.6.4.2.4 Number of filled grains panicle^{-1}. Filled grains from the above ten randomly selected panicles were counted, averaged and expressed as number of filled grains panicle^{-1}.

3.6.4.2.5 Spikelet sterility. From each of the ten randomly selected panicles total grains, filled grains and ill filled grains were counted and spikelet sterility is expressed in per cent.

$$\text{Spikelet sterility (\%)} = \frac{\text{Number of ill filled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}} \times 100$$

3.6.4.2.6 Test weight. Thousand-grains randomly drawn from the composite sample of grain yield of net plot in each treatment (dried to 14 per cent moisture content). were weighed and expressed in grams.

3.6.4.2.7 Grain yield. Grain from the net plot was thoroughly sun dried to 14 per cent moisture content, weighed and expressed in kg ha^{-1}.

***3.6.4.2.8 Straw yield*:** Straw obtained from the net plot was thoroughly sun dried until a constant weight and expressed in kg ha^{-1}.

3.6.4.2.9 **Harvest index.** The relationship of economic yield to the total biological yield was expressed as harvest index (HI).

$$\text{HI} = \frac{\text{Grain yield}}{\text{Total biolgoical yield}} \times 100$$

3.6.5 Quality Parameters of Rice Grain and Kernels

3.6.5.1 Milling per cent. A sample of five hundred grams of paddy was taken from each plot and milled with "Satake" grain testing husker and then polished to one minute (Ghosh, 1971).

$$\text{Milling } (\%) = \frac{\text{Weight of milled rice}}{\text{Weight of unhulled rice}} \times 100$$

3.6.5.2 Whole grain and broken grain per cent. The procedure followed was as out lined by Ghosh (1971) and expressed as per cent.

$$\text{Whole Grain } (\%) = \frac{\text{Weight of unbroken (whole) rice}}{\text{Weight of unhulled rice}} \times 100$$

$$\text{Broken Grain } (\%) = \frac{\text{Weight of broken rice}}{\text{Weight of unhulled rice}} \times 100$$

3.6.5.3 Protein content. The nitrogen content in the dehulled grain was obtained through micro kjeldhal method and was multiplied with a factor 6.25 to arrive at the protein content and expressed as per cent (Juliano *et al.*, 1973).

3.6.5.4 Amylose content: The amylose content of grain was estimated as per the procedure outlined by Williams *et al.* (1958) and expressed as per cent.

3.6.5.5 Elongation ratio. Five grams of milled rice was added in 50 ml of water and the water containing tubes were cooked for 20 minutes in a boiling water bath. The length of 20 cooked kernels was measured and the ratio between the mean lengths of cooked grain by mean length of raw grain is taken for Elongation ratio (ER) (Khan and Ali, 1985).

$$\text{ER} = \frac{\text{Average length of cooked kernals (mm)}}{\text{Average length of uncooked kernals (mm)}}$$

3.6.6 Plant Analysis

Plant samples collected for dry matter estimation at active tillering, panicle initiation, flowering and at harvest were dried, ground into fine powder and used for chemical analysis. N, P and K contents were analysed by the standard procedure out lined by Jackson (1973). The uptake of N, P and K in kg ha^{-1} at different stages of crop growth was calculated by multiplying the nutritional content with the respective dry matter production.

3.6.6.1 Grain and straw analysis. The nitrogen content of grain and straw was analysed separately and then multiplied with respective weights of grain and straw, which were summed up to present N uptake at harvest.

3.6.6.2 Agronomic efficiency (*AE*). It is response in yield per unit input as indicated by grain produced per kg of applied N and is computed by adopting the following formula suggested by Yoshida (1981).

$$\text{AE (\%)} = \frac{\begin{array}{ccc}\text{Grain yield in} & - & \text{Grain yield in}\\ \text{fertilized plot} & & \text{control plot}\end{array}}{\text{Quantity of fertilizer applied (N)}} \text{ x100}$$

***3.6.6.3 Physiological efficiency* (PE).** It indicates grain produced per kg of absorbed N and is computed using the formula suggested by Yoshida (1981).

$$\text{PE (\%)} = \frac{\begin{array}{ccc}\text{Grain yield in} & - & \text{Grain yield in}\\ \text{fertilized plot} & & \text{control plot}\end{array}}{\begin{array}{ccc}\text{N uptake in} & - & \text{N uptake in}\\ \text{fertilized plot} & & \text{control plot}\end{array}} \text{ x100}$$

3.6.6.4 Apparent recovery of nitrogen. It was computed following the formula suggested by Pillai and Vamadevan (1978) as detailed below.

$$\text{Apparent recovery of N (\%)} = \frac{\text{Uptake of N in particular treatment} - \text{Uptake of N in control plot}}{\text{Quantity of N applied for the treatment}} \text{ x}100$$

3.6.6.5 Nitrogen Harvest Index. The nitrogen harvest index (NHI) was computed as per the formula suggested by Spiretz (1977).

$$\text{NHI} = \frac{\text{N uptake in economic yield}}{\text{N uptake in biological yield}} \text{ x}100$$

3.6.7 Soil Fertility Dynamics

Initial composite soil samples were collected from the field prior to the lay out of the experiment and was analysed for organic carbon, available nitrogen, available phosphorus and available potassium.

Immediately after the harvest of rice crop, soil samples were collected from the individual plots of the treatments and analysed for organic carbon (Walkley and Black, 1934), available nitrogen (Subbaiah and Asija, 1956), available phosphorus (Olsen *et al.*, 1954) and available potassium (Jackson, 1973).

3.6.8 Economics

Gross and Net returns (Rs ha^{-1}) were computed considering the existing market price of the inputs and outputs. Benefit cost ratio (BCR) was worked out for different treatments by dividing the gross returns by corresponding cost of cultivation.

3.7 GROUNDNUT (*rabi*, 2000 and 2001)

Groundnut crop was raised during *rabi* season after the harvest of *kharif* rice in the same undisturbed layout.

3.7.1 Experimental Details

Groundnut crop was raised to find the residual effect of the treatments applied to the *kharif* rice crop. The layout of *kharif* crop was undisturbed and uniform sowing of groundnut crop was done. No manures and fertilizers were applied to groundnut crop and the treatments consisted of treatments imposed to *kharif* rice.

3.7.2 Variety

The test variety was K-134 (Vemana), a Spanish bunch type with a duration of 100-110 days during *rabi*. It is tolerant to leaf spot with uniform maturity. It is a high yielding cultivar with no dormancy.

3.7.3 Cultivation Details

3.7.3.1 Preparatory cultivation. Each plot of *kharif* rice was ploughed using power tiller without disturbing the layout. The plots were levelled individually using spades.

3.7.3.2 Seeds and sowing. The seeds were not given any chemical or biological treatment. Sowing was done with a spacing of 22.5 x 10 cm.

3.7.3.3 Fertilizers. No external application. Only residual fertility of *kharif* rice.

3.7.3.4 Weeding. Hand hoeing was done twice at 20 and 40 DAS.

3.7.3.5 Plant protection. Neem seed oil @ 5 ml l^{-1} of water was used as a prophylactic and as a repellent of sucking pests and leaf eating caterpillar.

3.7.3.6 Irrigation. In addition to pre-sowing irrigation, about eight subsequent irrigations were given at 8-10 days interval.

3.7.3.7 Harvesting and stripping. The crop was considered mature when more than 75 per cent of the pods from randomly selected plants (from boarder area) showed dark streaks inside the shell. The border rows of each treatment were harvested first and treated as bulk. The plants in the net plot area were pulled separately and pods were stripped. Pods and haulms were sun dried thoroughly till a constant weight is arrived and the yields were recorded separately for each net plot and expressed as kg ha^{-1}.

3.7.4 Biometric Observations

3.7.4.1 Plant height. Five plants from each net plot were chosen by random sampling and tagged, which were used for recording plant height at 30, 60, 90 DAS and at harvest.

3.7.4.2 Leaf area index (LAI). LAI was calculated at 30, 60, 90 DAS and at harvest from the destructively sampled plants from the border rows leaving the extreme row, using the LI-COR LT-3000 portable leaf area meter with transparent belt conveyor with a electronic digital display and expressed in cm^{-2}.

LAI was calculated by dividing the total leaf area with the corresponding land area occupied by plant as suggested by Watson (1952).

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Unit land area}}$$

***3.7.4.3 Dry matter production*:** The destructively sampled plants for measuring leaf area were used for estimation of dry matter production. The samples were first air dried in the shade and then over dried at 60°C to a constant weight and dry matter accumulation was expressed as kg ha^{-1}.

3.7.4.4 Nodule dry weight. Five plants along with soil were carefully removed by scooping the soil with the shovel up to a depth of 30 cm at 30, 60, 90 DAS and at harvest, from destructively sampling area from each plot. The detached nodules from the sampled plants were oven dried at 60°C to a constant weight and expressed in mg per plant.

3.7.4.5 Spad chlorophyll meter readings Readings by the Spad chlorophyll meter were recorded at different stages of crop growth from the lower leaflets of 3rd leaf from the top of ten randomly selected plants and the average readings are expressed as Spad chlorophyll meter readings.

***3.7.4.6 Number of pods plant^{-1}*:** Pods from five randomly selected plants from net plots were separated, counted, averaged and expressed as number of pods plant^{-1} for each treatment.

3.7.4.7 Hundred-pod weight. After through drying of pods, from each treatment weight of five randomly selected 100-pod samples were recorded, averaged and expressed in grams.

3.7.4.8 Hundred-kernel weight. From the samples shelled for recording shelling percentage, five samples of hundred kernels each were randomly drawn, weighed, averaged and expressed as 100-kernel weight in grams.

3.7.4.9 Shelling per cent. From each treatment net plot yield, five random samples of 100 g of pods were drawn, hand shelled, kernels separated and weights recorded.

The shelling percentage was worked out by the following formula.

$$\text{Shelling \%} = \frac{\text{Weight of kernals}}{\text{Weight of pods}} \times 100$$

3.7.4.10 Pod yield. Pods from net plots were sun dried to a constant weight and expressed as pod yield in kg ha^{-1}.

3.7.4.11 Haulm yield. After thorough sun drying, the haulms from each net plot, were weighed and expressed as haulm yield in kg ha^{-1}

3.7.4.12 Harvest index. The relationship of economic yield to the total biological yield was expressed as harvest index (HI).

$$HI = \frac{\text{Grain yield}}{\text{Total biolgoical yield}} \times 100$$

3.7.5 Plant Analysis

Plant samples collected for dry matter estimation at 30, 60, 90 DAS and at harvest were dried, ground into fine powder and used for chemical analysis. N, P and K contents were analysed by the standard procedure out lined by Jackson (1973). The uptake of N, P and K in kg ha^{-1} at different stages of crop growth was calculated by multiplying the nutritional content with the respective dry matter production.

3.7.6 Soil Fertility Dynamics

Soil samples were collected from the individual plots of the treatments before sowing of the groundnut and after harvesting. The samples were analysed for organic carbon (Walkely and Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al.* 1954) and available potassium (Jackson, 1973).

3.7.7 Economics

Gross and Net returns (Rs ha^{-1}) were computed considering the existing market price of the inputs and outputs. Benefit cost ratio (BCR) was worked out for different treatments by dividing the gross returns by corresponding cost of cultivation.

3.8 TOTAL DRY MATTER PRODUCTION OF THE CROPPING SYSTEM

Total dry matter production of the cropping system as a whole was obtained for each treatment by summing up the dry matter production of rice and groundnut.

3.9 ECONOMIC YIELD (RICE GRAIN EQUIVALENT) OF THE CROPPING SYSTEM

Pod yield of groundnut was converted into rice grain equivalent (RGE) on the basis of the prevailing market price using the following formula and expressed in kg ha^{-1}.

$$\text{RGE} = \frac{\text{Pod yield of groundnut (kg ha}^{-1}\text{)} \times \text{Price of groundnut (Rs kg}^{-1}\text{)}}{\text{Price of rice grain (Rs kg}^{-1}\text{)}}$$

By summing up the rice grain yield and rice grain equivalent yield of groundnut for each treatment, the total economical yield of the cropping system was arrived at.

3.10 NITROGEN BALANCE IN THE CROPPING SYSTEM

Soil available N balance in the cropping system (annual cropping cycle) was computed for different treatments as per the procedure suggested by Sadanandan and Mahapatra (1973).

3.11 ECONOMICS OF THE CROPPING SYSTEM

Gross and net returns per hectare were computed for the cropping system as a whole, considering the present market price of the inputs and produce. Benefit-cost ratio for the cropping system was worked out for different treatments, by dividing the gross returns by cost of cultivation.

3.12 STATISTICAL ANALYSIS

The data recorded on various growth and yield parameters of both rice and groundnut crops during the course of investigation were statistically anlaysed following the analysis of variance for randomized block design as suggested by Panse and Sukhatme (1985).

Wherever the treatmental differences were found significant ('F' test), critical difference was worked out at 0.05-probability level and the values are furnished. Treatmental differences that were non-significant were denoted as NS.

Results

Results

CHAPTER-IV

RESULTS

The results of the field experiment entitled "Prospects of organic farming in rice-based cropping system" conducted for two consecutive years during 2000 and 2001 on sandy clay loam soils of S.V. Agricultural College Farm, Tirupati are presented in this chapter.

The experiment was conducted for two seasons in each year of study, with rice during *kharif* season and groundnut during *rabi* season.

4.1 RICE (*kharif,* 2000 and 2001)

4.1.1 Growth Parameters

4.1.1.1 Plant height. Plant height measured at different stages of crop growth viz., active tillering, panicle initiation and flowering was significantly influenced by different nitrogen management practices, during both the years of study (Table 4.1)

4.1.1.1.1 Plant height at active tillering. In both the years of study, the tallest plants were recorded with 100 per cent N through exclusive green manuring with dhaincha (T_3), which were however, in parity with all the treatments of recommended N application, except FYM N_{100} (T_5). The lowest plant height was registered with no N application (T_1), which was comparable with application of *Azospirillum* alone (T_2) and the plant height under these two treatments was significantly inferior to rest of the recommended N application treatments, during both the years of study.

Table 4.1: Plant height (cm) of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000			*Kharif*, 2001		
	Active tillering	Panicle initiation	Flowering	Active tillering	Panicle initiation	Flowering
T_1	38.0	62.2	80.9	45.5	70.8	82.6
T_2	38.5	63.7	82.8	46.1	71.0	85.1
T_3	49.3	76.6	93.3	52.6	79.2	94.3
T_4	45.3	77.4	94.9	49.7	79.4	95.7
T_5	43.2	70.0	89.4	49.6	76.4	90.9
T_6	48.5	79.8	98.9	51.7	82.2	99.2
T_7	48.2	77.6	95.3	50.9	79.9	95.7
T_8	48.3	80.0	98.3	51.0	83.0	97.1
T_9	46.1	75.6	93.3	50.1	78.2	95.5
T_{10}	48.6	78.7	96.6	51.9	80.9	96.9
T_{11}	49.3	80.2	98.3	52.0	83.2	97.3
T_{12}	46.5	76.3	94.5	50.3	78.6	95.6
SEm ±	1.4	2.09	2.03	1.00	1.78	1.71
CD (P=0.05)	4.2	6.1	6.0	2.9	5.2	5.0

4.1.1.1.2 Plant height at panicle initiation. The treatment GLM N_{50} + F N_{50} + *Azo.* (T_{11}) registered the highest plant height during both the years of investigation, which was comparable with other recommended N application practices, except FYM N_{100} (T_5). However, all the treatments with recommended N application produced significantly higher plant height than no N application (T_1) and *Azospirillum* application alone (T_2), which were statistically similar to each other, during both the instances of investigation.

4.1.1.1.3 Plant height at flowering. The highest plant height was registered with 100 per cent N through fertilizer (T_6), which was comparable with all the treatments of recommended N application, except 100 per cent N through FYM (T_5) during both the years of study. The plant height recorded with FYM N_{100} (T_5) was however, comparable with the integrated N management practices of FYM N_{50} + F N_{50} + *Azo.* (T_{12}) and FYM N_{50} + F N_{50} (T_9) and with exclusive organic sources of N supply viz., GLM N_{100} (T_4) and GM N_{100} (T_3), during both the instances of study. The plant height recorded with no N application (T_1) and with *Azospirillum* alone (T_2) was comparable with each other and inferior to all the recommended N application treatments, during both the years of investigation.

4.1.1.2 Total number of tillers m^{-2}. Total number of tillers recorded at different stages of crop growth of rice viz., active tillering, panicle initiation, flowering and at harvest was significantly influenced by different nitrogen management practices (Table 4.2).

4.1.1.2.1 Total number of tillers m^{-2} at active tillering. The highest number of tillers m^{-2} was registered with the application of 100 per cent N through dhaincha green manuring (T_3), which was comparable with all the treatments of recommended N application, except with supply of 100 per cent N through FYM (T_5), during both the years of study. Application of *Azospirillum* alone (T_2) was comparable with non-supply of nitrogen (T_1) and significantly inferior to any of the treatments of recommended N application, during both the instances of study.

Table 4.2: Total number of tillers m^{-2} of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000				*Kharif*, 2001			
	Active tillering	Panicle initiation	Flowering	At harvest	Active tillering	Panicle initiation	Flowering	At harvest
T_1	375	384	356	301	382	403	385	305
T_2	386	402	372	309	402	421	396	314
T_3	571	555	448	374	606	580	463	375
T_4	512	565	471	387	526	582	487	405
T_5	469	492	436	347	497	522	456	366
T_6	553	596	515	405	566	591	536	426
T_7	538	571	477	389	548	586	489	405
T_8	541	619	488	397	556	607	518	411
T_9	521	539	454	379	535	564	482	395
T_{10}	562	571	480	394	592	588	491	406
T_{11}	565	620	501	401	599	621	524	419
T_{12}	533	547	460	383	538	567	483	400
SEm ±	28.1	29.3	21.5	9.9	30.0	20.2	18.4	15.9
CD (P=0.05)	82	86	63	29	88	59	54	47

4.1.1.2.2 Total number of tillers m^{-2} at panicle initiation. During both the years of study, the highest number of tillers m^{-2} was recorded with GLM N_{50} + F N_{50} + *Azo.* (T_{11}), which was comparable with all the treatments of recommended N application, except FYM N_{100} (T_5). All the treatments with recommended N application produced significantly higher number of tillers m^{-2} than no N application (T_1) and application of *Azospirillum* alone (T_2) and both of them were in parity with each other, during both the years of investigation.

4.1.1.2.3 Total number of tillers m^{-2} at flowering. The highest number of tillers m^{-2} was recorded with 100 per cent N through fertilizer (FN_{100}), which was comparable with integrated N management practices of GLM N_{50} + F N_{50} + *Azo.* (T_{11}), GLM N_{50} + F N_{50} (T_8), GM N_{50} + F N_{50} + *Azo.* (T_{10}), GM N_{50} + F N_{50} (T_7), FYM N_{50} + F N_{50} + *Azo.* (T_{12}) and FYM N_{50} + F N_{50} (T_9) and with exclusive green leaf manuring of GLM N_{100} (T_4), during both the years of study. The treatments of exclusive organic source of N supply viz., GM N_{100} (T_3) and FYM N_{100} (T_5) were comparable with each other and also with the integrated N management practices of GM N_{50} + F N_{50} + *Azo.* (T_{10}), GM N_{50} + F N_{50} (T_7), FYM N_{50} + F N_{50} + *Azo.* (T_{12}) and FYM N_{50} + F N_{50} (T_9), during both the years of study. But, all the treatments with recommended N application were significantly superior to control (no N) and application of *Azospirillum* alone (T_2), which were of course comparable with each other, during both the instances of study.

4.1.1.2.4 Total number of tillers m^{-2} at harvest. Tiller production was found to be the highest with 100 per cent N supply through fertilizer (T_6), which was comparable with all the integrated N management practices and the treatment of exclusive green leaf manuring GLM N_{100} (T_4), during both the years of investigation. Treatments of exclusive organic source of N supply viz., GM N_{100} (T_3) and FYM N_{100} (T_5) were comparable with each other. During both the years of study, the number of tillers produced with GM N_{100} (T_3) was comparable with all the integrated N management practices. However, the number of tillers produced with FYM N_{100} (T_5) was comparable only with GM N_{100} (T_3), during the first year but in the second year of study it was comparable with all the integrated N management practices, except with GLM N_{50} + F N_{50} + *Azo.* (T_{11}). The number of tillers produced with no N (T_1) and *Azospirillum* application alone (T_2) was in parity with each other, but inferior to any of the treatments with recommended N application.

4.1.1.3 Leaf area index (LAI). Leaf area index of rice measured at different growth stages of rice viz., active tillering, panicle initiation and flowering was significantly influenced by different N management practices, during both the years of study (Table 4.3).

4.1.1.3.1Leaf area index at active tillering. Application of 100 per cent recommended N through dhaincha green manuring (T_3) has recorded the highest leaf area index, which was comparable with all the treatments of recommended N application, except with FYM N_{100} (T_5), during both the years of study. The LAI recorded with FYM N_{100} (T_5) was comparable only with exclusive green leaf manuring of GLM N_{100} (T_4), during the first year and with GLM N_{100} (T_4), FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}) and GM N_{50} + F N_{50} (T_7) during the second year of study. The LAI recorded with no N (T_1) and with application of *Azospirillum* alone (T_2) was comparable with each other and significantly inferior to any of the treatments with recommended N application.

4.1.1.3.2 Leaf area index at panicle initiation. Combination of 50 per cent N through GLM and 50 per cent N through FN along with *Azospirillum* (T_{11}) recorded the highest LAI, which was comparable with all other recommended N application

Table 4.3: Leaf area index of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000			*Kharif*, 2001		
	Active tillering	Panicle initiation	Flowering	Active tillering	Panicle initiation	Flowering
T_1	1.06	3.76	3.08	1.11	3.98	3.05
T_2	1.25	3.92	3.20	1.28	4.50	3.16
T_3	2.12	6.35	4.69	2.29	6.92	4.46
T_4	1.88	6.41	5.03	2.04	6.94	4.85
T_5	1.64	5.57	4.19	1.75	5.81	4.20
T_6	2.05	6.75	5.82	2.25	7.01	5.50
T_7	1.99	6.53	5.08	2.10	6.95	4.88
T_8	1.99	6.98	5.42	2.19	7.18	5.42
T_9	1.93	6.19	4.91	1.97	6.86	4.65
T_{10}	2.09	6.68	5.12	2.26	7.01	4.97
T_{11}	2.12	7.00	5.58	2.26	7.27	5.48
T_{12}	1.97	6.29	4.92	2.04	6.89	4.71
SEm ±	0.092	0.361	0.324	0.148	0.389	0.348
CD (P=0.05)	0.27	1.06	0.95	0.43	1.14	1.02

treatments, except FYM N_{100} (T_5), during both the years of investigation. The LAI recorded with FYM N_{100} (T_5) was in parity with treatments of exclusive organic source of N supply viz., GLM N_{100} (T_4) and GM N_{100} (T_3) and integrated N management treatments of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}) and GM N_{50}+F N_{50} (T_7), during both the instances of investigation. LAI recorded with application of *Azospirillum* alone (T_2) and no N (T_1) was comparable with each other and significantly inferior to all the treatments of recommended N application.

4.1.1.3.3 Leaf area index at flowering. In both the years of study, the largest LAI was recorded with 100 per cent N through fertilizer (T_6) which was comparable with all the treatments of integrated N management and exclusive green leaf manuring, GLM N_{100} (T_4). The LAI recorded with GM N_{100} (T_3) was however, statistically similar to all the integrated N management practices and with exclusive organic sources of N supply, while the LAI registered with FYM N_{100} (T_5) was comparable with integrated N management treatments of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GM N_{50} + F N_{50} (T_7) and GM N_{50} + F N_{50} + *Azo.* (T_{10}) and with exclusive organic N sources of GM N_{100} (T_3) and GLM N_{100} (T_4), during both the years of study. The LAI recorded with application of *Azospirillum* alone (T_2) and no N (T_1) was statistically comparable and significantly inferior to all the treatments of recommended N application.

4.1.1.4 Dry matter production. Dry matter production recorded at different crop growth stages of rice viz., active tillering, panicle initiation, flowering and at harvest was significantly influenced by different N management practices, during both the years of investigation (Table 4.4).

4.1.1.4.1 Dry matter production at active tillering. During both the years of study, the highest dry matter production was recorded with 100 per cent N through dhaincha green manuring (T_3), which was comparable with all other recommended N application treatments, except FYM N_{100} (T_5). The treatment FYM N_{100} (T_5) recorded statistically similar dry matter production to that of integrated N management treatments of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GM N_{50} + F N_{50} (T_7) and GLM N_{50} + F N_{50} (T_8), 100 per cent N through fertilizer (T_6) and 100 per cent N through green leaf manuring (T_4), during both the years of investigation. During both the years of experimentation, the lowest dry matter production was registered with no nitrogen supply (T_1), which was of course comparable with *Azospirillum* application alone (T_2), and significantly inferior to any of the treatments with recommended N application.

4.1.1.4.2 Dry matter production at panicle initiation. Combination of 50 per cent N through neem leaf manure and 50 per cent N through fertilizer along with *Azospirillum* (T_{11}) recorded the highest dry matter production, which was comparable with all other treatments of recommended N supply, except FYM N_{100} (T_5), during both the years of the study. The dry matter production recorded with FYM N_{100} (T_5) was however, in parity with the integrated N application treatments of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GM N_{50} + F N_{50} (T_7) and GM N_{50} + F N_{50} + *Azo.* (T_{10}) and with exclusive organic sources of N application treatments of GM N_{100} (T_3) and GLM N_{100} (T_4), during both the years of study. During both the years of investigation, the treatment with no N supply (T_1) and *Azospirillum* application alone (T_2) registered statistically similar dry matter production, which was significantly lesser to all the treatments of recommended N supply.

Table 4.4: Dry matter production (kg ha^{-1}) of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000				*Kharif*, 2001			
	Active tillering	Panicle initiation	Flowering	At harvest	Active tillering	Panicle initiation	Flowering	At harvest
T_1	1518	3767	5866	7638	1594	3910	5879	8075
T_2	1558	4244	6270	8001	1636	4260	6143	8484
T_3	2139	5597	8261	10223	2146	6297	8241	10587
T_4	1908	5625	8964	10938	1953	6303	9083	11160
T_5	1834	5139	7852	9852	1868	5686	7761	10311
T_6	2071	5740	9888	11433	2070	6522	9435	11661
T_7	1947	5651	9420	10919	2035	6420	9187	11293
T_8	2025	5750	9621	11257	2051	6536	9369	11462
T_9	1926	5574	8816	10722	2018	6212	8810	10988
T_{10}	2097	5716	9538	11158	2113	6492	9308	11382
T_{11}	2125	5772	9858	11318	2122	6591	9421	11549
T_{12}	1944	5585	8960	10785	2020	6252	8850	11096
SEm ±	84.9	202.3	407.5	242.4	68.7	280.7	342.4	275.8
CD ($P=0.05$)	249	593	1195	711	202	823	1004	809

4.1.1.4.3 Dry matter production at flowering. Application of 100 per cent N through fertilizer (T_6) recorded the highest quantity of dry matter, which was comparable with all other treatments of recommended N application, except the two exclusive organic sources of N supply viz., GM N_{100} (T_3) and FYM N_{100} (T_5), during both the years of study. The dry matter produced with GM N_{100} (T_3) was comparable with the integrated N application treatments of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}) and GM N_{50} + F N_{50} (T_7) and with exclusive organic N supply treatments of GLM N_{100} (T_4) and FYM N_{100} (T_5), during both the years of study. However, the dry matter produced with FYM N_{100} (T_5) was comparable with GM N_{100} (T_3), FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}) and GLM N_{100} (T_4) during the first year and with only GM N_{100} (T_3) during the second year of investigation. The quantity of dry matter produced with *Azospirillum* application alone (T_2) and no N supply (T_1) was comparable with each other and significantly inferior to all the treatments with recommended N application.

4.1.1.4.4 Dry matter production at harvest. The highest dry matter production was recorded with 100 per cent N through fertilizer (T_6), which was comparable with rest of the treatments of recommended N supply, except 100 per cent N supply through FYM N_{100} (T_5), during both the years of study The dry matter produced with 100 per cent N through dhaincha green manure (T_3) was comparable with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GM N_{50} + F N_{50} (T_7) and GLM N_{100} (T_4), while the dry matter accumulated with FYM N_{100} (T_5) was statistically similar only with GM N_{100} (T_3), during both the instances of investigation. Application of *Azospirillum* alone (T_2) has registered an increase of dry matter production by 4.75 and 5.07 per cent over no N supply (T_1) during 2000 and 2001 respectively. However, the dry matter accumulation with *Azospirillum* alone (T_2) and no N (T_1) was comparable with each other and significantly lesser than any other treatments of recommended N supply.

4.1.2 Yield Attributes

Yield attributes of rice viz., productive tillers (panicles) m^{-2}, number of grains panicle^{-1}, filled grains panicle^{-1} and 1000 grain weight varied significantly due to different N management practices, during both the instances of the investigation (Table 4.5).

4.1.2.1 Productive tillers (panicles) m^{-2}. Among the different N management practices, application of 100 per cent N through fertilizer (T_6) has produced the highest number of panicles m^{-2}, which was comparable with all the integrated N management practices and with exclusive sources of N supply with GLM N_{100} (T_4), during both the years of investigation. Among different N management practices to supply 100 per cent N, application of 100 per cent N through FYM (T_5) has registered the lowest number of panicles m^{-2}, which was however comparable with GM N_{100} (T_3), FYM N_{50}+F N_{50} (T_9), FYM N_{50}+F N_{50}+*Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{50}+F N_{50} (T_7), during both the years of study. The number of panicles produced with the application of *Azospirillum* alone (T_2) and no N application (T_1) was comparable with each other and significantly inferior to all the treatments of recommended N application.

4.1.2.2 Number of grains panicle^{-1}. The highest number of grains panicle^{-1} was recorded with 100 per cent N through fertilizer (T_6), which was in parity with all the integrated N management treatments and exclusive organic source of N supply through green leaf manure (GLM N_{100}), during both the years of investigation. Among the treatments with recommended N management practices, application of 100 per cent N through FYM (T_5) has registered the lowest number of grains panicle^{-1}, during both the instances of investigation. Application of *Azospirillum* alone (T_2) was statistically no better than non-supply of N (T_1) and both these were significantly lesser than any other treatments of recommended N application, during both the years of study.

Table 4.5: Yield attributes of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000				*Kharif*, 2001			
	No.of panicles m^{-2}	No.of grains $panicle^{-1}$	Filled grains $panicle^{-1}$	1000 grain weight (g)	No.of panicles m^{-2}	No.of grains $panicle^{-1}$	Filled grains $panicle^{-1}$	1000 grain weight (g)
T_1	270	76.4	56.3	22.2	263	73.1	52.7	22.2
T_2	283	77.4	58.8	22.3	280	75.5	56.6	22.2
T_3	334	89.8	67.2	23.0	339	85.9	64.7	23.0
T_4	348	94.0	73.1	23.4	356	93.6	70.4	23.4
T_5	321	85.8	65.0	23.0	329	85.4	64.4	23.0
T_6	372	99.0	75.6	23.6	363	98.9	74.3	23.6
T_7	352	95.4	73.9	23.4	358	94.8	71.2	23.5
T_8	366	96.8	74.6	23.7	360	97.1	73.1	23.7
T_9	343	93.1	69.4	23.2	351	91.0	69.5	23.1
T_{10}	361	95.8	74.2	23.5	360	95.7	71.4	23.5
T_{11}	366	97.5	75.4	23.8	362	98.3	73.9	23.8
T_{12}	344	93.8	72.7	23.3	354	91.7	69.8	23.2
SEm ±	12.3	2.42	2.11	0.20	7.5	2.98	2.79	0.24
CD (P=0.05)	30	7.1	6.2	0.6	22	8.7	8.2	0.7

4.1.2.3 Number of filled grains panicle^{-1}. Application of 100 per cent N through fertilizer (T_6) has produced the highest number of filled grains panicle^{-1}, which was comparable with all the other recommended N application treatments, except with GM N_{100} (T_3) and FYM N_{100} (T_5), during both the years of investigation. Among the treatments with recommended N application, 100 per cent N through FYM (T_5) has registered the lowest number of grains panicle^{-1}, during both the years of study. The number of filled grains panicle^{-1} produced with non-supply of N (T_1) was statistically similar to *Azospirillum* application alone (T_2) and significantly inferior to the rest of N management practices.

4.1.2.4 Thousand-grain weight. During both the years of study, the highest thousand-grain weight was recorded with the application of 50 per cent N through green leaf manuring and 50 per cent N through fertilizer along with *Azospirillum* (T_{11}), which was however, comparable with all other treatments of integrated N management. practices and exclusive organic source of N supply through green leaf manuring (GLM N_{100}), during both the years of study. The thousand-grain weight produced with *Azospirillum* application alone (T_2) was comparable with no N supply (T_1) and was significantly inferior to all other treatments of recommended N application.

4.1.3 Yield

In both the years of study, grain yield and straw yield was significantly influenced by different N management practices (Table 4.6).

4.1.3.1 Grain yield. Application of 100 per cent N through fertilizer (T_6) has recorded the highest grain yield, which was however, comparable with all the integrated nutrient management practices viz., GM N_{50} + F N_{50} (T_7), GLM N_{50} + F N_{50} (T_8),

Table 4.6: **Grain yield, Straw yield (kg ha^{-1}) and Harvest index (%) of rice as influenced by different nitrogen management practices**

Treatments	*Kharif*, 2000			*Kharif*, 2001		
	Grain yield	Straw yield	Harvest index*	Grain yield	Straw yield	Harvest index*
T_1	3275	4263	43.4	3525	4550	43.6
T_2	3572	4428	44.7	3750	4778	44.0
T_3	4773	5449	46.7	4704	5783	44.9
T_4	4852	6087	44.4	4801	6358	43.0
T_5	4606	5246	46.8	4561	5550	45.1
T_6	5284	6149	46.2	5181	6480	44.4
T_7	5140	5927	46.4	5060	6293	44.6
T_8	5168	6089	45.9	5099	6368	44.5
T_9	4994	5728	46.6	4977	6011	45.3
T_{10}	5191	5967	46.5	5130	6352	44.7
T_{11}	5195	6123	45.9	5143	6407	44.5
T_{12}	5006	5779	46.4	4979	6177	44.9
SEm ±	117.2	146.9	--	120.0	166.2	--
CD (P=0.05)	344	431	--	352	487	--

* Data were not statistically analysed

FYM N_{50} + F N_{50} (T_9), GM N_{50} + F N_{50} + *Azo.* (T_{10}), GLM N_{50} + F N_{50} + *Azo.* (T_{11}) and FYM N_{50} + F N_{50} + *Azo.* (T_{12}), during both the years of study. The percentage increase in grain yield of the best treatment of F N_{100} (T_6) over the integrated N management treatments of GLM N_{50} + F N_{50} + *Azo.*, GM N_{50} + F N_{50} + *Azo.*, GLM N_{50} + F N_{50} , GM N_{50} + F N_{50}, FYM N_{50} + F N_{50} + *Azo.* and FYM N_{50} + F N_{50} was 1.7, 1.8, 2.2, 2.8, 5.6 and 5.8 respectively, during the first year and 0.7, 1.0, 1.6, 2.4, 4.1 and 4.1, respectively during the second year of study. Similarly, the increase in grain yield by F N_{100} (T_6) over exclusive organic N management treatments of GLM N_{100}, GM N_{100} and FYM N_{100} was 8.9, 10.7 and 14.7 per cent respectively, during the first year and 7.9, 10.1 and 13.6 per cent, respectively, during the second year of study. The yield recorded with exclusive green leaf manuring (GLM N_{100}) was however, statistically similar to all the recommended N management practices except F N100, while that with green manuring with dhaincha (GM N_{100}) was comparable with the other two organic sources of GLM N_{100} and FYM N_{100} and the combinations of FYM viz., FYM N_{50} + F N_{50} + *Azo.* and FYM N_{50} + F N_{50}, during both the years of study. However application of 100 per cent N through FYM (T_5) was comparable only with the other two exclusive organic sources of N supply viz., GLM N_{100} and GM N_{100}.

The treatments with no N supply (T_1) and *Azospirillum* application alone (T_2) were comparable with each other, but with significantly lower yield than any other N management practices supplying 100 per cent recommended N. However, application of *Azospirillum* alone (T_2) has recorded an yield increase of 9.1 and 6.4 per cent over control (T_1) during 2000 and 2001, respectively. The yield increase of F N_{100} (T_6) over *Azospirillum* application alone (T_2) was 47.9 and 38.2 per cent, respectively during the first and second year of study and over the control (no N) it was 61.3 and 47.0 per cent, respectively during 2000 and 2001.

4.1.3.2 Straw yield. The highest straw yield was recorded with F N_{100} (T_6) during both the years of investigation, which was comparable with other recommended N management practices supplying 100 per cent recommended N, except the two exclusive organic sources of N supply viz.. GM N_{100} and FYM N_{100}. The straw yield obtained with F N_{100} was comparable only with GM N_{100}, which was also of course statistically similar with combinations of farm yard manure viz., FYM N_{50} + F N_{50} and FYM N_{50} + F N_{50} + *Azo.*, during both the years of investigation.

The straw yield recorded with non-supply of N (T_1) and *Azospirillum* application alone (T_2) were at par with each other and significantly lower than the rest of the nitrogen management practices tried. However, application of *Azospirillum* alone (T_2) has recorded an yield increase of 3.9 and 5.0 per cent over no N application (T_1), during 2000 and 2001, respectively.

4.1.3.3 Harvest index. Harvest index of rice was not altered to a noticeable extent by different N management practices. However, marginally lower values of harvest index were observed with no N application (T_1), *Azospirillum* application alone (T_2) and application of 100 per cent N through neem leaf manure (T_4), during both the years of study.

4.1.4 Quality Characters of Rice Kernels (Table 4.7a and 4.7b)

4.1.4.1 Whole grain per cent. Different N management practices has shown considerable variation in whole grain per cent during both the years of experimentation. Application of 50 per cent N through green leaf manure and 50 per cent N through fertilizer along with *Azospirillum* (T_{11}) has registered the highest whole grain per cent, which was in parity with all the recommended N management practices, except 100 per cent through FYM (T_5), during both the years of investigation. The treatments of no N supply (T_1) and *Azospirillum* application alone (T_2) were comparable with each other, with significantly lower whole grain per cent than any other N management practices supplying 100 per cent recommended N.

4.1.4.2 Milling per cent. N management practices have exerted noticeable effect on the milling per cent of rice, during both the years of study. During both the years of investigation, the highest milling per cent was recorded with GLM N_{50} + F N_{50} + *Azo.* (T_{11}), which was however, in parity with all other recommended N management practices, except GM N_{100} (T_3) and FYM N_{100} (T_5). The two exclusive organic treatments of GM N_{100} (T_3) and FYM N_{100} (T_5) were statistically similar with each other, during both the years of study. Application of *Azospirillum* alone (T_2) and non-supply of N (T_1) were at par with each other, with significantly inferior values to all the other N management practices, during both the years of observation.

4.1.4.3 Broken grain per cent. Treatment with no N application (T_1) has registered the highest broken grain per cent, during both the years of investigation, which was however, comparable with *Azospirillum* application alone (T_2) and both these treatments were statistically superior to all other treatments with recommended N application. All the recommended N application treatments produced statistically comparable broken grain per cent, during both the years of experimentation.

4.1.4.4 Protein content. During both the years of investigation, the highest protein content was registered with GLM N_{50} + F N_{50} + *Azo.* (T_{11}), which was in parity with all the recommended N application treatments. Application of *Azospirillum* alone (T_2) was statistically no superior than no N application (T_1) during both the years of investigation and the protein content of these two treatments was significantly inferior to all the treatments of recommended N supply.

Table 4.7a: Quality of rice as influenced by different nitrogen management practices during *kharif*, 2000

Treatments	Whole grain per cent	Milling per cent	Broken grain per cent	Protein content (%)	Amylose content (%)	Elongation ratio
T_1	76.6	71.5	2.40	6.7	18.0	1.29
T_2	76.8	71.9	2.38	6.8	18.8	1.31
T_3	77.4	72.5	2.28	7.3	21.2	1.32
T_4	77.7	72.8	2.25	7.5	21.7	1.33
T_5	77.3	72.4	2.29	7.3	21.3	1.32
T_6	77.7	72.9	2.22	7.5	21.9	1.33
T_7	77.7	72.8	2.24	7.5	21.8	1.33
T_8	77.8	72.9	2.22	7.6	21.9	1.34
T_9	77.4	72.7	2.27	7.4	21.6	1.32
T_{10}	77.7	72.8	2.24	7.5	21.8	1.33
T_{11}	77.8	73.0	2.21	7.7	22.0	1.35
T_{12}	77.7	72.8	2.26	7.5	21.7	1.33
SEm ±	0.13	0.13	0.027	0.13	0.27	0.021
CD (P=0.05)	0.4	0.4	0.08	0.4	0.8	NS

Table 4.7b: Quality of rice as influenced by different nitrogen management practices during *kharif*, 2001

Treatments	Whole grain per cent	Milling per cent	Broken grain per cent	Protein content (%)	Amylose content (%)	Elongation ratio
T_1	77.0	71.8	2.39	6.8	18.5	1.31
T_2	77.0	72.0	2.38	7.0	18.9	1.31
T_3	77.5	72.5	2.28	7.4	21.2	1.32
T_4	77.7	72.8	2.24	7.5	21.7	1.33
T_5	77.5	72.4	2.29	7.4	21.5	1.32
T_6	77.7	72.8	2.23	7.5	21.8	1.33
T_7	77.7	72.8	2.24	7.5	21.7	1.33
T_8	77.7	72.8	2.23	7.6	21.8	1.34
T_9	77.6	72.7	2.26	7.4	21.6	1.35
T_{10}	77.7	72.8	2.23	7.5	21.8	1.34
T_{11}	77.8	72.9	2.22	7.6	21.9	1.35
T_{12}	77.7	72.7	2.25	7.5	21.7	1.33
SEm ±	0.15	0.064	0.028	0.09	0.27	0.014
CD (P=0.05)	0.4	0.2	0.08	0.3	0.8	NS

4.1.4.5 Amylose content. Application of GLM N_{50} + F N_{50} + *Azo*. (T_{11}) registered the highest amylose content of rice kernels, during both the years of study, which was in parity with all the recommended N application treatments. The treatments with no N application (T_1) and application of *Azospirillum* alone (T_2) were statistically similar to each other and significantly inferior to any of the recommended N application treatments.

4.1.4.6 Elongation ratio. Elongation ratio resulted from different N management practices did not differ to any statistically noticeable extent, during both the years of experimentation. However, the highest value was recorded with GLM N_{50} + F N_{50} + *Azo*. (T_{11}), while the lowest was recorded with non-supply of N (T_1).

4.1.5 Nitrogen Uptake

Nitrogen uptake recorded at different stages of crop growth of rice viz., active tillering, panicle initiation, flowering and at harvest was significantly influenced by different N management practices, during both the instances of the investigation (Table 4.8).

4.1.5.1 Nitrogen uptake at active tillering. Application of 100 per cent N through green manuring (T_3) has recorded the highest N uptake, during both the years of study, which was comparable with the treatments of recommended N application, except FYM N_{100} (T_5). The treatment FYM N_{100} has registered statistically similar N uptake with all the recommended N application treatments, except 100 per cent N through fertilizer (T_6), during both the years of study. The N uptake with no N supply (T_1) and *Azospirillum* application alone (T_2) was comparable with each other and significantly lower than other N management practices supplying 100 per cent recommended N.

Table 4.8 : Nitrogen uptake (kg ha^{-1}) at various stages of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000					*Kharif*, 2001				
	Active tillering	Panicle initiation	Flowering	At harvest		Active tillering	Panicle initiation	Flowering	At harvest	
				Grain	Straw				Grain	Straw
T_1	29.5	35.6	43.8	35.3	16.6	25.6	36.2	44.3	38.3	18.0
T_2	31.5	40.2	50.4	39.4	18.7	27.4	40.2	48.5	41.3	20.1
T_3	47.0	54.8	70.3	55.8	24.3	43.4	60.1	67.4	56.7	29.5
T_4	40.9	55.7	74.1	56.2	28.7	36.5	61.5	76.1	58.1	31.6
T_5	39.5	51.1	68.9	54.1	23.6	35.3	56.2	62.2	56.6	25.8
T_6	44.9	58.7	80.3	63.5	30.6	40.5	66.2	79.7	63.2	33.8
T_7	43.7	56.3	74.6	60.2	27.7	39.5	63.6	76.7	61.3	30.8
T_8	44.4	59.2	78.7	61.2	29.5	40.2	66.2	77.5	61.4	32.6
T_9	42.3	55.5	72.6	58.5	27.3	38.6	60.4	72.5	59.5	29.8
T_{10}	45.3	58.6	76.8	61.4	27.8	40.9	64.6	77.2	61.7	31.2
T_{11}	46.0	60.5	80.0	62.9	30.1	41.8	66.6	78.9	62.7	32.8
T_{12}	42.6	55.6	74.0	60.0	27.7	38.7	61.0	73.9	60.7	29.8
SEm ±	2.39	3.06	3.37	2.27	1.43	2.63	2.88	2.81	1.56	1.37
CD (P=0.05)	7.0	9.0	9.9	6.7	4.2	7.7	8.4	8.2	4.6	4.0

4.1.5.2 Nitrogen uptake at panicle initiation. During both the years of study, application of 50 per cent N through green leaf manure and 50 per cent N through fertilizer along with *Azospirillum* (T_{11}) has registered the highest N uptake, which was in parity with N uptake by treatments of recommended N application, except with 100 per cent N through FYM (T_5), during both the years of investigation. Application of *Azospirillum* alone (T_2) has not recorded any appreciable N uptake compared to no N application (T_1), during both the years of study and the N uptake of these two treatments was significantly inferior to any of the recommended N application treatments tried.

4.1.5.3 Nitrogen uptake at flowering. In both the years of study, the treatment of 100 per cent N through fertilizer (T_6) has registered the highest uptake of N by rice crop, which was comparable with the recommended N application treatments, except GM N_{100} (T_3) and FYM N_{100} (T_5). The uptake of N with application of *Azospirillum* alone (T_2) was statistically comparable with no N application (T_1), during both the years of study and was inferior to all the treatments of recommended N application.

4.1.5.4 Nitrogen uptake by grain. The highest N uptake by grain was recorded with 100 per cent N through fertilizer (T_6), which was at par with all the integrated N application treatments, during both the yeas of investigation. Among the treatments with recommended N application, the lowest N uptake, during both the years of experimentation was registered with supply of 100 per cent N through farm yard manure (T_5), which was however, comparable with the other two exclusive organic sources of N supply viz., GLM N_{100} (T_4) and GM N_{100} (T_3) and also with the combinations of FYM viz., FYM N_{50} + F N_{50} (T_9) and FYM N_{50} + F N_{50} + *Azo.* (T_{12}). No appreciable increase in N uptake was registered with *Azospirillum* application (T_2) over no N application (T_1) and the N uptake with these two treatments was statistically inferior to any of the recommended N application treatments.

4.1.5.5 Nitrogen uptake by straw. During both the years of investigation, the highest N uptake by straw was registered with supply of 100 per cent N through fertilizer (T_6), which was comparable with all the treatments of recommended N application, except with GM N_{100} (T_3) and FYM N_{100} (T_5). Among the treatments of recommended N application, the lowest N uptake by straw was registered with 100 per cent N through FYM (T_5), during both the years of study. No significant increase in N uptake was noticed with application of *Azospirillum* alone (T_2) over no N application (T_1) and the N uptake by both the treatments was inferior to all other treatments with recommended N application, during both the years of study.

4.1.5.6 Nitrogen harvest index (NHI). Different N management practices did not exert any marked influence on the NHI of rice crop (Table 4.9).

4.1.6 Phosphorus Uptake

Phosphorus uptake recorded at different stages of crop growth of rice viz., active tillering, panicle initiation, flowering and at harvest was significantly influenced by different N management practices, during both the years of study (Table 4.10).

4.1.6.1 Phosphorus uptake at active tillering. During both the years of investigation, the highest uptake of phosphorus was registered with supply of 100 per cent N through green manure (T_3), which was however, in parity with all the recommended N application treatments, during both the years of experimentation. The uptake of P with *Azospirillum* alone (T_2) and with no N application (T_1) was statistically similar, during both years of study and significantly inferior to any of the treatments of recommended N application.

Table 4.9: Nitrogen harvest index (%) of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000	*Kharif*, 2001
T_1	68.0	68.0
T_2	67.8	67.3
T_3	69 7	65.8
T_4	66.2	64.8
T_5	69.6	68.7
T_6	67.5	65.2
T_7	68.5	66.6
T_8	67.5	65.3
T_9	68.2	66.6
T_{10}	68.8	66.4
T_{11}	67.6	65.7
T_{12}	68.4	67.1

*Data were not analyzed statistically

4.1.6.2 Phosphorus uptake at panicle initiation. The highest uptake of phosphorus at panicle initiation was recorded with 50 per cent N through green leaf manure and 50 per cent N through fertilizer along with *Azospirillum* (T_{11}), during both the years of study. The phosphorus uptake by all the treatments of recommended N application was comparable with each other and was significantly superior to application of *Azospirillum* alone (T_2) and no N application (T_1), during both the years of study. Statistically comparable P uptake was registered with *Azospirillum* application alone (T_2) and with no N application (T_1), during both the instances of study.

4.1.6.3 Phosphorus uptake at flowering. Supply of 100 per cent N through fertilizer (T_6) has registered the highest uptake of P by rice crop, which was in parity with the treatments of recommended N management practices, except with 100 per cent N through FYM (T_5) and 100 per cent N through green manuring (T_3), during both the instances of investigation. Application of *Azospirillum* alone (T_2) did not show any appreciable increase in P uptake over that of no N application (T_1), during both the years of study. The P uptake of these two treatments was significantly lower than any of the recommended N application practices.

4.1.6.4 Phosphorus uptake at harvest. During both the years of study, the highest P uptake was registered with F N_{100} (T_6), which was comparable with all other recommended N management practices, except FYM N_{100} (T_5) and GM N_{100} (T_3). Application of *Azospirillum* alone (T_2) could not show any statistical superiority over no N application (T_1), during both the years of study and the phosphorus uptake by these two treatments was significantly lower than any of the treatments with recommended N application.

Table 4.10: Phosphorus uptake (kg ha^{-1}) at various stages of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000				*Kharif*, 2001			
	Active tillering	Panicle initiation	Flowering	At harvest	Active tillering	Panicle initiation	Flowering	At harvest
T_1	6.4	12.0	15.3	16.4	6.7	11.3	14.9	16.7
T_2	7.2	13.3	17.0	18.8	7.2	12.1	15.5	18.4
T_3	12.0	20.8	25.4	28.6	12.4	21.4	26.1	28.7
T_4	10.5	21.4	28.8	31.0	10.4	22.6	28.5	30.8
T_5	9.9	20.0	24.3	26.4	9.8	20.4	24.8	27.5
T_6	11.2	22.1	30.9	33.5	11.7	23.1	30.5	33.9
T_7	11.9	21.5	30.5	32.4	12.0	22.7	29.5	31.5
T_8	11.3	22.3	30.8	32.9	11.9	23.1	29.9	32.2
T_9	11.0	20.9	26.6	30.2	11.0	21.8	28.3	30.2
T_{10}	11.9	21.8	30.7	32.5	12.2	22.8	29.3	32.2
T_{11}	11.5	22.5	30.8	33.4	12.0	23.3	30.2	32.8
T_{12}	11.1	21.2	27.9	30.4	11.6	22.0	28.3	30.3
SEm ±	0.75	1.27	1.74	1.52	0.89	1.05	1.43	1.56
CD (P=0.05)	2.2	3.7	5.1	4.5	2.6	3.1	4.2	4.6

4.1.7 Potassium Uptake

Potassium uptake recorded at different stages of crop growth of rice viz., active tillering, panicle initiation, flowering and at harvest varied significantly due to different N management practices, during both the instances of the course of investigation (Table 4.11).

4.1.7.1 Potassium uptake at active tillering. Potassium uptake was found to be the highest with supply of 100 per cent N through green manure (T_3), which was comparable with different recommended N application treatments, except with exclusive organic N source of FYM N_{100} (T_5), during both the years of study. Uptake of K was the lowest with no N application (T_1), which was however, comparable with application of *Azospirillum* alone (T_2), during both the years of study and both were significantly inferior to all the treatments of recommended N application.

4.1.7.2 Potassium uptake at panicle initiation. During both the years of study, application of GLM N_{50} + F N_{50} + *Azo.* (T_{11}) has registered the highest K uptake, which was in parity with the treatments of recommended N application, except 100 per cent N through FYM (T_5). No appreciable increase in K uptake was noticed with the application of *Azospirillum* alone (T_2) over no N application (T_1) and the potassium uptake by these treatments was inferior to all the treatments of recommended N application, during both the years of study.

4.1.7.3 Potassium uptake at flowering. During both the years of investigation, the highest K uptake was recorded with F N_{100} (T_6), which was at par with the treatments of recommended N application, except with the two exclusive organic sources of N supply viz., GM N_{100} (T_3) and FYM N_{100} (T_5). The potassium uptake with FYM N_{100} (T_5) was however, statistically similar only with GM N_{100} (T_3), during both the years

Table 4.11: Potassium uptake (kg ha^{-1}) at various stages of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000				*Kharif*, 2001			
	Active tillering	Panicle initiation	Flowering	At harvest	Active tillering	Panicle initiation	Flowering	At harvest
T_1	59.2	90.4	130.2	151.8	57.4	94.8	144.5	161.4
T_2	62.0	101.3	140.5	162.6	60.0	101.7	150.0	169.7
T_3	80.7	131.2	185.0	214.5	81.5	146.6	206.1	225.8
T_4	72.5	131.5	202.0	229.6	72.0	147.4	219.7	238.5
T_5	71.7	121.2	174.6	203.8	69.9	135.8	192.8	216.5
T_6	76.0	137.0	212.9	244.8	75.3	154.5	234.0	250.4
T_7	78.6	134.6	203.8	233.2	78.7	147.6	224.1	241.1
T_8	76.9	137.8	208.1	239.8	76.4	155.3	231.6	244.4
T_9	75.2	128.9	194.5	227.6	77.7	143.9	216.8	232.9
T_{10}	78.9	135.0	207.7	234.5	80.3	151.0	227.9	243.6
T_{11}	77.4	138.8	209.8	244.3	76.9	155.7	232.7	246.1
T_{12}	75.9	130.8	195.3	229.2	74.7	146.5	218.8	236.5
SEm ±	3.00	4.67	6.55	5.93	3.24	5.19	7.93	7.29
CD ($P=0.05$)	8.8	13.7	19.2	17.4	9.5	15.2	23.3	21.4

of examination. Potassium uptake with the application of *Azospirillum* alone (T_2) and no N (T_1) was comparable with each other and significantly inferior to all other treatments with recommended N application, during both the years of study

4.1.7.4 Potassium uptake at harvest. During both the years of experimentation, the highest K uptake was recorded with supply of 100 per cent N through fertilizer (T_6), which was however, in parity with all the treatments of recommended N application, except 100 per cent N through FYM (T_5) and through green manure (T_3). Application of *Azospirillum* alone (T_2) did not show any statistical superiority over no N application (T_1) and these two treatments were significantly inferior to any of the recommended N application practices tried, during both the years of study

4.1.8 Post Harvest Soil Fertility Status

Nitrogen management practices have exerted significant influence on the post harvest soil organic carbon, available nitrogen and available potassium, during both the years of study (Table 4.12).

4.1.8.1 Soil organic carbon. Application of 100 per cent N through FYM (T_5) has registered the highest value of residual soil organic carbon, which was comparable with all the treatments of recommended N application, except with F N_{100} (T_6), during both the years of study. Among the treatments of recommended N application, the lowest quantity of residual organic carbon was recorded with application of 100 per cent N through fertilizer, during both the years of study, which was significantly inferior to all the recommended N application treatments and comparable only with the application of *Azospirillum* alone (T_2) and non-supply of N (T_1) during both the years of study. The residual organic carbon content accumulated with the best treatment of FYM N_{100} (T_5) was 29.0, 33.3 and 33.3 per cent higher than that with F N_{100} (T_6), *Azospirillum* application alone (T_2) and no N (T_1), respectively, during the fist year of study and 34.4, 34.4 and 38.7 per cent, respectively, during the second year of experimentation.

4.1.8.2 Soil available nitrogen. In both the years of study, the highest quantity of soil available N was recorded with application of 100 per cent N through FYM (T_5), which was comparable with the treatments of recommended N application, except with F N_{100} (T_6). Among the treatments of recommended N application, the lowest residual N values were recorded with 100 per cent N through fertilizer (T_6) in both the years of study, which was however, significantly superior to application of *Azospirillum* alone (T_2) and no N application (T_1), which were comparable with each other, during both years of study.

4.1.8.3 Soil available phosphorus. During both the years of investigation, the residual phosphorous content of soil did not vary to an appreciable extent due to different N management practices. However, in both the years of experimentation, the highest soil available phosphorus was recorded with FYM N_{100} (T_5) and the lowest values of residual available phosphorus was recorded with the control plot (T_1).

4.1.8.4 Soil available potassium. During both the years of experimentation, the highest quantity of residual available potassium was recorded with the application of 100 per cent N through FYM (T_5), which was comparable with rest of the N management treatments, except with 100 per cent N through fertilizer (T_6), *Azo.* (T_2) and no N (T_1). The lowest values of residual available potassium was with control plot (T_1), during both the years of investigation.

Table 4.12: Post harvest soil fertility status (kg ha^{-1}) and organic carbon (%) after rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000				*Kharif*, 2001			
	Available N	Available P_2O_5	Available K_2O	Organic carbon	Available N	Available P_2O_5	Available K_2O	Organic carbon
T_1	130.8	23.8	115.8	0.30	143.3	24.7	146.7	0.32
T_2	136.5	24.0	119.2	0.30	149.7	24.7	150.7	0.32
T_3	187.5	25.8	138.3	0.39	190.6	26.3	176.3	0.42
T_4	187.5	25.0	149.2	0.38	189.3	25.0	181.0	0.40
T_5	198.3	29.7	174.2	0.40	194.5	30.6	204.7	0.43
T_6	166.5	25.7	125.0	0.31	171.5	26.0	156.7	0.32
T_7	170.8	26.3	134.2	0.36	181.5	27.3	172.0	0.38
T_8	173.3	27.3	139.2	0.36	182.7	27.8	180.7	0.38
T_9	177.7	29.3	154.2	0.39	187.5	30.3	189.7	0.40
T_{10}	177.5	26.5	138.3	0.37	186.7	27.7	179.5	0.39
T_{11}	170.0	27.0	137.5	0.36	180.5	27.7	175.3	0.38
T_{12}	175.8	28.3	151.5	0.37	183.7	29.0	186.5	0.39
SEm ±	9.82	2.05	14.64	0.014	7.33	2.01	14.90	0.016
CD (P=0.05)	28.8	NS	42.9	0.04	21.5	NS	43.7	0.05

4.1.9 Economics

Gross returns, net returns and benefit cost ratio of rice were altered to a noticeable extent by different N management practices applied to rice, during both the years of investigation (Table 4.13).

4.1.9.1 Gross returns. During both the years of experimentation, the highest gross returns were realized with 100 per cent N application through fertilizer (T_6), which were comparable with all the integrated N treatments and significantly superior to exclusive organic treatments of GLM N_{100} (T_4), GM N_{100} (T_3) and FYM N_{100} (T_5). Application of *Azospirillum* alone (T_2) did not give any significant additional benefit in gross returns over the control (T_1) and the gross returns with these two treatments were significantly inferior to all the recommended N application practices tried, during both the years of study.

4.1.9.2 Net returns. The highest net returns were realized with 100 per cent N through fertilizer (T_6), which were significantly superior to all other N management practices, during both the years of study. Excluding the treatment of F N_{100} (T_6), higher net returns were recorded with GM N_{50} + F N_{50} + *Azo.* (T_{10}), which were comparable with all the integrated N management treatments and statistically superior to treatments of exclusive organic sources of N supply, during both the years of investigation. Among the treatments of recommended N application, the lowest net returns were recorded with FYM N_{100} (T_5), which were comparable only with the other two exclusive sources of N supply viz., GLM N_{100} (T_4) and GM N_{100} (T_3), during both the years of examination. Net returns realized with the application of *Azospirillum* alone (T_2) and no N (T_1) were statistically similar with each other and significantly lesser than any of the recommended N application treatments.

Table 4.13: Economics of rice as influenced by different nitrogen management practices

Treatments	*Kharif*, 2000			*Kharif*, 2001		
	Gross returns (Rs)	Net returns (Rs)	Benefit-Cost Ratio	Gross returns (Rs)	Net returns (Rs)	Benefit-Cost Ratio
T_1	19572	6291	1.47	21038	7757	1.58
T_2	21181	7732	1.57	22334	8885	1.66
T_3	27952	12711	1.83	27857	12616	1.83
T_4	28825	11600	1.67	28774	11549	1.67
T_5	26965	10740	1.66	26893	10668	1.66
T_6	31032	16817	2.18	30765	16550	2.16
T_7	30145	14586	1.94	30020	14461	1.93
T_8	30407	14500	1.91	30271	14364	1.90
T_9	29266	13859	1.90	29393	13986	1.91
T_{10}	30430	14703	1.93	30414	14687	1.93
T_{11}	30567	14492	1.90	30520	14445	1.90
T_{12}	29364	13789	1.89	29483	13908	1.89
SEm ±	671.6	671.6	0.045	629.1	629.1	0.049
CD (P=0.05)	1970	1970	0.13	1845	1845	0.14

4.1.9.3 Benefit cost ratio. The highest benefit cost ratio was recorded with the application of 100 per cent N through fertilizer (T_6), which was significantly superior to all other N management practices. The treatments GLM N_{100} (T_4) and FYM N_{100} (T_5) resulted in lower values than the other recommended N application treatments, during both the years of investigation. The benefit cost ratio with the application of *Azospirillum* alone (T_2) was however, comparable with no N application (T_1), FYM N_{100} (T_5) and GLM N_{100} (T_4), during both the years of demonstration.

4.2 GROUNDNUT (*Rabi*, 2000 and 2001)

Groundnut crop was raised during *rabi* season, with the residual fertility of treatments imposed to preceding *kharif* rice in the same undisturbed layout. The experimental results pertaining to growth parameters, yield attributes, yield, nutrient uptake and economics of groundnut, as well as soil fertility dynamics are presented below.

4.2.1 Growth Parameters

4.2.1.1 Plant height. Plant height measured at different stages of groundnut crop viz., 30, 60, 90 days after sowing (DAS) and at harvest has shown considerable statistical variation, during both the years of inquiry (Table 4.14).

4.2.1.1.1 Plant height at 30 DAS. During both the years of investigation, the highest plant height .was recorded with the application of 100 per cent N through FYM to preceding rice (T_5), which was comparable with all the treatments of recommended N application, except with the application of 100 per cent N through fertilizer (T_6). The lowest plant height was recorded with no N application (T_1), which was however, in parity with all the experimental treatments, except with FYM N_{50} + F N_{50} (T_9) and FYM N_{100} (T_5) applied to preceding rice, during both the years of study.

Table 4.14: Plant height (cm) of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	4.2	10.1	19.1	22.0	4.2	10.5	19.7	20.5
T_2	4.2	10.1	19.1	21.1	4.2	11.1	19.8	20.6
T_3	4.6	11.6	21.3	22.7	4.5	11.9	21.8	22.4
T_4	4.6	11.7	21.3	22.4	4.6	12.2	22.4	23.0
T_5	4.8	12.1	22.8	24.2	4.7	12.8	23.3	23.8
T_6	4.2	10.2	19.3	21.3	4.2	11.3	20.1	20.9
T_7	4.4	11.3	20.7	22.7	4.4	11.6	21.5	22.3
T_8	4.5	11.4	20.9	22.6	4.5	11.8	21.6	22.4
T_9	4.8	12.1	22.4	23.6	4.6	12.4	23.2	23.5
T_{10}	4.3	11.2	20.3	22.3	4.4	11.6	20.4	22.2
T_{11}	4.5	11.4	20.8	22.4	4.4	11.7	21.6	22.3
T_{12}	4.7	12.0	21.7	23.5	4.6	12.4	22.7	23.1
SEm ±	0.17	0.35	0.91	0.89	0.15	0.41	1.07	0.95
CD (P=0.05)	0.5	1.0	2.7	2.6	0.4	1.2	3.1	2.8

4.2.1.1.2 Plant height at 60 DAS. Supply of 100 per cent N through FYM to preceding rice (T_5) has recorded the highest plant height, which was statistically similar with all the treatments of recommended N application, except F N_{100} (T_6), during both the years of investigation. The lowest LAI was recorded with no N (T_1) to preceding rice, during both the years of study.

4.2.1.1.3 Plant height at 90 DAS. The highest plant height was recorded with the supply of 100 per cent N through FYM to preceding rice (T_5), during both the years of experimentation, which was statistically superior only to 100 per cent N through fertilizer (T_6), *Azospirillum* application alone (T_2) and no N supply (T_1). During both the years of study, the lowest plant height was registered with no N application to preceding rice (T_1).

4.2.1.1.4 Plant height at harvest. Application of 100 per cent N through FYM N_{100} (T_5) to preceding rice has registered the highest plant height during both the instances of experimentation. which was comparable with treatments of recommended N application, except 100 per cent N through fertilizer to preceding rice crop, during both the instances of study. The lowest plant height during both the years of investigation, was recorded with non-supply of nitrogen to preceding rice crop.

4.2.1.2 Leaf area index (LAI). Leaf area index recorded at different stages of groundnut crop viz., 30, 60, 90 DAS and at harvest has shown considerable variation, during both the years of study (Table 4.15).

4.2.1.2.1 Leaf area index at 30 DAS. During both the years of investigation, the highest LAI of groundnut was recorded with application of 100 per cent N through FYM (T_5) to preceding rice, which was comparable with other recommended N management practices, except application of 100 per cent N through fertilizer (T_6). During both the instances of investigation, the lowest LAI was recorded with no N (T_1) imposed to preceding rice.

Table 4.15: Leaf Area Index (LAI) of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	0.49	1.50	2.88	2.66	0.49	1.60	2.99	2.73
T_2	0.50	1.53	2.90	2.71	0.49	1.64	3.01	2.74
T_3	0.54	1.70	3.07	2.84	0.56	1.74	3.20	2.96
T_4	0.55	1.71	3.08	2.86	0.56	1.75	3.23	2.98
T_5	0.58	1.86	3.34	3.11	0.59	1.80	3.41	3.19
T_6	0.51	1.58	2.91	2.72	0.50	1.64	3.02	2.75
T_7	0.53	1.63	3.00	2.77	0.53	1.68	3.10	2.92
T_8	0.53	1.69	3.03	2.83	0.55	1.70	3.13	2.93
T_9	0.56	1.75	3.27	3.06	0.58	1.79	3.36	3.09
T_{10}	0.52	1.62	2.96	2.75	0.53	1.68	3.05	2.91
T_{11}	0.53	1.69	3.01	2.81	0.54	1.69	3.12	2.92
T_{12}	0.56	1.74	3.20	2.96	0.58	1.78	3.35	3.07
SEm ±	0.020	0.085	0.099	0.092	0.020	0.042	0.085	0.078
CD (P=0.05)	0.06	0.25	0.29	0.27	0.06	0.12	0.25	0.23

4.2.1.2.2 Leaf area index at 60 DAS. During both the occasions of experimentation, the highest LAI was recorded with 100 per cent N through FYM to preceding rice, which was comparable with rest of the recommended N applied treatments, except 100 per cent N through fertilizer (T_6). During both the years of study, the LAI was the lowest with no N (T_1) to preceding rice.

4.2.1.2.3 Leaf area index at 90 DAS. The highest LAI was recorded with 100 per cent N through FYM applied to preceding rice (T_5), which was at par with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3), during the both years of study. The lowest LAI was recorded with no N supply (T_1) to preceding rice, which was however, comparable with other N management practices, except the combinations of farmyard manure viz., FYM N_{50} + F N_{50} + *Azo.* (T_{12}), FYM N_{50} + F N_{50} (T_9) and FYM N_{100} (T_5), during both the years of investigation.

4.2.1.2.4 Leaf area index at harvest. During both the years of investigation, the highest LAI was recorded with FYM N_{100} (T_5), which was statistically comparable with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3). The lowest LAI, during both the years of experimentation was recorded with no N supply (T_1) to preceding rice, which was comparable with no N supply (T_1) to preceding rice, which was comparable with all the treatments, except with the combinations of farmyard manure viz.. FYM N_{50} + F N_{50} + *Azo.* (T_{12}), FYM N_{50} + F N_{50} (T_9) and FYM N_{100} (T_5).

4.2.1.3 Dry matter production. Dry matter production recorded at different growth stages of groundnut crop viz., 30, 60, 90 DAS and at harvest were significantly influenced by different N management practices adopted to preceding rice (Table 4.16).

4.2.1.3.1 Dry matter production at 30 DAS. During both the years of investigation, the highest dry matter accumulation was recorded with 100 per cent N through FYM to preceding rice (T_5), which was in parity with all the N management practices, except F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1) imposed to preceding rice. The lowest dry matter accumulation was recorded with no N (T_1) applied to preceding rice, during both the years of investigation.

4.2.1.3.2 Dry matter production at 60 DAS: The highest dry matter production was recorded with supply of 100 per cent N through FYM to preceding rice (T_5), during both the years of experimentation, which was comparable with other N management practices, except with F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1) applied to preceding rice. During both the instances of investigation, the lowest dry matter was produced with non-supply of N (T_1) to preceding rice.

4.2.1.3.3 Dry matter production at 90 DAS. During both the years of study, the highest dry matter accumulation was registered with FYM N_{100} (T_5), which was comparable with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3) applied to preceding rice crop. The lowest dry matter was however, recorded with no N application (T_1) to preceding rice, during both the instances of investigation.

4.2.1.3.4 Dry matter production at harvest. Application of 100 per cent N through FYM N_{100} (T_5) to preceding rice has registered the highest dry matter accumulation, during both the instances of experimentation, which was comparable with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3) imposed to preceding rice crop. During both the years of experimentation, the lowest dry matter production was registered with non-supply of N (T_1) to preceding rice, which was comparable with all the N management treatments, except FYM N_{50} + F N_{50} + *Azo.* (T_{12}), FYM N_{50} + F N_{50} (T_9) and FYM N_{100} (T_5).

Table 4.16: Dry matter production (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	660	2433	4723	6453	664	2468	4565	5609
T_2	681	2530	4787	6463	669	2554	4628	5642
T_3	754	2843	5253	6893	728	2649	4986	6008
T_4	758	2863	5307	6913	731	2651	5026	6163
T_5	796	2987	5590	7213	779	2882	5390	6441
T_6	688	2567	4840	6540	682	2569	4684	5787
T_7	718	2781	5143	6730	715	2609	4747	5836
T_8	746	2807	5210	6773	721	2643	4827	5997
T_9	786	2913	5410	7170	741	2820	5258	6330
T_{10}	714	2690	5077	6653	702	2600	4706	5795
T_{11}	742	2787	5190	6750	718	2616	4821	5978
T_{12}	770	2893	5343	7003	735	2797	5146	6315
SEm ±	29.0	78.1	122.4	149.0	27.3	104.0	139.8	148.0
CD (P=0.05)	85	229	359	437	80	305	410	434

4.2.1 Yield Attributes

Yield attributes of groundnut viz.. number of pods plant^{-1}, hundred pod weight, hundred kernal weight and shelling percentage varied significantly due to the residual effect of different N management practices applied to preceding rice. during both the instances of investigation (Table 4.17).

4.2.2.1 Number of pods plant^{1}. During both the years of investigation the highest number of pods plant^{-1} was recorded with the application of 100 per N through FYM to preceding rice (T_5), which was comparable with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3) enforced to preceding rice. The lowest number of pods plant^{-1} was registered with non-supply of N (T_1), which was comparable with *Azospirillum* alone (T_2), F N_{100} (T_6), GM N_{50} + F N_{50} + *Azo.* (T_{10}), GM N_{50} + F N_{50} (T_7), GLM N_{50} + F N_{50} + *Azo.* (T_{11}) and GLM N_{50} + F N_{50} (T_8), during both the years of investigation.

4.2.2.2 Hundred-pod weight. In both the years of study, the residual effect of application of 100 per cent N through FYM to preceding rice crop (T_5) recorded the highest pod weight, which was comparable with all the N management practices, except F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (N_1) applied to preceding rice crop. Hundred-pod weight was the lowest with non-supply of N (T_1) to preceding rice, during both the years of investigation.

4.2.2.3 Hundred-kernal weight. The highest hundred-kernal weight was registered with 100 per cent N through FYM to *kharif* rice (T_5), which was in parity with all the N management practices, except F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1) applied to *kharif* rice, during both the years of investigation. The lowest hundred-kernel weight was registered with no N application (T_1), which was however,

Table 4.17: Yield attributes of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	No. of pods plant^{-1}	100 pod weight (g)	100 kernal weight (g)	Shelling (%)	No. of pods plant^{-1}	100 pod weight (g)	100 kernal weight (g)	Shelling (%)
T_1	12.3	87.1	32.9	72.0	11.8	78.8	33.2	72.1
T_2	12.4	87.6	33.0	72.3	11.8	79.6	33.2	72.4
T_3	13.4	88.5	34.2	73.3	13.0	83.2	34.6	74.1
T_4	13.5	89.9	34.5	73.6	13.2	83.3	34.6	74.2
T_5	13.8	91.9	35.6	74.8	13.6	85.7	35.1	74.4
T_6	12.7	87.7	33.3	72.3	11.9	79.9	33.3	72.9
T_7	12.8	88.6	33.9	72.8	12.2	82.3	33.8	73.2
T_8	12.9	89.3	34.0	72.9	12.3	82.9	34.0	73.7
T_9	13.7	91.4	35.2	74.1	13.4	84.8	34.9	74.3
T_{10}	12.8	88.0	33.8	72.4	12.0	82.2	33.8	73.0
T_{11}	12.8	88.9	34.0	72.8	12.3	82.8	33.9	73.5
T_{12}	13.6	90.1	34.9	73.9	13.3	84.2	34.8	74.3
SEm ±	0.20	1.34	0.65	0.94	0.38	1.64	0.51	1.17
CD (P=0.05)	0.6	3.9	1.9	NS	1.1	4.8	1.5	NS

statistically similar with F N_{100} (T_6), GM N_{50} + F N_{50} + *Azo.* (T_{10}), GM N_{50} + F N_{50} (T_7), GLM N_{50} + F N_{50} + *Azo.* (T_{11}), GLM N_{50} + F N_{50} (T_8), GM N_{100} (T_3) and GLM N_{100} (T_4) imposed to preceding rice, during both the years of investigation.

4.2.2.4 Shelling percentage. In both the years of investigation, shelling percentage did not show any significant variation due to residual effect of N management practices to *kharif* rice.

4.2.3 Yield

4.2.3.1 Pod yield. Residual effect of *kharif* rice treatments exerted marked influence on the pod yield of *rabi* groundnut during both the years of study (Table 4.18)

In both the years of study, application of 100 per cent N through FYM to preceding rice crop (T_5) produced the highest pod yield of groundnut. The best treatment of FYM $_{100}$ (T_5) was in parity with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3), during both the years of investigation. The lowest pod yield was registered with no N application (T_1) imposed to preceding rice, during both the years of experimentation.

4.2.3.2 Haulm yield. Haulm yield of groundnut was significantly altered by residual effect of *kharif* rice treatments, during both the years of study (Table 4.18). In both the years of investigation, the highest haulm yield of groundnut was recorded with 100 per cent N through FYM(T_5) applied to rice, which was in parity with rest of the N management practices to *kharif* rice, except F N_{100} (T_6), *Azo.* (T_2) and no N (T_1), during both the years of study. The lowest haulm yield of groundnut was recorded with no N (T_1) to preceding rice, during both the years of investigation.

Table 4.18: Pod yield, haulm yield (kg ha^{-1}) and harvest index (%) of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000			*Rabi*, 2001		
	Pod yield	Haulm yield	Harvest index*	Pod yield	Haulm yield	Harvest index*
T_1	2223	4208	34.6	1962	3575	35.4
T_2	2243	4234	34.6	2023	3647	35.7
T_3	2433	4460	35.3	2176	3985	35.3
T_4	2449	4460	35.4	2228	3985	35.9
T_5	2553	4627	35.6	2320	4145	35.9
T_6	2306	4234	35.3	2040	3715	35.4
T_7	2356	4376	35.0	2069	3767	35.5
T_8	2397	4410	35.2	2092	3876	35.1
T_9	2544	4662	35.3	2296	4122	35.8
T_{10}	2331	4338	35.0	2067	3747	35.6
T_{11}	2489	4388	36.2	2080	3852	35.1
T_{12}	2475	4527	35.3	2267	4098	35.6
SEm ±	54.6	99.1	-	76.9	135.9	-
CD (P=0.05)	160	291	-	226	399	-

* Data were not analysed statistically

4.2.3.3 Harvest index. Harvest index of groundnut was not altered to a noticeable extent with the residual effect of different N management practices applied to preceding rice (Table 4.18).

4.2.4 Nodule Dry Weight

In both the years of study, the nodule dry weight of groundnut at 30 and 60 DAS was significantly influenced by the residual effect of *kharif* rice treatments, but during the later stages of crop growth viz., 90 DAS and at harvest, there was no significant variation in the nodule dry weight due to the N management practices to preceding rice (Table 4.19)

4.2.4.1 Nodule dry weight at 30 DAS. Nodule dry weight was the highest with 100 per cent N through farm yard manure (T_5) applied to preceding rice, which was at par with other N management practices imposed to *kharif* rice, except with F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1), during both the years of study. During both the years of study, the lowest nodule dry weight was registered with no N (T_1) imposed to preceding rice.

4.2.4.2 Nodule dry weight at 60 DAS. During both the years of investigation, the highest nodule dry weight of groundnut was recorded with the residual effect of 100 per cent N through FYM applied to preceding rice (T_5), which was however, comparable with all the treatments imposed to *kharif* rice, except 100 per cent N through fertilizer (T_6), *Azospirillum* alone (T_2) and no N (T_1) applied to preceding rice, during both the years of investigation. The lowest nodule dry weight was recorded with no N (T_1) applied to preceding rice, during both the years of study.

Table 4.19: Nodule dry weight (mg plant^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	33.0	126.0	108.0	99.7	36.0	126.0	116.3	103.7
T_2	33.3	128.0	107.0	98.7	36.2	127.0	113.3	99.7
T_3	35.0	134.7	112.7	104.7	39.1	136.7	114.7	112.7
T_4	35.3	135.3	111.0	105.7	39.2	138.7	118.7	110.3
T_5	36.0	142.5	116.7	112.7	39.7	143.3	122.7	116.7
T_6	33.3	128.0	108.7	102.7	36.5	129.7	115.7	104.7
T_7	35.0	130.7	112.3	103.7	38.5	134.7	117.3	113.0
T_8	35.0	134.7	109.7	105.7	38.8	136.0	120.3	108.7
T_9	36.0	136.7	118.7	110.7	39.4	142.7	124.7	119.0
T_{10}	34.3	130.0	109.7	104.7	38.2	132.7	116.7	109.7
T_{11}	35.0	134.0	110.7	103.7	38.6	135.7	119.0	110.7
T_{12}	35.7	135.3	117.7	111.7	39.2	139.0	123.7	114.7
SEm ±	0.78	4.54	5.01	5.18	1.02	4.06	5.82	6.2
CD (P=0.05)	2.3	13.3	NS	NS	3.0	11.9	NS	NS

4.2.5 Nitrogen Uptake

In both the years of study, nitrogen uptake at different stages of crop growth of groundnut viz., 30, 60, 90 DAS and at harvest was significantly influenced by residual effect of different N management practices applied to *kharif* rice (Table 4.20).

4.2.5.1 Nitrogen uptake at 30 DAS. During both the years of study, the highest N uptake was recorded with residual effect of 100 per cent N through FYM (T_5) applied to preceding rice, which was comparable with all the N management practices applied to preceding rice crop, except F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1) imposed to *kharif* rice, during both the years of investigation. During both the years, the lowest N uptake was recorded with no N (T_1) imposed to *kharif* rice.

4.2.5.2 Nitrogen uptake at 60 DAS. The highest N uptake was recorded with the residual effect of 100 per cent N through FYM applied to *kharif* rice, during both the instances of the investigation. The best treatment of FYM N_{100} (T_5) was in parity with the residual effect of other N management practices applied to preceding rice, except 100 per cent N through fertilizer (T_6), *Azospirillum* application alone (T_2) and no N (T_1) applied to *kharif* rice, during both the years of investigation. However, during both the years of study, the lowest N uptake was noticed with non-supply of N (T_1) to previous rice.

4.2.5.3 Nitrogen uptake at 90 DAS. During both the years of inquiry, the highest N uptake was recorded with the residual effect of 100 per cent N through FYM (T_5) applied to preceding rice, which was in parity with FYM N_{50} + F N_{50} + *Azo*. (T_{12}) and FYM N_{50} + F N_{50} (T_9), GLM N_{100} (T_4) and GM N_{100} (T_3) imposed to *kharif* rice. The lowest N uptake was recorded with the residual effect of no N (T_1) administered to *kharif* rice, during both the years of experimentation.

Table 4.20: Nitrogen uptake (kg ha^{-1}) at various stages of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	14.3	63.8	77.4	81.6	14.2	64.2	74.0	77.4
T_2	14.4	66.5	77.9	82.5	14.3	66.2	76.4	80.2
T_3	16.6	75.8	87.2	91.2	15.6	70.2	83.8	88.6
T_4	16.8	75.8	87.7	91.5	15.7	71.6	85.3	90.6
T_5	17.3	77.7	93.4	96.4	16.6	75.5	90.0	94.4
T_6	14.5	68.3	79.5	84.1	14.4	66.8	76.8	80.7
T_7	15.7	72.1	83.8	88.5	15.3	68.7	78.8	83.9
T_8	16.4	74.1	85.0	89.7	15.6	69.9	80.7	86.5
T_9	17.1	76.8	90.4	96.2	16.1	75.0	88.3	93.0
T_{10}	15.8	72.6	82.2	87.9	15.4	68.8	78.1	82.9
T_{11}	16.3	73.6	84.6	89.6	15.5	69.5	80.1	85.0
T_{12}	16.9	76.5	88.3	94.4	16.0	74.4	87.0	91.3
SEm ±	0.57	2.19	2.45	2.05	0.65	2.46	2.56	2.17
CD (P=0.05)	1.7	6.4	7.2	6.0	1.9	7.2	7.5	6.4

4.2.5.4 Nitrogen uptake at harvest. During both the years of evaluation, the highest N uptake by groundnut crop was registered with the residual effect of 100 per cent N through FYM (T_5) applied to preceding rice, which was comparable with the treatments of FYM N_{50} + F N_{50} + *Azo.* (T_{12}), FYM N_{50} + F N_{50} (T_9), GLM N_{100} (T_4) and GM N_{100} (T_3). During both the years of experimentation, the lowest N uptake was recorded with no N (T_1) applied to preceding rice crop.

4.2.6 Phosphorus uptake

Phosphorus uptake at different stages of crop growth of groundnut viz., 30, 60, 90 DAS and at harvest was significantly influenced by the residual effect of different N management practices applied to *kharif* rice (Table 4.21).

4.2.6.1 Phosphorus uptake at 30 DAS. During both the years of investigation, the highest phosphorus uptake by groundnut crop was registered with the residual effect of 100 per cent N through FYM applied to preceding rice crop (T_5). The best treatment of FYM N_{100} (T_5) was in parity with the residual effect of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4), GM N_{100} (T_3), GLM N_{50} + F N_{50} (T_8) and GLM N_{50} + F N_{50} + *Azo.* (T_{11}) applied to preceding rice crop, during the both years of investigation. During both the years of experimentation, the lowest phosphorus uptake by groundnut crop was recorded with no N (T_1) applied to *kharif* rice, which was comparable with the residual effect of *Azospirillum* alone (T_2), F N_{100} (T_6) and GM N_{50}+F N_{50}+*Azo.* (T_{10}) administered to *kharif* rice crop.

4.2.6.2 Phosphorus uptake at 60 DAS. The highest phosphorus uptake by groundnut crop during both the years of observation was registered with FYM N_{100} (T_5) applied to preceding crop of rice, which was in parity with all the N management practices, except F N_{100} (T_6), *Azospirillum* alone (T_2) and no N applied to preceding rice crop. During both the years of experimentation, the lowest phosphorus uptake was registered with no N (T_1) applied to preceding rice.

Table 4.21: Phosphorus uptake (kg ha^{-1}) at various stages of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	1.9	5.7	8.2	8.9	1.8	5.7	7.9	8.0
T_2	1.9	6.3	8.5	8.9	1.9	6.0	8.0	8.4
T_3	2.4	6.8	9.4	9.9	2.4	6.7	8.7	9.2
T_4	2.4	6.9	9.6	10.0	2.4	6.7	8.9	9.3
T_5	2.7	7.5	10.1	10.6	2.7	7.2	9.7	9.9
T_6	1.9	6.4	8.6	9.0	1.9	6.0	8.1	8.5
T_7	2.3	6.6	8.6	9.2	2.3	6.3	8.2	8.5
T_8	2.4	6.7	8.9	9.5	2.4	6.5	8.4	8.9
T_9	2.6	7.2	9.7	10.2	2.5	6.9	9.5	9.8
T_{10}	2.2	6.6	8.8	9.3	2.2	6.3	8.2	8.5
T_{11}	2.4	6.7	8.9	9.3	2.4	6.4	8.2	8.7
T_{12}	2.5	7.1	9.6	10.2	2.5	6.9	9.3	9.3
SEm ±	0.08	0.31	0.27	0.23	0.10	0.31	0.34	0.31
CD (P=0.05)	0.3	0.9	0.8	0.7	0.3	0.9	1.0	0.9

4.2.6.3 Phosphorus uptake at 90 DAS. During both the years of study, the highest phosphorus uptake was recorded with the residual effect of FYM N_{100} (T_5) applied to preceding rice crop, which was in parity with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3), during both the years of study. During both the instances of investigation. the lowest phosphorus uptake was registered with no N (T_1) applied to *kharif* rice.

4.2.6.4 Phosphorus uptake at harvest. During both the instances of study, the highest phosphorus uptake was recorded with the residual effect of 100 per cent N through FYM (T_5) applied to preceding rice, which was comparable with the residual effect of FYM N_{50} + F N_{50} + *Azo.* (T_{12}), FYM N_{50} + F N_{50} (T_9), GLM N_{100} (T_4) and GM N_{100} (T_3) enforced to *kharif* rice. The lowest phosphorus uptake was recorded with the residual effect of no N (T_1) applied to *kharif* rice, during both the instances of investigation.

4.2.7 Potassium uptake

During both the years of investigation, potassium uptake at different stages of crop growth of groundnut viz., 30, 60, 90 DAS and at harvest was significantly influenced by the residual effect of different N management practices applied to preceding rice (Table 4.22).

4.2.7.1 Potassium uptake at 30 DAS. During both the years of study, the highest potassium uptake was recorded with the residual effect of 100 per cent N through FYM (T_5) applied to preceding rice, which was in parity with the residual effect of different N management practices, except with F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1) applied to *kharif* rice. The lowest potassium uptake was recorded with the residual effect of no N (T_1), during both the years of experimentation.

Table 4.22: **Potassium uptake (kg ha^{-1}) at various stages of groundnut as influenced by different nitrogen management practices to preceding rice**

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	16.6	40.1	60.0	62.4	16.7	39.7	58.4	60.1
T_2	17.2	40.5	60.8	62.6	16.9	40.9	59.2	60.2
T_3	19.4	46.6	67.8	68.4	19.1	43.4	64.9	66.7
T_4	19.9	46.7	69.0	69.5	19.4	43.8	65.5	67.4
T_5	21.7	50.2	72.7	74.4	21.2	48.4	69.5	72.6
T_6	17.3	41.3	61.5	63.8	17.1	41.4	60.0	62.0
T_7	18.8	44.1	65.0	66.0	18.5	42.8	60.7	63.8
T_8	19.0	46.4	67.0	67.5	18.9	43.4	62.8	66.0
T_9	20.3	48.7	69.8	72.5	19.9	46.8	68.9	70.6
T_{10}	18.6	45.7	65.8	67.0	18.0	42.9	61.2	63.3
T_{11}	19.4	45.8	66.7	67.2	19.1	43.2	62.4	65.3
T_{12}	21.1	48.0	69.0	70.3	19.6	46.4	66.9	69.9
SEm ±	1.26	2.42	1.58	2.15	1.36	1.96	1.81	2.15
CD (P=0.05)	3.7	7.1	4.6	6.3	4.0	5.7	5.3	6.3

4.2.7.2 Potassium uptake at 60 DAS. The highest potassium uptake was recorded with the residual effect of 100 per cent N through FYM (T_5), which was in parity with the residual effect of different N management practices, except with F N_{100} (T_6), *Azospirillum* alone (T_2) and no N application to preceding rice crop, during both the years of investigation. During both the years of study, the lowest potassium uptake was recorded with the residual effect of no N (T_1) applied to preceding rice, which was however, statistically similar with all the recommended N application treatments, except the combinations of FYM viz., FYM N_{50} + F N_{50} + *Azo.* (T_{12}), FYM N_{50} + F N_{50} (T_9) and FYM N_{100} (T_5) imposed to preceding rice.

4.2.7.3 Potassium uptake at 90 DAS. The highest potassium uptake by groundnut crop was noticed with the supply of 100 per cent N through FYM (T_5) to preceding rice crop, which was in parity with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3) applied to *kharif* rice, during both the years of study. During both the years of experimentation, the lowest potassium uptake was recorded with no N (T_1) application to preceding rice.

4.2.7.4 Potassium uptake at harvest. During both the instances of study, the highest potassium uptake was recorded with the residual effect of 100 per cent N through FYM to *kharif* rice (T_5), which was comparable with FYM N_{50} + F N_{50} + *Azo* (T_{12}), FYM N_{50} + F N_{50} (T_9), GLM N_{100} (T_4) and GM N_{100} (T_3) imposed to preceding rice. During both the years of investigation, the lowest potassium uptake was registered with no N (T_1) application to preceding rice.

4.2.8 Soil Fertility Dynamics

4.2.8.1 Soil organic carbon. In both the years of study, residual effect of *kharif* rice treatments imposed on *rabi* groundnut exerted significant influence on the post harvest soil organic carbon status (Table 4.23).

The residual effect of 100 per cent N through FYM to preceding rice (T_5) recorded the highest value of post harvest soil organic carbon, which was comparable with all the N management practices applied to preceding rice, during both the years of investigation. During both the years of experimentation, the lowest value of soil organic carbon was recorded with no N (T_1) applied to preceding rice, which was however, comparable with *Azospirillum* alone (T_2) and no N (T_1) applied to preceding rice crop.

4.2.8.2 Soil available nitrogen. During both the years of observation, the highest post harvest soil available N was noticed with the residual effect of 100 per cent N through FYM applied to preceding rice (T_5), which was comparable with other N management practices to *kharif* rice, except F N_{100} (T_6), no N (T_1) and *Azospirillum* alone (T_2) (Table 4.23). The lowest value of soil available nitrogen was recorded with non-supply of N (T_1) to *kharif* rice crop, during both the years of experimentation.

4.2.8.3 Soil available phosphorus. In both the years of study, residual effect of *kharif* rice treatments did not show any significant influence on post harvest soil available phosphorus after groundnut (Table 4.23).

4.2.8.4 Soil available potassium. In both the years of investigation, the highest post harvest soil available potassium of groundnut was registered with the residual effect of 100 per cent N through FYM applied to preceding rice crop (T_5), which was comparable with other N management practices to preceding rice, except F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1) imposed to *kharif* rice. The lowest quantity of post harvest soil available potassium was noticed with the residual effect of no N (T_1) applied to preceding rice (Table 4.23).

Table 4.23: Post harvest soil fertility status (kg ha^{-1}) and organic carbon (%) after groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000				*Rabi*, 2001			
	Available N	Available P_2O_5	Available K_2O	Organic carbon	Available N	Available P_2O_5	Available K_2O	Organic carbon
T_1	150.7	21.0	114.2	0.32	148.3	21.8	125.0	0.33
T_2	156.7	21.3	115.8	0.33	150.3	22.0	134.0	0.34
T_3	177.5	24.0	139.2	0.39	181.3	24.7	172.0	0.41
T_4	172.5	23.0	141.7	0.40	178.5	24.0	172.5	0.42
T_5	178.3	22.0	149.2	0.42	184.0	22.7	177.5	0.43
T_6	156.7	23.0	119.2	0.36	153.5	23.7	146.7	0.35
T_7	167.5	22.0	134.2	0.38	175.5	22.3	167.5	0.39
T_8	171.7	23.0	139.2	0.38	176.3	23.5	171.7	0.40
T_9	177.5	22.0	146.7	0.41	182.5	22.7	177.5	0.42
T_{10}	163.3	24.0	134.2	0.38	175.0	24.3	164.0	0.39
T_{11}	167.5	23.0	137.5	0.38	176.0	23.3	171.5	0.40
T_{12}	173.3	22.0	145.0	0.41	180.5	22.0	177.5	0.42
SEm ±	6.65	2.66	9.76	0.014	8.67	1.48	10.15	0.014
CD (P=0.05)	19.5	NS	28.6	0.04	25.4	NS	29.8	0.04

4.2.9 Economics

4.2.9.1 ***Gross returns.*** In both the years of study, residual effect of *kharif* rice treatments imposed on *rabi* groundnut exerted marked influence on gross returns of groundnut (Table 4.24).

In both the years of investigation, the highest gross returns were obtained with the residual effect of 100 per cent N through FYM (T_5) applied to *kharif* rice, which were in parity with the residual effect of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4), GM N_{100} (T_3), GLM N_{50} + F N_{50} (T_8) and GLM N_{50} + F N_{50} + *Azo.* (T_{11}) applied to preceding rice crop. The lowest gross returns were recorded with the residual effect of non-supply of N (T_1) applied to preceding rice, which were however, in parity with *Azospirillum* alone (T_2), F N_{100} (T_6), GM N_{50} + F N_{50} + *Azo.* (T_{10}) and GM N_{50} + F N_{50} (T_7) enforced to preceding rice, during both the instances of investigation.

4.2.9.2 ***Net returns.*** Residual effect of *kharif* rice treatments imposed on *rabi* groundnut has significantly influenced the net returns of groundnut, in both the years of study (Table 4.24).

During both the years of study, the highest net returns were recorded with the residual effect of 100 per cent N applied through FYM to preceding rice (T_5), which were comparable with the residual effect of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4), GM N_{100} (T_3), GLM N_{50} + F N_{50} (T_8) and GLM N_{50} + F N_{50} + *Azo.* (T_{11}) applied to preceding rice. The lowest net returns were recorded with the residual effect of non-supply of N (T_1) applied to preceding rice, which were however, in parity with *Azospirillum* alone (T_2), F N_{100} (T_6), GM N_{50} + F N_{50} + *Azo.* (T_{10}) and GM N_{50} + F N_{50} (T_7) enforced to preceding rice, during both the instances of investigation.

Table 4.24: Economics of groundnut as influenced by different nitrogen management practices to preceding rice

Treatments	*Rabi*, 2000			*Rabi*, 2001		
	Gross returns (Rs)	Net returns (Rs)	Benefit-Cost Ratio	Gross returns (Rs)	Net returns (Rs)	Benefit-Cost Ratio
T_1	26438	15629	2.45	23195	12386	2.15
T_2	26664	15855	2.47	23877	13068	2.21
T_3	28790	17981	2.65	25745	14936	2.38
T_4	28950	18141	2.68	26265	15456	2.43
T_5	30157	19348	2.79	27345	16536	2.53
T_6	27294	16485	2.53	24115	13306	2.23
T_7	27936	17127	2.58	24457	13648	2.26
T_8	28380	17571	2.63	24796	13987	2.29
T_9	30102	19293	2.78	27082	16273	2.51
T_{10}	27648	16839	2.56	24417	13608	2.26
T_{11}	28278	17469	2.62	24652	13843	2.28
T_{12}	29277	18468	2.71	26768	15959	2.48
SEm ±	744.6	744.6	0.068	948.6	948.6	0.089
CD (P=0.05)	2184	2184	0.20	2782	2782	0.26

4.2.9.3 Benefit cost ratio. Nitrogen management practices applied to preceding rice crop have significantly influenced the benefit cost ratio of residual groundnut crop (Table 4.24).

During both the years of study, the highest benefit cost ratio was recorded with the residual effect of 100% N through FYM (T_5) imposed to *kharif* rice, which was in parity with the residual effect of FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50} + *Azo.* (T_{12}), GLM N_{100} (T_4), GM N_{100} (T_3), GLM N_{50} + F N_{50} (T_8) and GLM N_{50} + F N_{50} + *Azo.* (T_{11}) applied to preceding rice. The lowest benefit cost ratio recorded with no N (T_1) applied to *kharif* rice, which was in statistical similarity with *Azospirillum* alone (T_2), F N_{100} (T_6), GM N_{50} + F N_{50} + *Azo.* (T_{10}) and GM N_{50} + F N_{50} (T_7), during both the years of experimentation.

4.3 NITROGEN MANAGEMENT IN THE CROPPING SYSTEM AS A WHOLE

Hither to, the influence of different nitrogen management practices on the performance of *kharif* rice crop and the residual effect on the succeeding *rabi* groundnut crop in the cropping system have been presented crop wise. Performance of the cropping system as a whole, under the influence of different N management practices to *kharif* rice as reflected by the productivity, economic returns and the dynamics of soil fertility is presented here under in separate sections.

4.3.1 Total Dry Matter Production of the Cropping System

In both the years of study, total dry matter production of rice-groundnut cropping system differed significantly due to different N management practices applied to rice (Table 4.25).

Table 4.25: Total dry matter production (kg ha^{-1}) of the cropping system as influenced by different nitrogen management practices to *kharif* rice

Treatments	2000	2001
T_1	14091	13684
T_2	14464	14126
T_3	17116	16495
T_4	17851	17323
T_5	17065	16452
T_6	17973	17448
T_7	17649	17189
T_8	18030	17459
T_9	17892	17318
T_{10}	17811	17177
T_{11}	18068	17527
T_{12}	17788	17411
SEm ±	585.8	342.4
CD (P=0.05)	1718	1004

Among the different N management practices applied to *kharif* rice, application of GLM N_{50} + F N_{50} + *Azo.* (T_{11}) recorded the highest quantity of dry matter, during both the years of cropping system. During both the years, the total dry matter production with all the treatments of recommended N application was comparable with each other. However, during both the years of study, the total dry matter produced with *Azo.* (T_2) and no N (T_1) applied to rice was comparable to each other and significantly inferior to any of the treatments with recommended N application.

4.3.2 Economic Yield (Rice Grain Equivalent) of the Cropping System

Economic yield of the cropping system as a whole, expressed as rice grain equivalent yield was significantly altered by different N management practices applied to rice in both the years of study (Table 4.26).

The highest economic yield of the cropping system was recorded with the application of FYM N_{50} + F N_{50} (T_9) to rice crop, during both the years of the cropping system. Rice grain equivalent yield produced with all the treatments of recommended N application was comparable with each other, during both the years of experimentation. The economic yield of the cropping system produced with application of *Azospirillum* alone (T_2) and no N (T_1) to rice was statistically similar with each other and significantly inferior to all other treatments with recommended N application to *kharif* rice, during both the years of investigation.

4.3.3 Economics of Nitrogen Management Practices in the Cropping System

Various economic parameters worked out for the cropping system as a whole are presented in this section (cost of cultivation for various treatments for the cropping system as a whole is presented in Appendix K).

Table 4.26: Rice grain equivalent yield (kg ha^{-1}) of the cropping system as influenced by different nitrogen management practices to *kharif* rice

Treatments	2000	2001
T_1	7721	7449
T_2	8058	7796
T_3	9639	9056
T_4	9750	9257
T_5	9712	9201
T_6	9896	9261
T_7	9852	9198
T_8	9962	9283
T_9	10082	9569
T_{10}	9853	9264
T_{11}	9973	9303
T_{12}	9956	9513
SEm ±	173.9	165.5
CD (P=0.05)	510	485

Gross returns, net returns and benefit cost ratio of the cropping system were altered to a noticeable extent by different nitrogen management practices applied to rice, during both the years of study (Table 4.27).

4.3.3.1 Gross returns. The highest gross returns were recorded with FYM N_{50} + F N_{50} (T_9) applied to *kharif* rice, which were comparable with rest of recommended N applied treatments, during both the years of investigation. The gross returns of the cropping system produced with the application of *Azospirillum* alone (T_2) and no N (T_1) to rice crop were comparable with each other and significantly lower to all other treatments with recommended N application to *kharif* rice, during both the years of investigation.

4.3.3.2 Net returns. The highest net returns during the first year were recorded with application of F N_{100} and during second year they were with FYM N_{50} + F N_{50} (T_9), both of which were comparable with all the recommended N management practices, except the two exclusive organic sources of N application viz., FYM N_{100} (T_5) and GLM N_{100} (T_4) applied to *kharif* rice. During both the years of experimentation, the net returns obtained with *Azospirillum* alone (T_2) and no N (T_1) applied to rice were comparable with each other and significantly inferior to any of the treatments with recommended N application.

4.3.3.3 Benefit cost ratio. During both the years of study, the highest benefit cost ratio was recorded with 100 per cent N through fertilizer (T_6) applied to rice, which was comparable with FYM N_{50} + F N_{50} (T_9) and FYM N_{50} + F N_{50} + *Azo*. (T_{12}). Among all the recommended N management practices to rice crop, the lowest benefit cost ratio was recorded with no N (T_1) application, during both the years of study, which was however, comparable with *Azospirillum* alone (T_2) applied to rice crop. However, during both the years, *Azospirillum* alone (T_2) application has recorded statistically similar benefit cost ratio with 100 per cent N through exclusive green leaf manuring (T_4).

Table 4.27: Economics of the rice-groundnut cropping system as influenced by different nitrogen management practices to rice

Treatments	Cropping system 2000			Cropping system, 2001		
	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Benefit cost ratio	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Benefit cost ratio
T_1	46010	21920	1.91	44233	20143	1.84
T_2	47845	23587	1.97	46211	21953	1.90
T_3	56472	30692	2.18	53602	27552	2.06
T_4	57775	29741	2.06	55039	27005	1.96
T_5	57122	30088	2.11	54238	27204	2.01
T_6	58326	33302	2.33	54880	29856	2.19
T_7	58081	31713	2.20	54477	28109	2.07
T_8	58787	32071	2.20	55067	28351	2.06
T_9	59368	33152	2.26	56475	30259	2.15
T_{10}	58078	31542	2.19	54831	28295	2.07
T_{11}	58845	31961	2.19	55172	28288	2.05
T_{12}	58641	32257	2.22	56252	29867	2.13
SEm ±	946.2	946.2	0.038	883.2	883.2	0.034
CD (P=0.05)	2775	2775	0.11	2590	2590	0.10

4.3.4 Dynamics of Soil Organic Carbon in the Cropping System

Irrespective of the nitrogen management practices adopted to *kharif* rice, the soil organic carbon content tended to increase with the raising of rice crop followed by groundnut crop (Table 4.28). However, the increase was relatively higher, with the treatments of N supply through exclusive organic sources viz., FYM N_{100} (T_5), GLM N_{100} (T_4) and GM N_{100} (T_3) followed by integrated combinations of FYM N_{50} + F N_{50} + *Azo.* (T_{12}), FYM N_{50} + F N_{50} (T_9), GLM N_{50} + F N_{50} + *Azo.* (T_{11}), GM N_{50} + F N_{50} (T_7), GLM N_{50} + F N_{50} (T_8) and GM N_{50} + F N_{50} + *Azo.* (T_{10}). During both the instances of investigation the increase in organic carbon content of soil in the cropping system was the lowest with no N (T_1) application to rice crop.

4.3.5 Dynamics of Soil Available Nitrogen in the Cropping System

In both the years of study, the available nitrogen content of the soil tended to increase with the raising of rice crop and decreased marginally with the raising of groundnut crop (Table 4.29). Different N management practices adopted in the cropping system altered the available N status of the soil to a considerable extent. The highest soil available N status was maintained with application of FYM N_{100} (T_5) to rice crop, while the lowest was associated with no N application (T_1).

4.3.5.1 Soil available nitrogen balance in the cropping system. In both the years of study, different nitrogen management practices applied to rice altered the balance of available N in the soil (Table 4.30a and 4.30b). During both the years, nitrogen balance in the cropping system was negative with the treatments of no N (T_1), *Azospirillum* alone (T_2) and 100 per cent N through fertilizer (T_6) imposed to rice crop. All other treatments recorded positive balance of soil available nitrogen in the cropping system, indicating a net gain of soil available nitrogen. Among all the

Table 4.28: Dynamics of soil organic carbon (%) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system

Treatments	Initial soil O C prior to green manure sowing in *kharif*, 2000	Soil O C after rice harvest (*kharif*, 2000)	Soil O C after groundnut harvest (*rabi*, 2000)	Soil O C after rice harvest (*kharif*, 2001)	Soil O C after groundnut harvest (*rabi*, 2001)
T_1	0.27	0.30	0.32	0.32	0.33
T_2	0.27	0.30	0.33	0.32	0.34
T_3	0.27	0.39	0.39	0.42	0.41
T_4	0.27	0.38	0.40	0.40	0.42
T_5	0.27	0.40	0.42	0.43	0.43
T_6	0.27	0.31	0.36	0.32	0.35
T_7	0.27	0.36	0.38	0.38	0.39
T_8	0.27	0.36	0.38	0.38	0.40
T_9	0.27	0.39	0.41	0.40	0.42
T_{10}	0.27	0.37	0.38	0.39	0.39
T_{11}	0.27	0.36	0.38	0.38	0.40
T_{12}	0.27	0.37	0.41	0.39	0.42
SEm ±	--	0.014	0.014	0.016	0.014
CD (P=0.05)		0.04	0.04	0.05	0.04

Table 4.29: Dynamics of soil available nitrogen (kg ha^{-1}) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system

Treatments	Initial soil N prior to green manure sowing in *kharif*, 2000	Soil N after rice harvest (*kharif*, 2000)	Soil N after groundnut harvest (*rabi*, 2000)	Soil N after rice harvest (*kharif*, 2001)	Soil N after groundnut harvest (*rabi*, 2001)
T_1	157.5	130.8	150.7	143.3	148.3
T_2	157.5	136.5	156.7	149.7	150.3
T_3	157.5	187.5	177.5	190.6	181.3
T_4	157.5	187.5	172.5	189.3	178.5
T_5	157.5	198.3	178.3	194.5	184.0
T_6	157.5	166.5	156.7	171.5	153.5
T_7	157.5	170.8	167.5	181.5	175.5
T_8	157.5	173.3	171.7	182.7	176.3
T_9	157.5	177.7	177.5	187.5	182.5
T_{10}	157.5	177.5	163.3	186.7	175.0
T_{11}	157.5	170.0	167.5	180.5	176.0
T_{12}	157.5	175.8	173.3	183.7	180.5
SEm ±	-	9.82	6.65	7.33	8.67
CD (P=0.05)	-	28.8	19.5	21.5	25.4

Table 4.30a: Soil available nitrogen balance (kg ha^{-1}) in the cropping system, 2000

Treatments	Initial soil N	N applied to crops		Total quantity of N applied	N uptake by crops		Total quantity of N removed	Computed balance	Actual balance	Net gain or loss
		Rice	Groundnut		Rice	Groundnut				
T$_1$	157.5	-	-	-	51.9	81.6	133.5	-133.5	150.7	-6.8
T$_2$	157.5	-	-	-	58.1	82.5	140.6	-140.6	156.7	-0.8
T$_3$	157.5	80	-	80	80.1	91.2	171.3	-91.3	177.5	+20.0
T$_4$	157.5	80	-	80	84.9	91.5	176.4	-96.4	172.5	+15.0
T$_5$	157.5	80	-	80	77.7	96.4	174.1	-94.1	178.3	+20.8
T$_6$	157.5	80	-	80	94.1	84.1	178.2	-98.2	156.7	-0.80
T$_7$	157.5	80	-	80	87.9	88.5	176.4	-96.4	167.5	+10.0
T$_8$	157.5	80	-	80	90.7	89.7	180.4	-100.4	171.7	+14.2
T$_9$	157.5	80	-	80	85.8	96.2	182.0	-102.0	177.5	+20.0
T$_{10}$	157.5	80	-	80	89.2	87.9	177.1	-97.1	163.3	+5.8
T$_{11}$	157.5	80	-	80	93.0	89.6	182.6	-102.6	167.5	+10.0
T$_{12}$	157.5	80	-	80	87.7	94.4	182.1	-102.1	173.3	+15.8

Table 4.30b: Soil available nitrogen balance (kg ha^{-1}) in the cropping system, 2001

Treatments	Initial soil N	N applied to crops		Total quantity of N applied	N uptake by crops		Total quantity of N removed	Computed balance	Actual balance	Net gain or loss
		Rice	Groundnut		Rice	Groundnut				
T_1	150.7	-	-	-	56.3	77.4	133.7	-133.7	148.3	-2.4
T_2	156.7	-	-	-	61.4	80.2	142.1	-142.1	150.3	-6.4
T_3	177.5	80	-	80	86.2	88.6	171.2	-91.2	181.3	+3.8
T_4	172.5	80	-	80	89.7	90.6	179.9	-99.9	178.5	+6.0
T_5	178.3	80	-	80	82.4	94.4	176.8	-96.8	184.0	+11.5
T_6	156.7	80	-	80	97.0	80.7	172.7	-92.7	153.5	-3.2
T_7	167.5	80	-	80	92.1	83.9	176.4	-96.4	175.5	+8.0
T_8	171.7	80	-	80	94.0	86.5	182.8	-102.8	176.3	+4.6
T_9	177.5	80	-	80	89.3	93.0	181.2	-101.2	182.5	+5.0
T_{10}	163.3	80	-	80	92.9	82.9	175.2	-95.2	175.0	+11.5
T_{11}	167.5	80	-	80	95.5	85.0	181.8	-101.8	176.0	+8.5
T_{12}	173.3	80	-	80	90.5	91.3	181.6	-101.6	180.5	+7.2

nitrogen management practices, the highest net gain of soil available nitrogen was recorded with FYM N_{100} (T_5), during the first year of study and with FYM N_{100} (T_5) and GLM N_{50} + F N_{50} + *Azo.* (T_{11}), during the second year of study.

4.3.6 Dynamics of Soil Available Phosphorus in the Cropping System

In both the years of study, irrespective of the nitrogen management practices adopted to rice crop, soil available phosphorus tended to increase with the rice crop and decrease with the groundnut crop (Table 4.31). Different N management practices adopted in the cropping system has not altered the available phosphorus status of the soil to a noticeable extent, during both the years of experimentation.

4.3.7 Dynamics of Soil Available Potassium in the Cropping System

In both the years of investigation, different nitrogen management practices imposed to *kharif* rice altered the available potassium status of the soil (Table 4.32).

In general, the available potassium status tended to increase with the rice crop and decrease with the groundnut crop, but the increase was in greater proportion with the second rice crop. Irrespective of the nitrogen management practices, the final potassium status of the soil after the last crop of experimentation was higher than the initial status. During both the years of study, the highest quantity of available potassium content was registered with 100 per cent N through FYM (T_5) applied to rice crop.

Table 4.31: Dynamics of soil available phosphorous (kg ha^{-1}) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system

Treatments	Initial soil P_2O_5 prior to green manure sowing in *kharif*, 2000	Soil P_2O_5 after rice harvest (*kharif*, 2000)	Soil P_2O_5 after groundnut harvest (*rabi*, 2000)	Soil P_2O_5 after rice harvest (*kharif*, 2001)	Soil P_2O_5 after groundnut harvest (*rabi*, 2001)
T_1	22.0	23.8	21.0	24.7	21.8
T_2	22.0	24.0	21.3	24.7	22.0
T_3	22.0	25.8	24.0	26.3	24.7
T_4	22.0	25.0	23.0	25.0	24.0
T_5	22.0	29.7	22.0	30.6	22.7
T_6	22.0	25.7	23.0	26.0	23.7
T_7	22.0	26.3	22.0	27.3	22.3
T_8	22.0	27.3	23.0	27.8	23.5
T_9	22.0	29.3	22.0	30.3	22.7
T_{10}	22.0	26.5	24.0	27.7	24.3
T_{11}	22.0	27.0	23.0	27.7	23.3
T_{12}	22.0	28.3	22.0	29.0	22.0
SEm ±	--	2.05	2.66	2.01	1.48
CD (P=0.05)	--	NS	NS	NS	NS

Table 4.32: Dynamics of soil available potassium (kg ha^{-1}) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system

Treatments	Initial soil K_2O prior to green manure sowing in *kharif*, 2000	Soil K_2O after rice harvest (*kharif*, 2000)	Soil K_2O after groundnut harvest (*rabi*, 2000)	Soil K_2O after rice harvest (*kharif*, 2001)	Soil K_2O after groundnut harvest (*rabi*, 2001)
T_1	119.0	115.8	114.2	146.7	125.0
T_2	119.0	119.2	115.8	150.7	134.0
T_3	119.0	138.3	139.2	176.3	172.0
T_4	119.0	149.2	141.7	181.0	172.5
T_5	119.0	174.2	149.2	204.7	177.5
T_6	119.0	125.0	119.2	156.7	146.7
T_7	119.0	134.2	134.2	172.0	167.5
T_8	119.0	139.2	139.2	180.7	171.7
T_9	119.0	154.2	146.7	189.7	177.5
T_{10}	119.0	138.3	134.2	179.5	164.0
T_{11}	119.0	137.5	137.5	175.3	171.5
T_{12}	119.0	151.5	145.0	186.5	177.5
SEm ±	--	14.64	9.76	14.90	10.15
CD (P=0.05)	--	42.9	28.6	43.7	29.8

Discussion

CHAPTER – V

DISCUSSION

Field experiments were conducted at the wetland farm of Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh to study the "Prospects of organic farming in rice-based cropping system" for two consecutive years (2000 and 2001). The experimental results presented in the preceding chapter are discussed here under to elucidate the findings.

5.1 WEATHER

Weather during the cropping cycle. 2000 (cropping period of the system from 03-07-2000 to 25-03-2001) and 2001 (cropping period of the system from 05-7-2001 to 04-04-2002) was congenial for optimum performance of rice as well as groundnut crops. During the crop growth periods of rice and groundnut, weather parameters did not deviate much from the decennial mean of the location of study and as such, weather did not constrain the optimal performance of the crops under different treatments. However, there was a little fluctuation in the yield levels of rice and groundnut crops between the two years of investigation, but the fluctuation was not so large as to demand pooled analysis. The minor variations in yield of crops between years might be due to marginal impact of several biotic and abiotic stresses operated during crop growth period. the situation, which is not uncommon in field experimentation across years.

5.2 JUSTIFICATION OF THE STUDY AND TREATMENTS

The experiment was laid out in randomized block design with three replications. The same layout was followed during both the years of study (2000 and 2001) in order to draw inferences more accurately and also to trace any accrued residual effects. There were twelve treatments comprising of different nitrogen management practices, applied to rice and groundnut crop was raised to study the residual fertility of *kharif* rice.

Nitrogen management practices were formulated with different sources viz., *Azospirillum*, green manure, green leaf manure, farmyard manure and fertilizer, with different combinations. The twelve treatments consisted of a control plot with no N application (T_1-no N); biological source of N supply through application of *Azospirillum* alone (T_2-*Azo.*); organic source of N supply with application of 100 per cent recommended dose of N through green manure (T_3-GM N_{100}), green leaf manure (T_4-GLM N_{100}) and farmyard manure (T_5-FYM N_{100}); application of 100 per cent N through fertilizer (T_6-F N_{100}) and integrated management treatments of application of 50 per cent N each through green manure and fertilizer (T_7-GM N_{50}+F N_{50}), 50 per cent N each through green leaf manure and fertilizer (T_8-GLM N_{50}+F N_{50}), 50 per cent N each through FYM and fertilizer (T_9-FYM N_{50}+F N_{50}), 50 per cent N each through green manure and fertilizer along the *Azospirillum* (T_{10}-GM N_{50} + F N_{50}+*Azo.*), 50 per cent N each through green leaf manure and fertilizer along with *Azospirillum* (T_{11}-GLM N_{50}+F N_{50}+*Azo.*) and 50 per cent N each through FYM and fertilizer along with *Azospirillum* (T_{12}-FYM N_{50}+F N_{50}+Azo).

Except the treatments of no N (T_1) and *Azospirillum* alone (T_2), the quantity of nitrogen supplied to rice crop through different combinations of nitrogen sources, did not differ and the quantity applied was as per the recommendation (80 kg N ha^{-1}) made to the region by RARS, Tirupati. The treatment, control (no N) was considered as bench mark for ascertaining the performance of other treatments, while, that of *Azo.* alone was to study the exclusive contribution of the biofertilizer. Even though the quantity of N supplied in other treatments was same, in the treatments T_3, T_4 and

T_5 the total quantity of nitrogen was supplied through organic sources, while in treatment T_6.the total N was supplied through fertilizer; in the treatments T_7, and T_8 and T_9 the recommended N supply was through combination of organic source and fertilizer with 50 per cent contribution from each and in the treatments T_{10}, T_{11} and T_{12}, the earlier integrated treatments of T_7, T_8 and T_9 were reinforced with *Azospirillum*. Thus, there was ample scope in the present study to investigate the performance of low land rice crop under varied sources of nitrogen nutrition viz.. three different exclusive organic sources, fertilizer alone and the combination of equal quantity of N through organic sources and fertilizer with and with out *Azospirillum*.

Groundnut crop was raised during *rabi* season after the harvest of *kharif* rice, in the same undisturbed layout and with out imposition of any treatments. Thus, there was adequate scope to determine the residual effect of different N management practices to rice on the performance of succeeding groundnut crop.

A cropping system must be location specific and acceptability of a cropping system depends on its efficient utilization of available resources, suitability to climatic conditions and the output of the cropping system must cater the needs of the farmers. From this point of view, selection of rice, the staple food crop and groundnut, the leading oilseed crop of A.P.. is justified. Also, the system is very popular of the region and in many parts of Andhra Pradesh.

Application of recommended quantity of nitrogen to the component crops in a cropping system is often uneconomical. Nitrogen requirement through external source to the groundnut crop is relatively less than the cereals. Many times, the crop meets the nutrient requirement through biological N fixation and external application of costly N without considering the residual N status may only increase the cost of cultivation. Thus, recommendation of nitrogen, based on cropping system as a whole. was considered efficient way of utilization of the costly input, nitrogen, where the carry over effect could be fully utilized by succeeding crop of groundnut.

Hence, there is adequate scope in the present study, to determine the direct and residual effect of green manure. green leaf manure, farmyard manure, fertilizer and their combinations on the *kharif* rice as well as succeeding groundnut crop. Total dry matter production, economic yield and monetary returns of the individual crops and the cropping system as a whole and nutrient dynamics of the soil, in the rice-groundnut cropping system were recorded and documented.

5.3 NITROGEN NUTRITION TO RICE CROP

Nitrogen alone contributes to 60.2 per cent of total variation in yield of low land rice (Yoshida, 1981), the fact that indicates the significance of adequate N nutrition to rice crop. Rice crop supplied with recommended dose of N for a given situation ensures adequacy of its availability in the rhizo-ecosystem and comfortable level of absorption coupled with favourable translocation to the needed plant parts at appropriate time during growing period.

Rice crop enjoying adequate N supply produces taller plants, more number of tillers, larger leaf area, higher dry matter accrual, more number of lengthier panicles with higher number of sound grains of increased weight, the result of which is finally reflected in terms of higher yield. Needless to say, the N uptake by rice plants during different growth stages manifests favorable growth as well as yield structure, resulting in elevated magnitude of yield and some times the quality of grain too (Blaise and Rajendra Prasad, 1996).

It has been well established that performance of modern rice varieties is proportional to N supply. When N is not supplied through any external source, rice crop has to obviously depend upon soil N, which might not be sufficient to produce even a moderate level of yield. In the present study, non-supply of N through any source resulted in poor performance of rice as could be noticed by the lowest values of all the growth parameters, yield attributes, nutrient uptake and yield.

5.4 EFFECT OF INORGANIC (FERTILIZER) NITROGEN ON RICE CROP

Supply of 100 per cent N through fertilizer to rice (T_6) was found to be superior to any other nitrogen management practice, with regard to all the parameters of crop and soil investigated, during both the years of study. This superiority with the treatment of F N_{100}, might be attributed to due to ready availability of comfortable level of instantly usable nitrogen by rice crop, which would have created favourable environment of nitrogen nutrition in the rhizo-ecosystem of lowland rice. Fertilizer N was applied with 50 per cent as basal and the remaining 50 per cent in two equal splits at active tillering and panicle initiation stages of rice crop. Such situation of comfortable level of instantly usable nitrogen favours optimum nitrogen uptake by rice crop at different growth stages. Similar situation existed during the present study as reflected by better dry matter production (Fig. 5.1a & 5.1b), higher number of total and production tillers (Fig. 5.2a & 5.2b), grain yield (Fig. 5.3a & 5.3b)and N, P and K uptake at flowering and harvest of rice crop (Fig. 5.4a & 5.4b, 5.5a & 5.5b, 5.6a & 5.6b).

Increased uptake of N by the treatment of F N_{100} was the result of higher DMP and enhanced absorption of N, while that of P and K might be due to better foraging of soil, due to vigorous root growth, thus accumulating more P and K in plant in addition to enhanced DMP.

Fig 5.1a: Stage-wise dry matter production (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2000

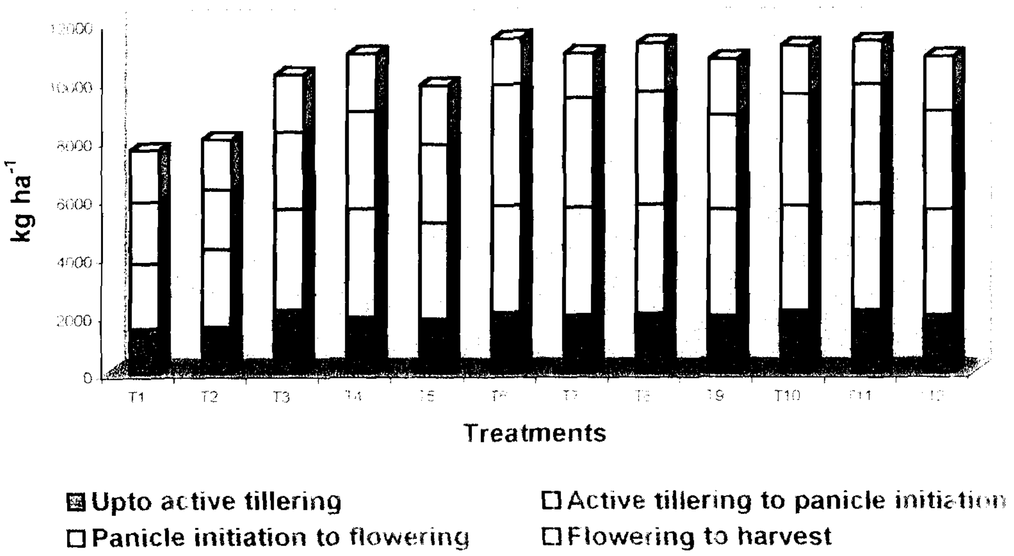


Fig 5.1b: Stage-wise dry matter production (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2001

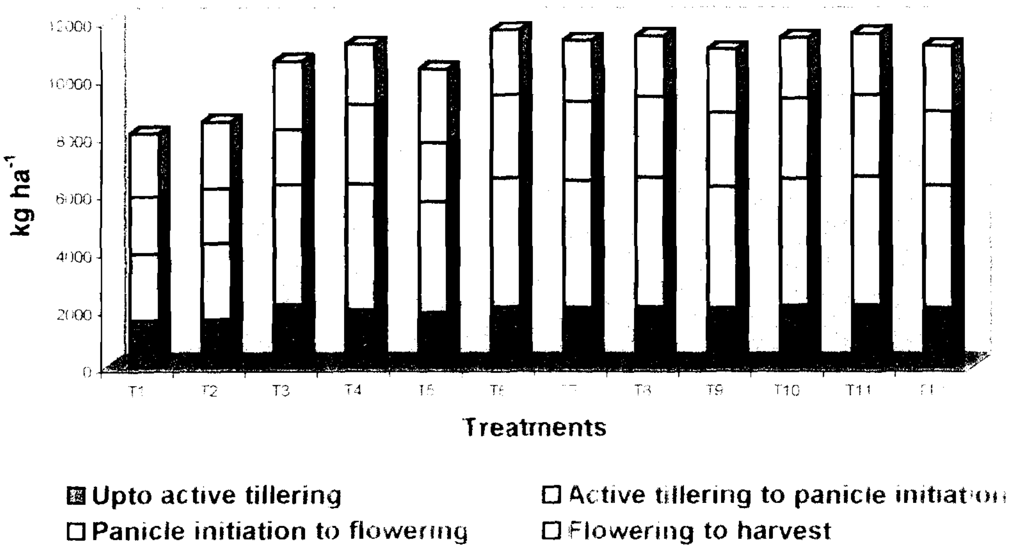


Fig 5.2a: Total and productive tillers m^{-2} of rice as influenced by different nitrogen management practices - *kharif*, 2000

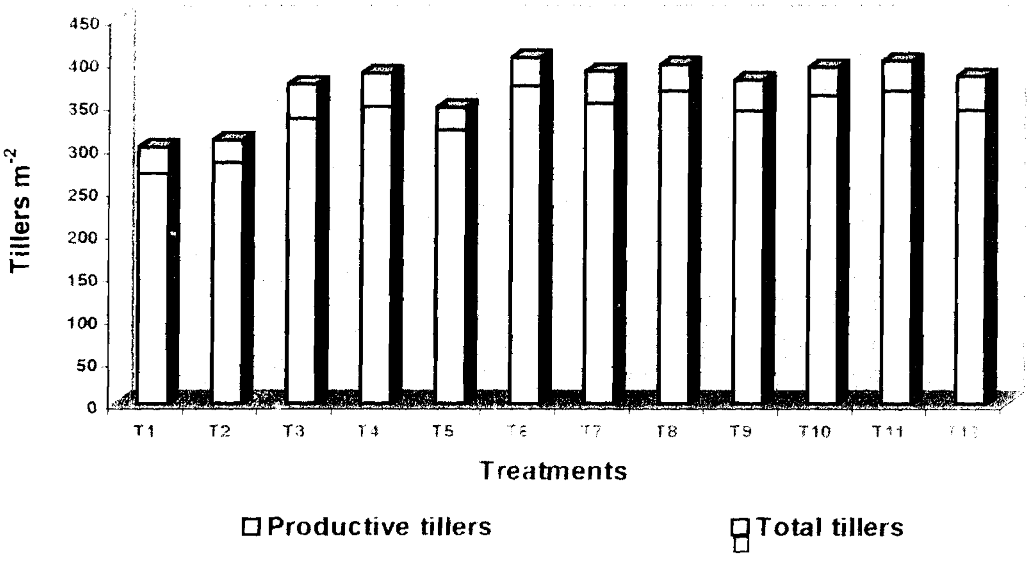


Fig 5.2b: Total and productive tillers m^{-2} of rice as influenced by different nitrogen management practices - *kharif*, 2001

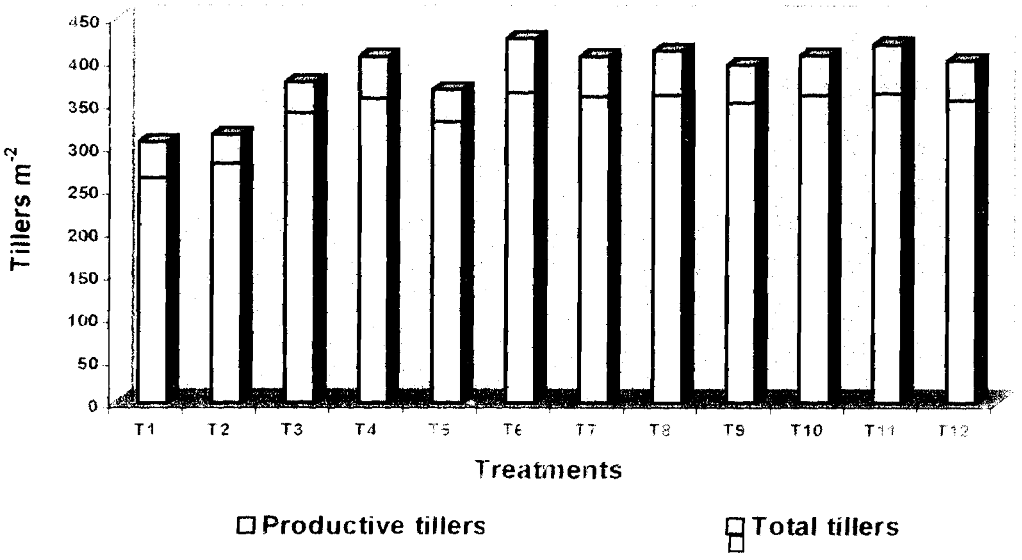


Fig 5.3a: Total dry matter production and grain yield (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2000

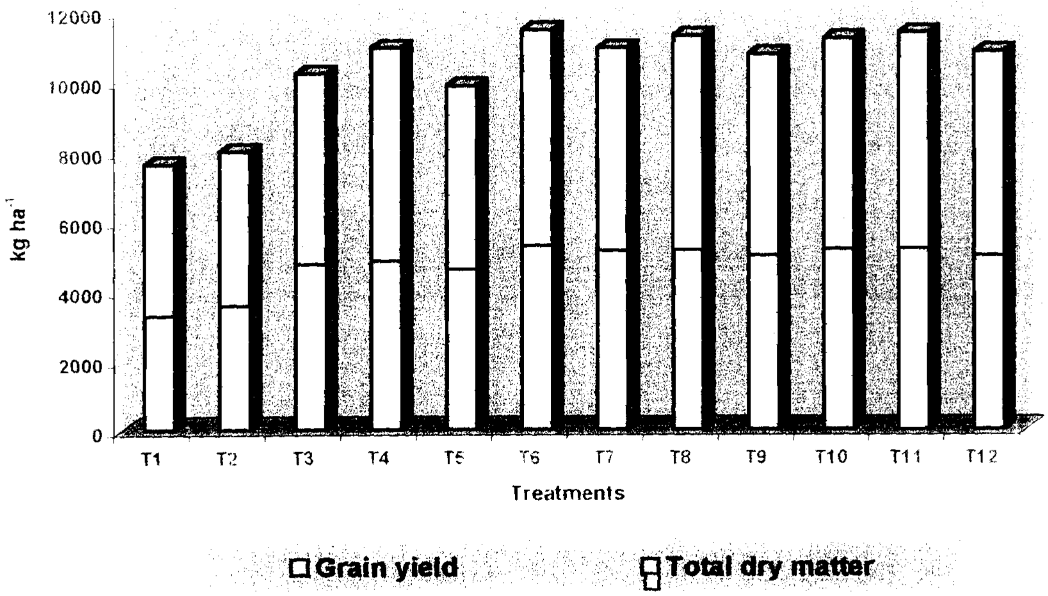


Fig 5.3b: Total dry matter production and grain yield (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2001

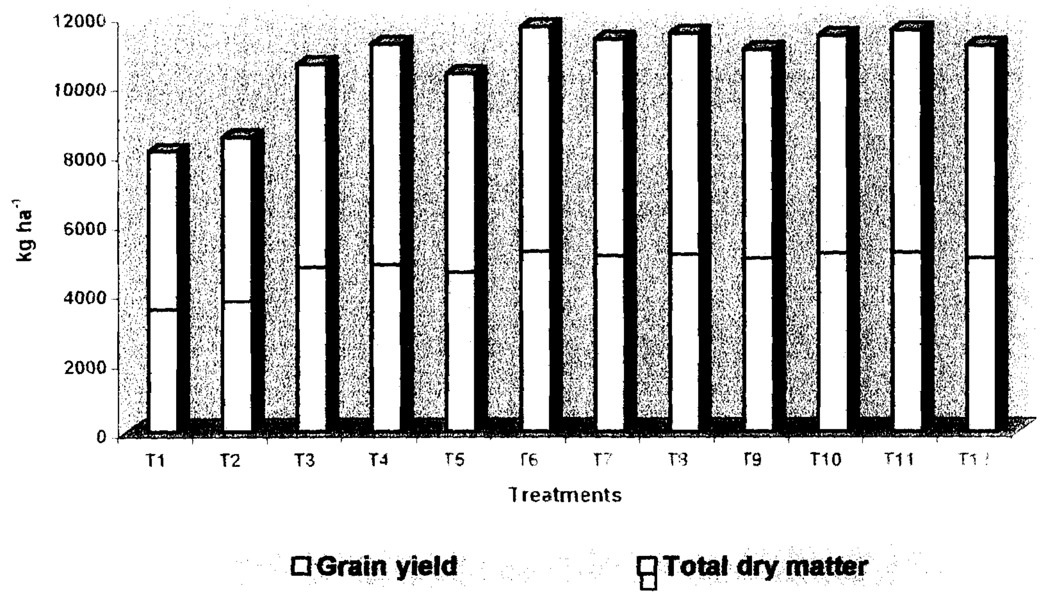


Fig 5.4a: Stage-wise nitrogen uptake (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2000

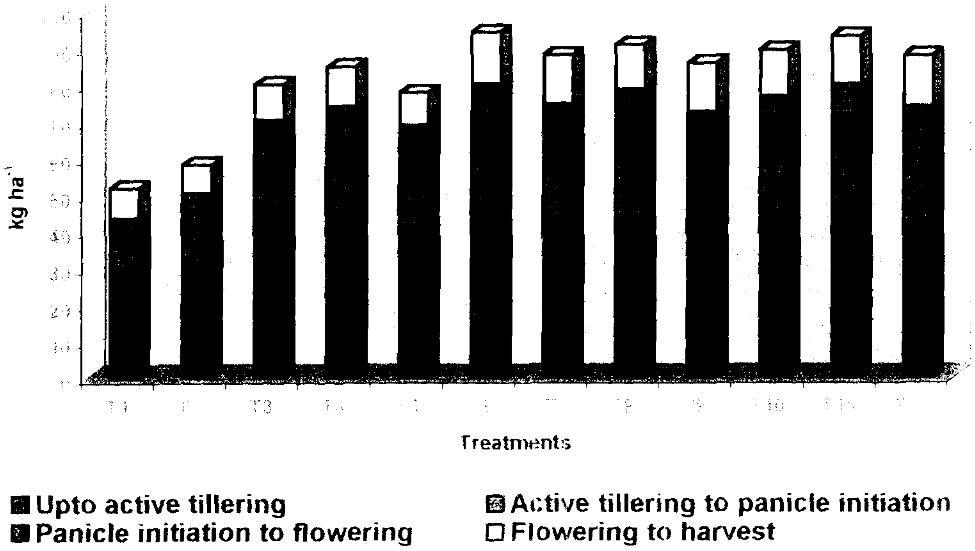


Fig 5.4b: Stage-wise nitrogen uptake (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2001

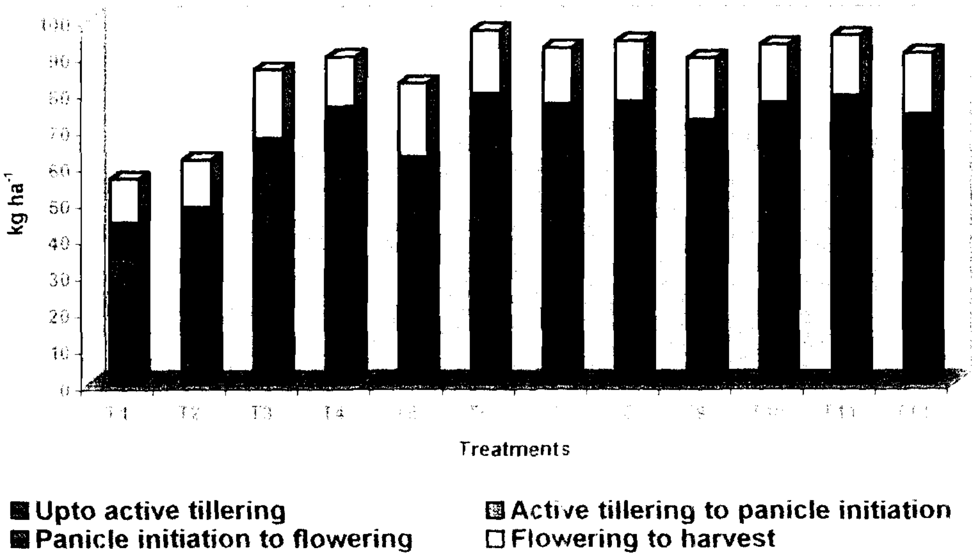


Fig 5.5a: Stage-wise phosphorus uptake (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2000

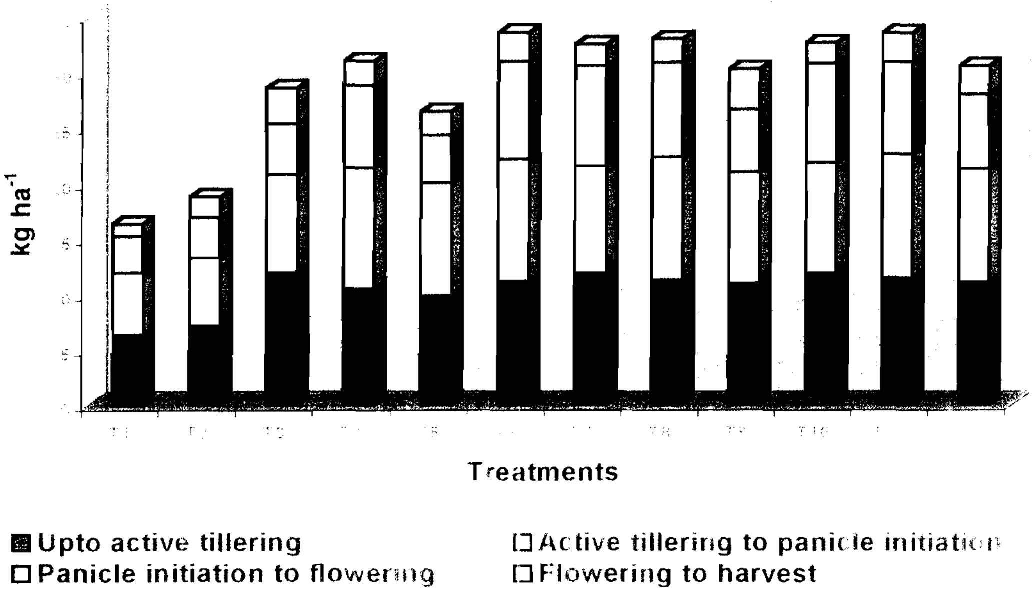


Fig 5.5b: Stage-wise phosphorus uptake (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2001

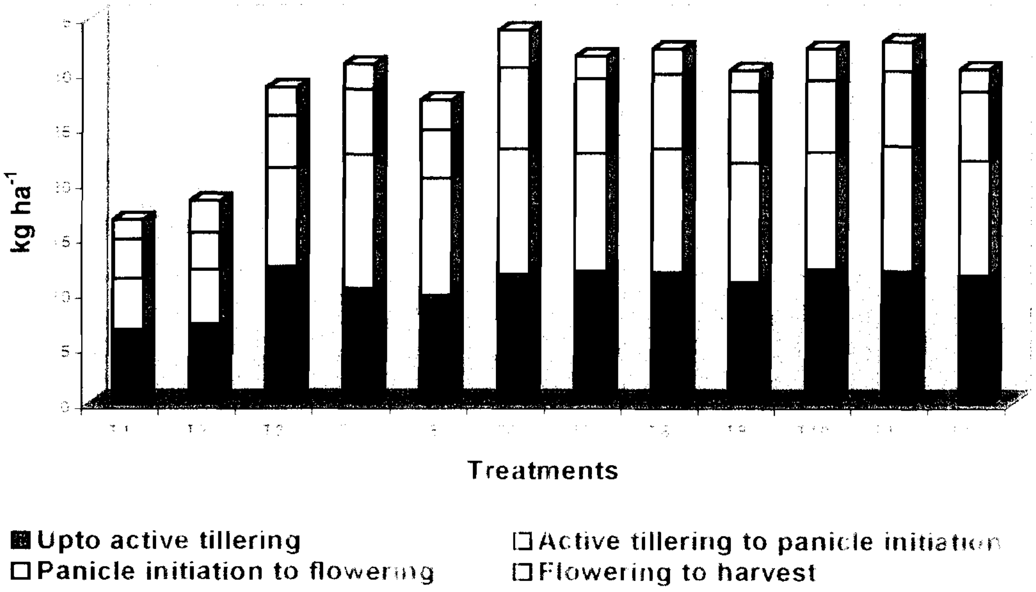


Fig 5.6a: Stage-wise potassium uptake (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2000

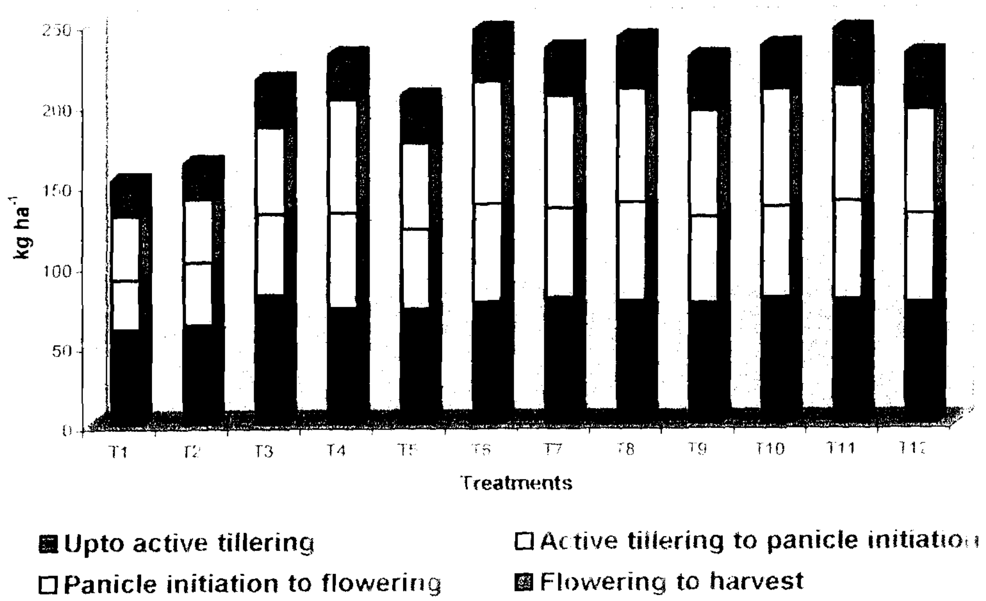
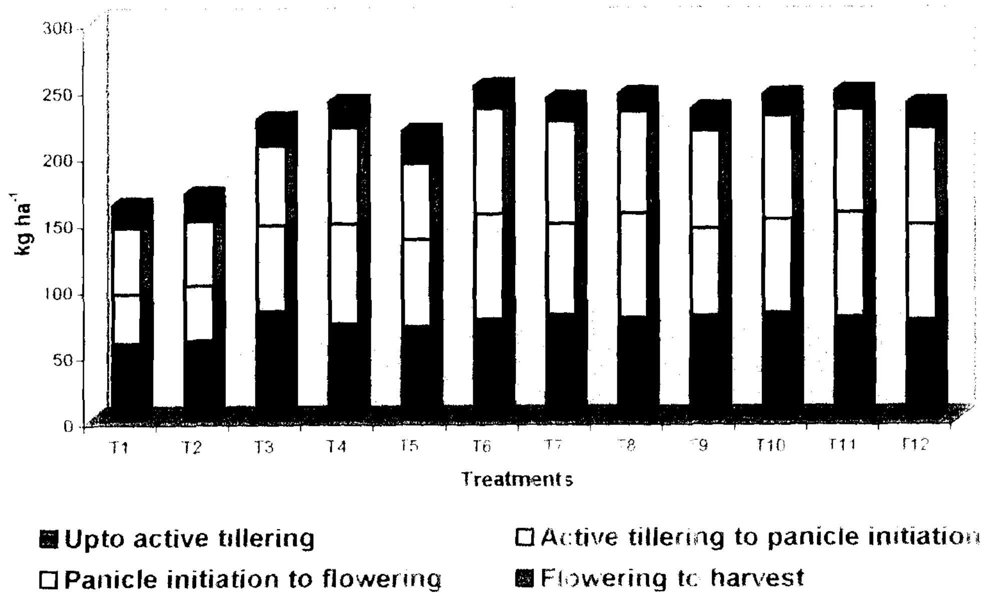


Fig 5.6b: Stage-wise potassium uptake (kg ha^{-1}) of rice as influenced by different nitrogen management practices - *kharif*, 2001



Favourable effects of N on rice and its positive response to applied N has been undisputed and universally established by voluminous research, as was reviewed comprehensively by Mamaril *et al.* (1987)

5.5 EFFECT OF ORGANIC SOURCES OF NITROGEN ON RICE CROP

Organic manures under go decomposition at a slower rate under submerged conditions, releasing ammonical nitrogen in regulated quantities over a long period of time. Thus, the rhizo-ecosystem of lowland gets enriched with less leachable form of available nitrogen, but many a time, insufficient to meet the nitrogen requirement of rice crop at appropriate time during crop growing period.

The decomposition and the availability of nitrogen in the soil solution depend upon the type of organic manures used. The results of the present study showed that application of 100 per cent N through dhiancha green manuring (T_3) has produced taller plants, more number of tillers m^{-2}, larger leaf area and higher dry matter production and higher N, P and K uptake at active tillering stage of crop growth. This might be due to required amount of readily available nitrogen in the rhizo-ecosystem of soil formed from the succulent green manure fraction, which undergoes quick decomposition and releases nitrogen quickly. The results corroborates the concept of Bouldin (1987), that the green manure contains two fractions, one of which undergoes faster decomposition and releases N for the current crop, while the other mineralizes at a slower rate. However, the subdued crop performance of rice during later stages might be due to insufficient nitrogen availability at appropriate time of crop requirement.

The performance of rice crop was sub-optimal with the other two organic sources of N supply viz., GLM N_{100} (T_4) and FYM N_{100} (T_5) and they were only superior to no N (T_1) and application of *Azospirillum* alone (T_2). This might be due to less readily available nitrogen in soil solution due to the process of slow mineralisation of these two organic sources under lowland conditions.

5.6 EFFECT OF INTEGRATED NITROGEN MANAGEMENT PRACTICES ON RICE CROP

The performance of rice crop with integrated N management practices was in parity with application of 100 per cent N through fertilizer. This might be due to favourable environment of N nutrition in the rhizo-ecosystem of lowland rice by the integration of organic and inorganic sources of N in equal proportion. Fertilizer N would be available to crop instantly immediately after application, while organic N would be mineralized slowly but continuously. Thus, initial requirement of N would be met from the former source and subsequent requirement of N from latter source, assuring continuous N supply throughout the growing period. Such situation favours N uptake by rice crop at different growth stages. Similar situation would have existed during the present study, as indicated by N uptake at different growth stages (Fig 5.4a & b).

Superior performance of rice crop with 100 per cent fertilizer N and its statistical comparability with integrated N management practices, as exhibited in the present study corroborates the findings of Setty and Channabasavanna (1990), Arumugam *et al.* (1992), Rathore *et al.* (1993) and Jose Mathew *et al.* (1994).

5.7 EFFECT OF AZOSPIRILLUM ON RICE CROP

In the present study, the fruitfulness of biofertilization with soil application of *Azospirillum* alone was not traceable, during both the instances of investigation. Though the beneficial effect of *Azospirillum* on low land rice was reported from several studies (Gopalaswamy and Raj, 1977; Sudhir Pradhan *et al.* 1998), such effect was not noticed in the present investigation. Fruitless nature of biofertilizers under field conditions is not uncommon due to edaphic and climatic limitations.

Striking impact of biofertilization with *Azospirillum* could not be traced in the study, which might be due to several possible reasons such as inefficiency and incompatibility of inoculated strain under the agro-eco situation of experimental site and insufficiency of dose tried for soil inoculation (though recommended dose was used).

However, the results obtained in this study in respect of biofertilization with *Azospirillum* to low land rice cannot be generalized and the opinion expressed regarding the fruitless nature of *Azospirillum* is only over simplification.

5.8 COMPARISON OF DIFFERENT NITROGEN MANAGEMENT PRACTICES TO RICE

Application of 100 per cent N through fertilizer (T_6) has recorded the highest grain yield, which was however, comparable with all the integrated nutrient management practices of GLM N_{50} + F N_{50}+ Azo, GM N_{50} + F N_{50} + Azo, GLM N_{50} + F N_{50}, GM N_{50} + F N_{50}, FYM N_{50} + F N_{50} + Azo and FYM N_{50} + F N_{50} and the yield increase with F N_{100} was 1.7, 1.8, 2.2, 2.8, 5.6 and 5.8 per cent, respectively, during the first year and 0.7, 1.0, 1.6, 2.4, 4.1 and 4.1 percent, respectively, during the second year of study. The increase in grain yield with F N_{100} (T_6) over exclusive organic N management treatments of GLM N_{100}, GM N_{100} and FYM N_{100} was 8.9, 10.7 and 14.7 per cent, respectively, during the first year and 7.9, 10.1 and 13.6 per cent, respectively, during the second year of study, while the yield increase over *Azospirillum* alone (T_2) was 47.9 and 38.2 per cent, respectively during the first and second year of study, and over the control (no N) it was 61.3 and 47.0 per cent, respectively during 2000 and 2001.

The percentage yield increase by the best treatment of F N_{100} (T_6) over other integrated treatments was only marginal and was not of any statistical significance, during both the years of study.

The comparable performance of rice crop with fertilizer alone and with different integrated N management treatments and their superiority over exclusive organic sources of N, might be due to favourable environment of N nutrition in the rhizo-ecosystem of lowland rice. Fertilizer N would be available to crop instantly immediately after application, while organic N would be mineralized slowly but continuously. Thus initial requirement of N would be met from the former source and subsequent requirement of N from latter source, assuring continuous N supply through out the growing period.

5.9 QUALITY CHARACTERS OF RICE

Except the treatment of 100 per cent N through FYM (T_5), application of recommended dose of N did not show any considerable variation in milling characters of rice grain (whole grain per cent, milling per cent and broken grain per cent). The protein and amylase content recorded with recommended dose of different N management practices was comparable with each other. But all the above quality characters recorded with no N application (T_1) and *Azospirillum* alone (T_2) were comparable with each other and significantly inferior to any of the recommended N application treatments.

Rice crop enjoyed comfortable N nutrition has resulted in better quality of rice. Most of the milling, nutritional and cooking quality characters are genotype dependent and would be altered to a marginal extent by management practices. There is no published evidence regarding the relationship between N management and quality of rice. However, lower protein content of kernels observed with no N (T_1) and *Azospirillum* alone (T_2) was obviously due to lower N content in grain (Table 4.8).. Biochemically protein content is dependent on N content (AOAC, 1984). Increased protein content of rice kernels with N application has been documented by Patel *et al.* (1997) and similar results were obtained in the present investigation, with the application of recommended dose of nitrogen. through different sources.

5.10 NUTRIENT UPTAKE OF RICE

Among the N management practices, application of 100 per cent N through green manure (T_3) has resulted in highest uptake of nitrogen, phosphorus and potassium at active tillering. The higher uptake of N, P and K at panicle initiation was recorded with application of 50 per cent N through green leaf manure and fertilizer along with *Azospirillum* (GLM N_{50} + F N_{50} +*Azo.*), during both the years of study. However, at flowering and at harvest, the highest uptake of N, P and K was registered with the application of 100 per cent N through fertilizer.

The enhanced uptake of N at various crop growth stages with the respective treatments might be due to higher amount of available nitrogen in the rhizo-ecosystem system of soil, while the absorption of P and K might be due to better foraging of soil, due to vigorous root growth, thus accumulating more P and K in plant.

The highest nutrient uptake at active tillering with GM N_{100} might be due to large amount of nitrogen in the rhizo-ecosystem of soil derived from the quickly decomposing green manure fraction.

The highest nutrient uptake at panicle initiation with GLM N_{50} + F N_{50}+ *Azo.* might be due to coincidence of greater net mineralisation of N from the decomposition of neem leaf manure and the supplemental external application of fertilization N at panicle initiation and of course, the combination has been reinforced with basal application of *Azospirillum*.

The highest nutrient uptake at flowering and at harvest stage with F N_{100} might be due to ready availability of comfortable level of instantly usable nitrogen by rice crop supplied through external application of fertilizer N through top dressing.

5.11 SOIL FERTILITY STATUS POST HARVEST OF RICE

Post harvest soil status with regard to organic carbon (Fig. 5.7), available nitrogen and potassium (Fig. 5.8a & 5.8b) was superior with application of 100 per cent N through FYM (FYM N_{100} - T_5), which was however, comparable with all the recommended N application treatments, except 100 per cent N through fertilizer (T_6). The lowest status of the above mentioned soil fertility parameters were recorded with no N (T_1), which was comparable with *Azospirillum* alone (T_2). The available phosphorus status did not vary to a statistically traceable extent due to different N management practices.

Fig 5.7: Post harvest soil organic carbon (%) after rice as influenced by different nitrogen management practices

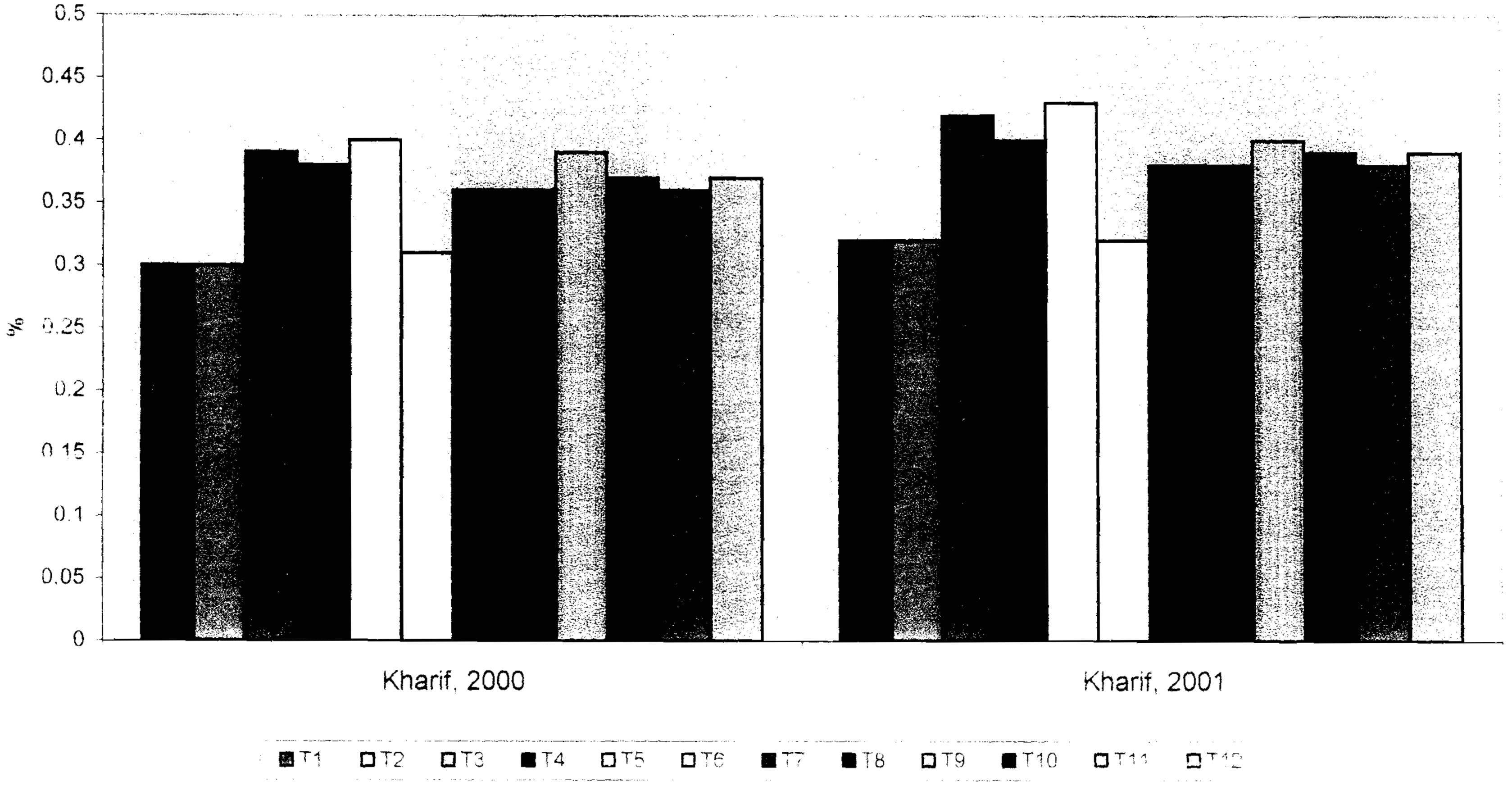


Fig 5.8a: Post harvest soil available N, P and K (kg ha^{-1}) after rice as influenced by different nitrogen management practices - *kharif*, 2000

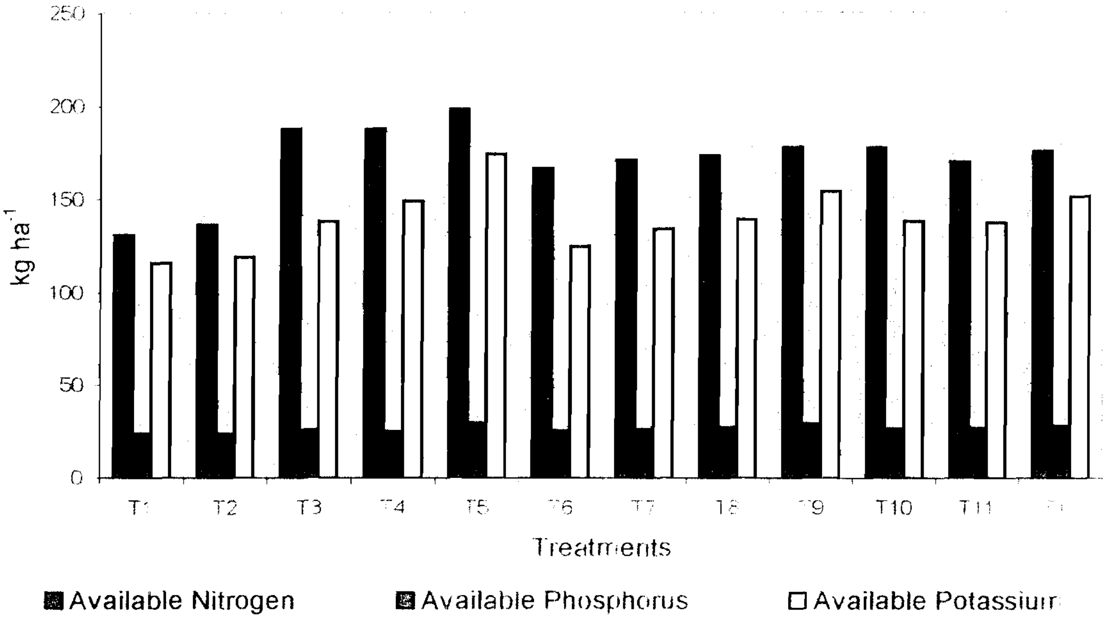
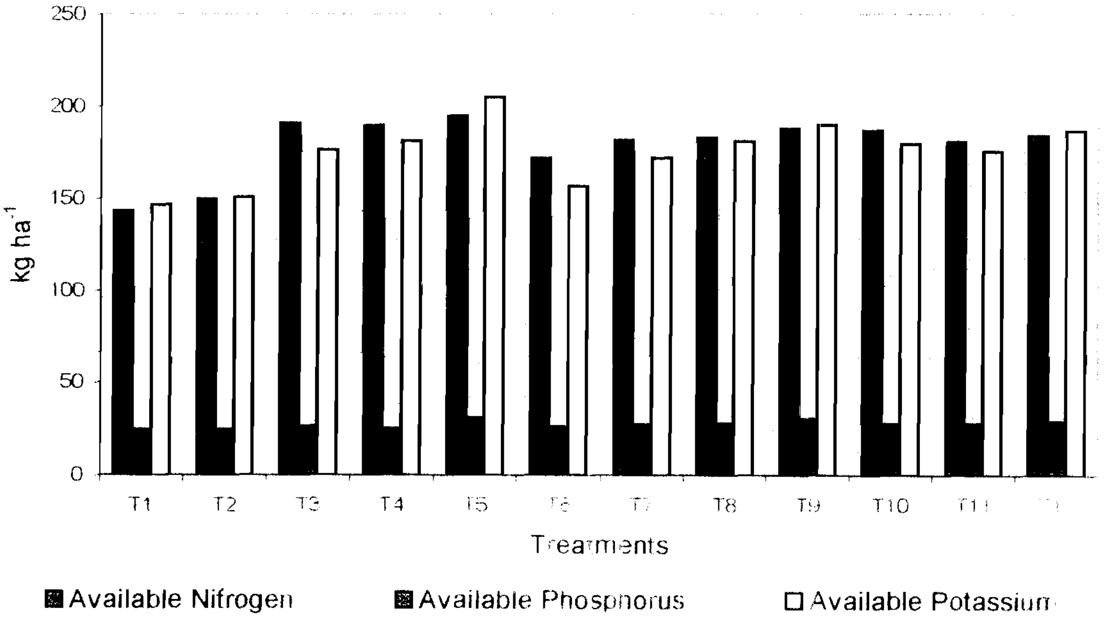


Fig 5.8b: Post harvest soil available N, P and K (kg ha^{-1}) after rice as influenced by different nitrogen management practices - *kharif*, 2001



The above trend clearly indicated that application of recommended N either through exclusive organic source or the combination of organics and fertilizer to supply 50 per cent N through each, would leave substantial quality of soil nutrients after the harvest of rice and increase the soil organic carbon content (Fig No.7 and 8a & b). The results are in accordance with the findings of Maskina and Meelu (1984), that organic manures quite often leave substantial residual effect on succeeding crops in the cropping system. The sustainable advantage noticed in the present study with the integration of organic manures and fertilizer has been amply indicated by Srinivasulu Reddy (1988), Vasanth Kumar (1996) and Upendra Rao (1998). Slowly mineralizing organic fractions under anaerobic lowland conditions would have left behind enriched status of soil fertility, even after sufficient uptake of nutrients by rice crop.

5.12 ECONOMICS OF RICE CROP

The highest gross returns were recorded with application of 100 percent N through fertilizer (T_6), which were comparable with all the integrated N management treatments. However, the net returns and the BC ratio obtained with F N_{100} were significantly higher to any of the N management treatments (Fig. 5.9a & 5.9b). The trend of gross returns was similar to grain yield realized and it was due to this simple reason that application of 100 per cent N and all the integrated N management practices were statistically similar.

Since the cost of N through fertilizer was relatively cheaper than any of the organic sources of N, the net returns and the BC ratio realized with F N_{100} were significantly higher than any of the N management practices. Supply of 100 per cent N through fertilizer was distinctly more profitable than either application of organic manures alone or their combination with fertilizer to the rice crop.

Fig 5.9a: Economics of rice as influenced by different nitrogen management practices - *kharif*, 2000

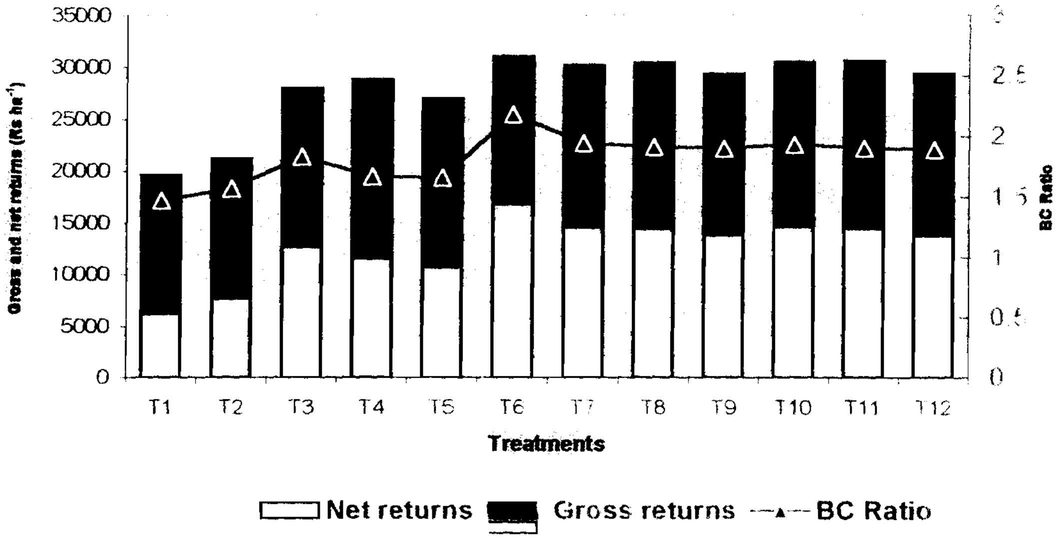
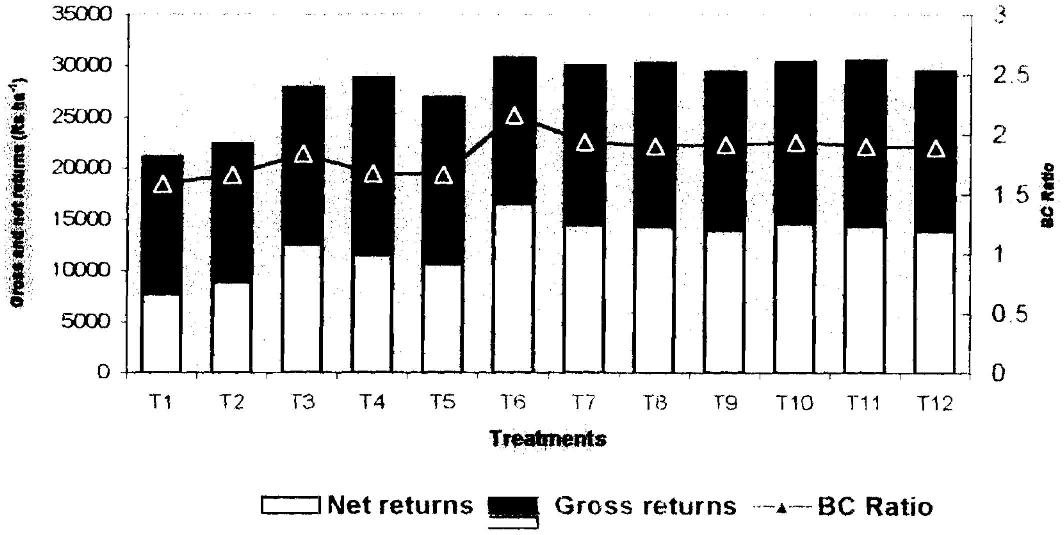


Fig 5.9b: Economics of rice as influenced by different nitrogen management practices - *kharif*, 2001



5.13 RESIDUAL EFFECT OF NITROGEN MANAGEMENT PRACTICES ON SUCCEEDING CROP OF GROUNDNUT

Residual effect of different nitrogen management practices imposed on *kharif* rice has exerted marked influence on the growth, yield, nitrogen uptake and economics of groundnut as well as the post harvest soil fertility.

Supply of 100 per cent N through FYM (T_5) to preceding rice has recorded the highest plant height, LAI and dry matter production (Fig. 5.10a & 5.10b), which were significantly superior to only the treatments of no N (T_1), *Azospirillum* alone (T_2) and F N_{100} (T_5) imposed to preceding rice. This might be due to substantial amount of residual nutrients left by the treatments of preceding rice crop on succeeding groundnut crop.

The yield attributes of groundnut viz., number of pods plant^{-1}, hundred-pod weight and hundred-kernel weight as well as pod (Fig. 5.11a & 5.11b)and haulm yield were the highest with application of 100 per cent N through FYM to preceding rice crop (T_5), which was however, comparable with FYM N_{50} +F N_{50} (T_9), FYM N_{50} + F N_{50}+*Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3). This might be due to the residual effect with the treatments of the combination of FYM and the exclusive organic sources of N, which was comparatively higher than that of the other combinations of organics and fertilizer N applied to preceding rice crop. With in the organic sources, differential residual response with different sources can be attributed to their pattern of mineralisation and proportion of their substitution. In the present study, the residual effect of organic sources at higher proportions was evident from higher dry matter accrual, number of pods plant^{-1}, 100 pod weight, pod and haulm yield and nitrogen uptake as well as post harvest fertility status of the soil. This clearly indicates that organic sources at higher proportions can only sustain the nutrient status of soil to produce reasonable residual effect.

Fig 5.10a: Stage-wise dry matter production (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2000

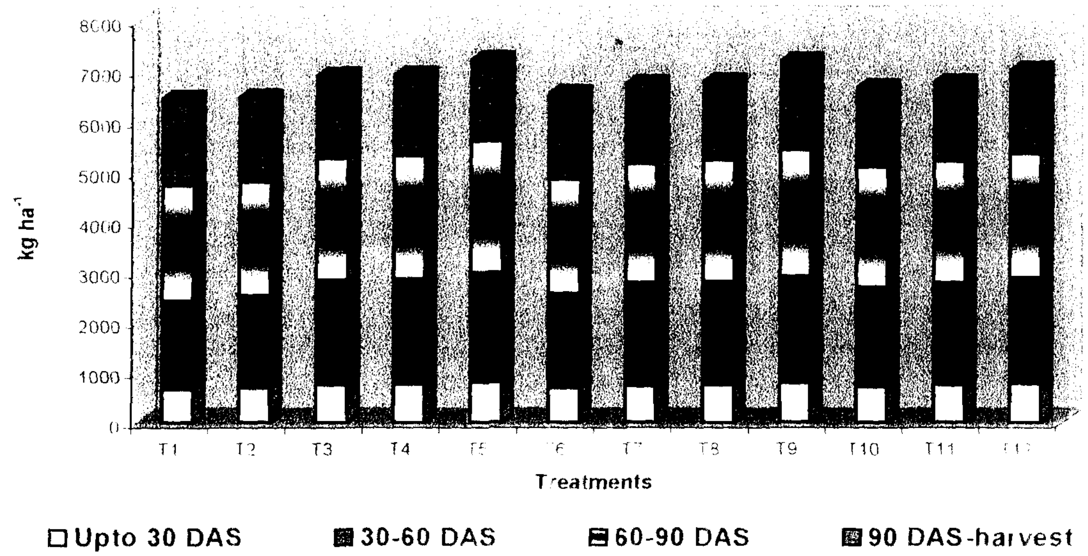


Fig 5.10b: Stage-wise dry matter production (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2001

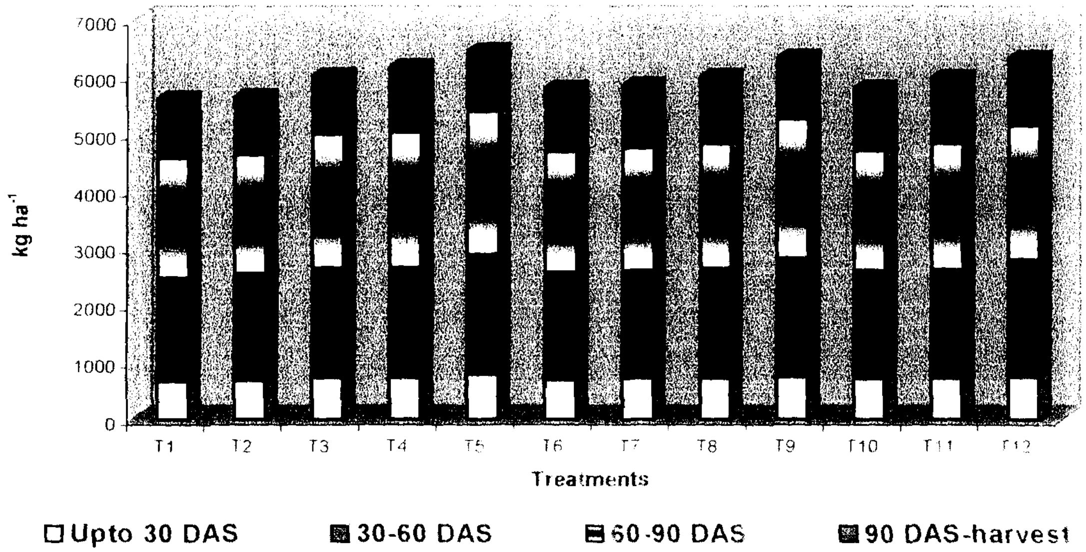


Fig 5.11a: Total dry matter production and pod yield (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice- *rabi*, 2000

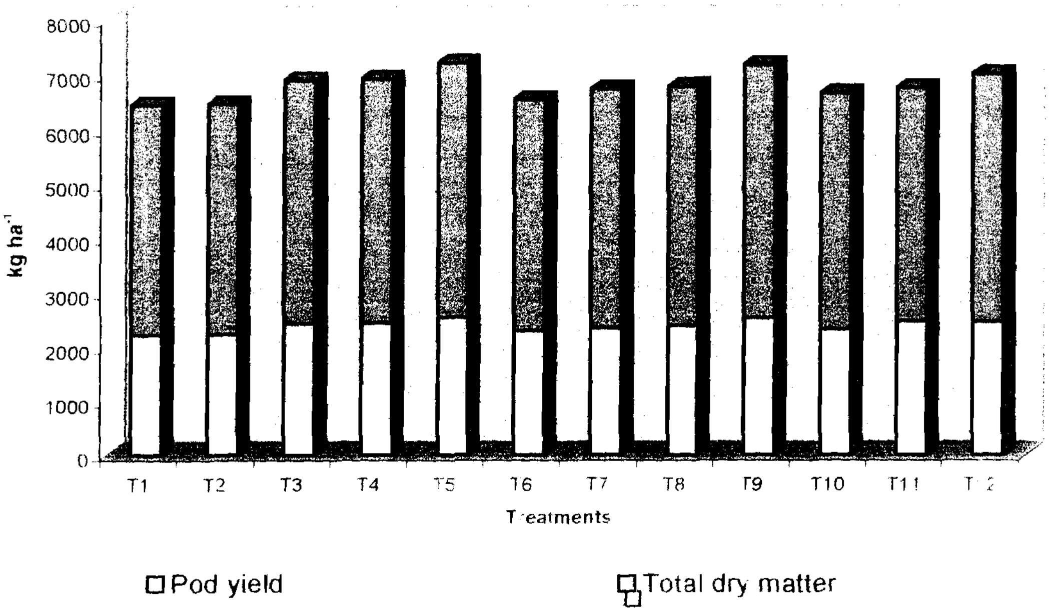
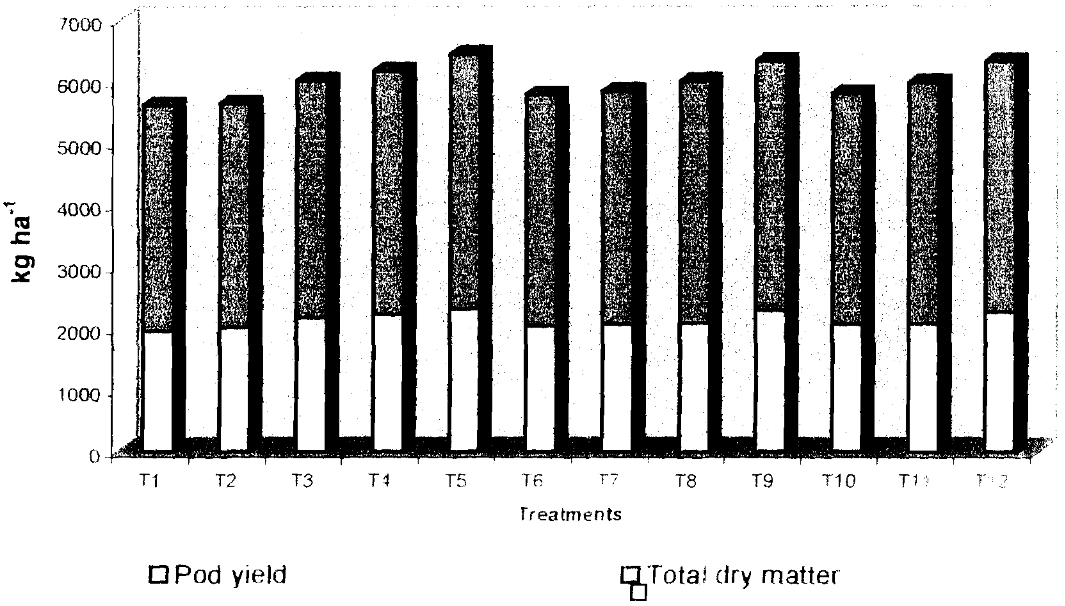


Fig 5.11b: Total dry matter production and pod yield (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice- *rabi*, 2001



Organic manures, besides supplying nutrients to the current crop, quite often leave substantial residual effect on succeeding crops in the cropping system (Maskina and Meelu, 1984). Significant carry over effect due to substitution of nitrogen with higher proportions of organic sources to rice crop on the succeeding crops was also reported by Rao and Bharadwaj (1980), Rathore *et al.* (1993), Thimmegowda and Devakumar (1994), Paulraj and Velayudham (1995) and Sujathamma *et al* (1996). Residual effect of fertilizer nitrogen applied to rice was not traceable on the succeeding groundnut crop (Ramaseshaiah *et al.*, 1985).

At 30 and 60 DAS, nodule dry weight was the highest with 100 per cent N through FYM (T_5) applied to preceding rice, which was at par with other N management. practices imposed to *kharif* rice, except with F N_{100} (T_6), *Azospirillum* alone (T_2), and no N (T_1), while at 90 DAS and at harvest, there was no significant variation in nodule dry weight due to different N management practices to preceding rice. This was perhaps due to the residual fertility, especially soil P with the treatments of combinations of organic sources during the early stages of crop growth, while during the later stages, the effect of residual fertility might be insignificant and also the activity of nodules would have been ceased.

Higher uptake of nitrogen (Fig. 5.12a & 5.12b) by groundnut crop with application of 100 percent N through FYM (T_5) to preceding rice crop might be due to higher availability of nitrogen in the soil and enhanced dry matter production. The higher uptake of P (Fig. 5.13a & 5.13b) and K (Fig. 5.14a & 5.14b) with the same treatment of FYM N_{100} might be due to better foraging of soil, due to vigorous root growth, thus accumulating more P and K in plant in addition to enhanced DMP, under the influence of higher amount of residual N.

Fig 5.12a: Stage-wise nitrogen uptake (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2000

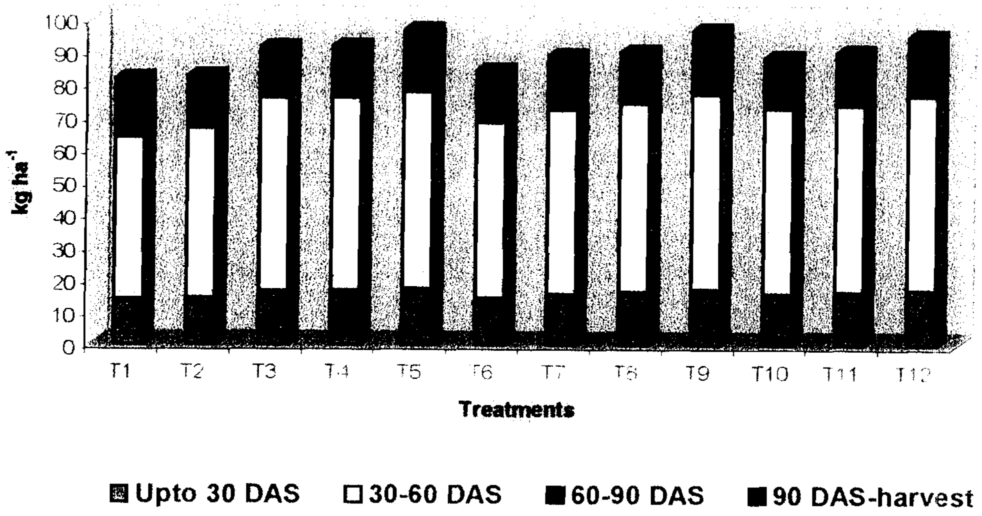


Fig 5.12b: Stage-wise nitrogen uptake (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2001

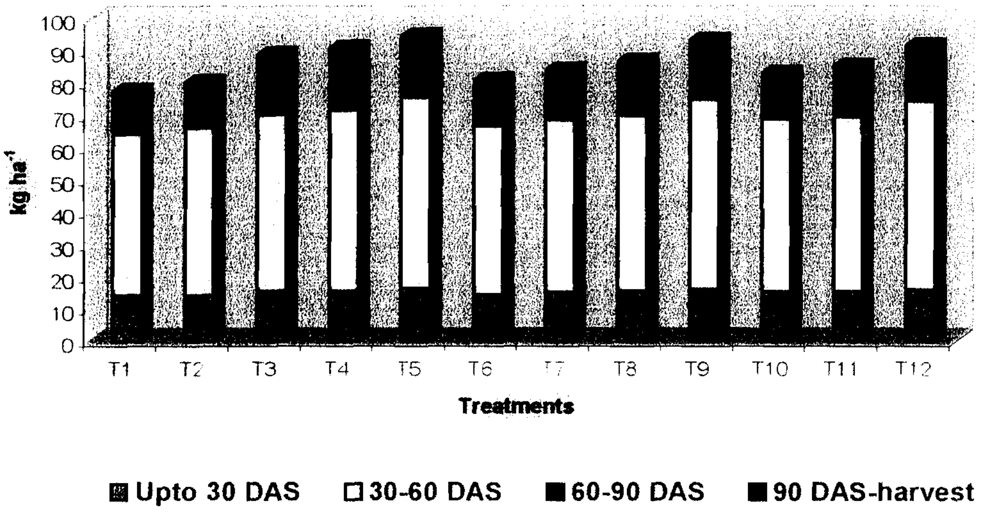


Fig 5.13a: Stage-wise phosphorus uptake (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2000

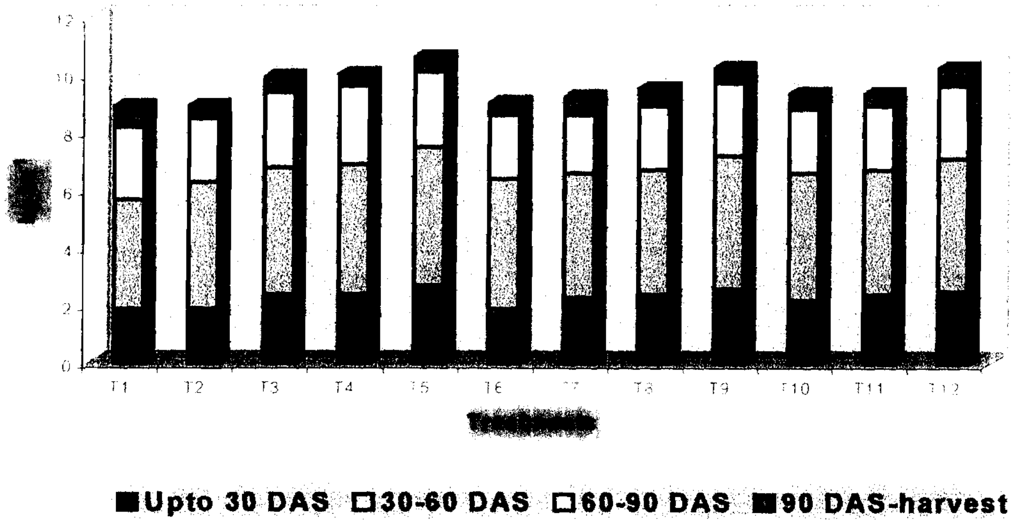


Fig 5.13b: Stage-wise phosphorus uptake (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2001

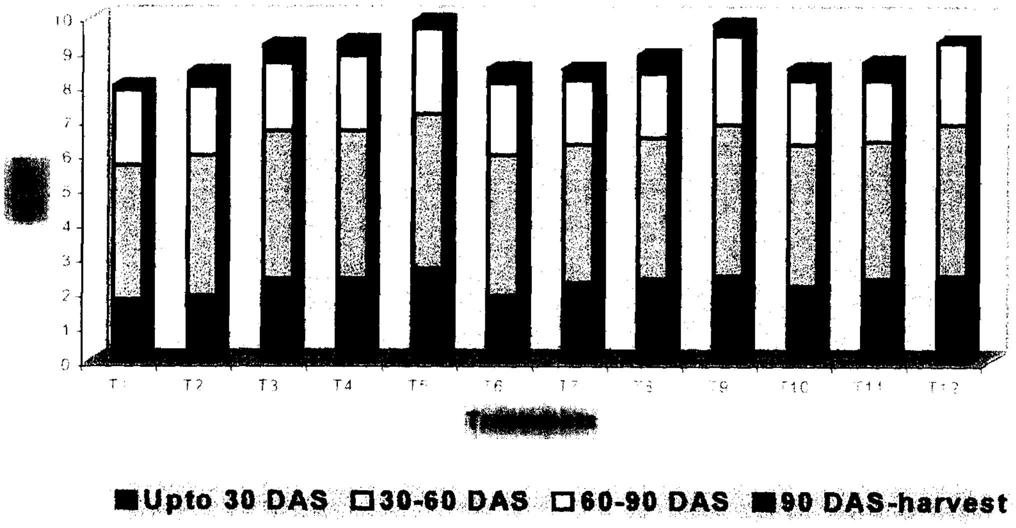


Fig 5.14a: Stage-wise potassium uptake (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2000

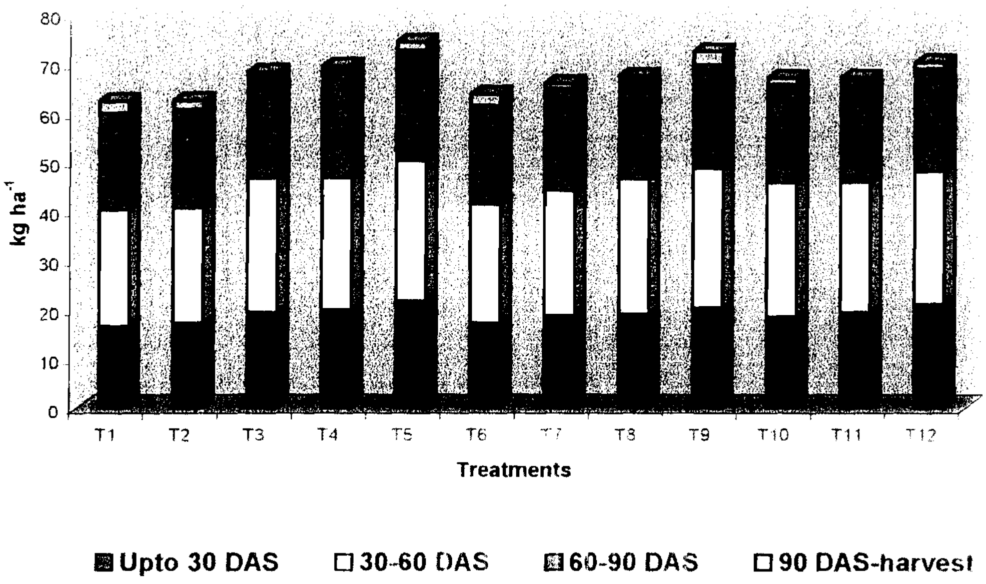
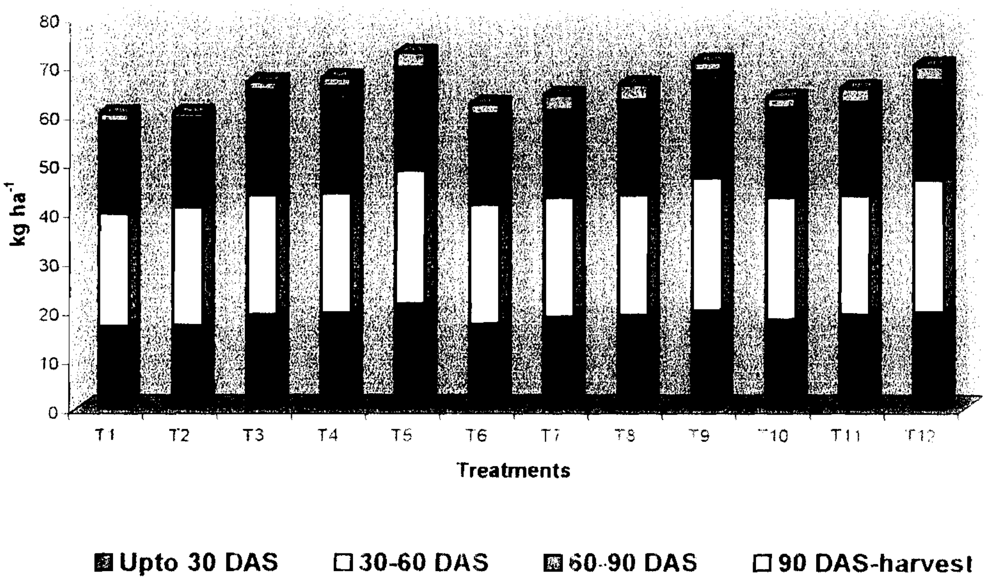


Fig 5.14b: Stage-wise potassium uptake (kg ha^{-1}) of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2001



T_1 : N_0
T_2 : *Azo.*
T_3 : GM N_{100}
T_4 : GLM N_{100}
T_5 : FYM N_{100}
T_6 : F N_{100}
T_7 : GM N_{50} + F N_{50}
T_8 : GLM N_{50} + F N_{50}
T_9 : FYM N_{50} + F N_{50}
T_{10} : GM N_{50} + F N_{50}+ *Azo.*
T_{11} : GLM N_{50} + F N_{50}+ *Azo.*
T_{12} : FYM N_{50} + F N_{50}+ *Azo.*

The highest organic carbon (Fig. 5.15), available nitrogen and available potassium content of soil (post harvest) were noticed with the application of 100 per cent N through FYM (T_5) to preceding rice, which was however, comparable with all the recommended N application treatments, except 100 per cent N through fertilizer (Fig. 5.16a & 5.16b). The available phosphorus did not show any significant variation with different N management treatments, even though it was highest with FYM N_{100}, while the lowest was with F N_{100}.

Slow decomposition and mineralisation of organic manures added in large quantities to preceding rice crop would have enriched the organic carbon, available nitrogen, phosphorus and potassium status of soil after the harvest of groundnut. These results are in agreement with those of Meelu and Morris (1984), Rajendra Prasad (1985), Buresh and De Datta (1991).

The highest gross and net returns as well as BC ratio recorded (Fig. 5.17a & 5.17b) with 100 per cent N through FYM (T_5) to preceding rice, were due to higher pod and haulm yield realized by this treatment and also since groundnut crop was raised as residual crop of rice, the cost of cultivation did not differ among the treatments.

5.14 BIOLOGICAL YIELD OF RICE-GROUNDNUT CROPPING SYSTEM

Biological productivity of the cropping system expressed in terms of total dry matter production was at the highest (Fig 5.18) with application of GLM N_{50} + F N_{50}+*Azo.* (T_{11}) to *kharif* rice, which was comparable with all the recommended N application practices. The superiority of this treatment and its comparability with other integrated N management treatments can be attributed to ready availability of comfortable level of instantly usable nitrogen by rice crop, adequate residual nitrogen nutrition to groundnut, favouring in greater absorption of nitrogen, which ultimately

Fig 5.15: Post harvest soil organic carbon (%) after groundnut as influenced by different nitrogen management practices to preceding rice

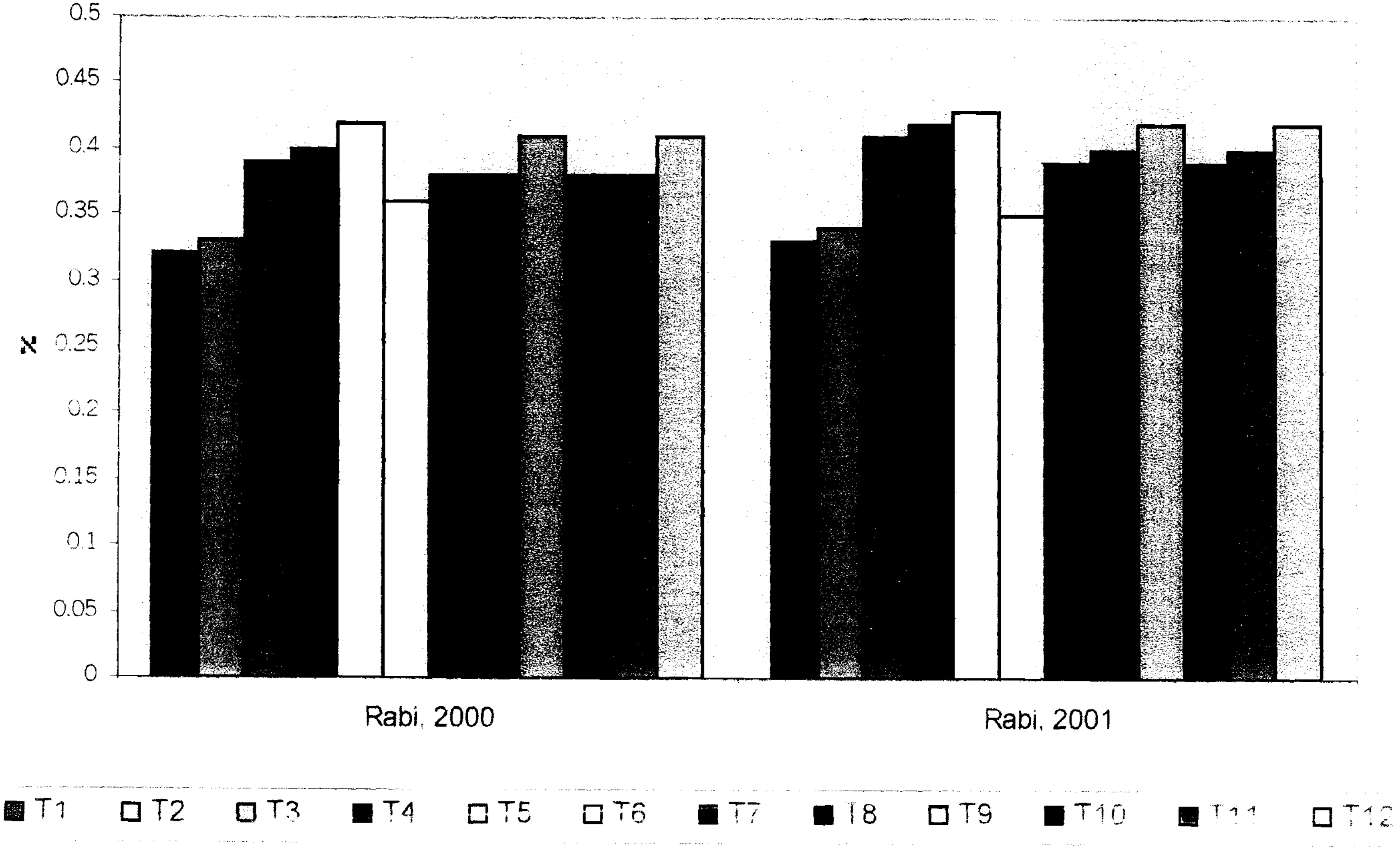


Fig 5.16a: Post harvest soil available N, P and K (kg ha^{-1}) after groundnut as influenced by different nitrogen management practices to preceding rice- *rabi*, 2000

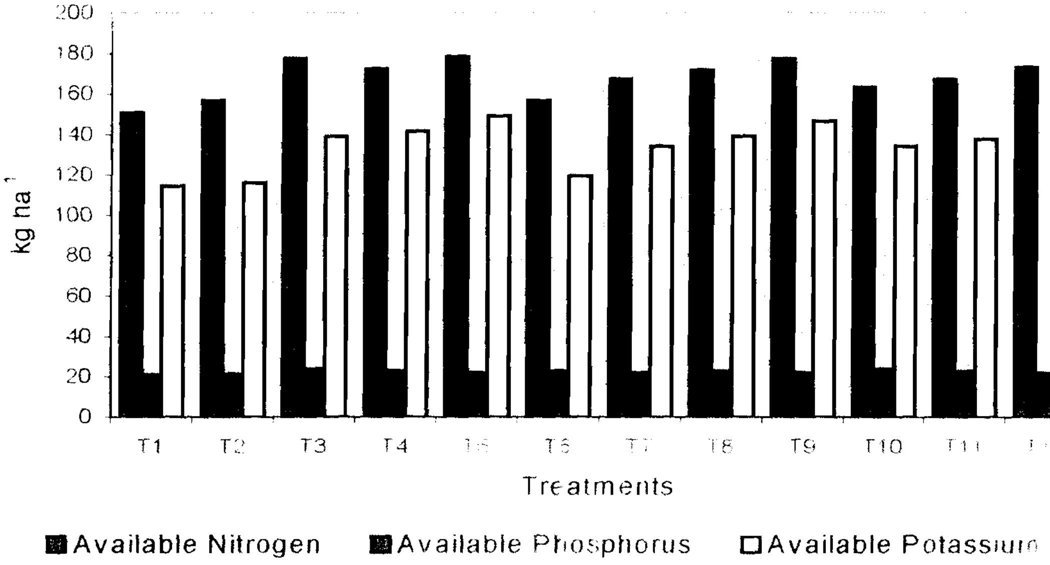


Fig 5.16b: Post harvest soil available N, P and K (kg ha^{-1}) after groundnut as influenced by different nitrogen management practices to preceding rice- *rabi*, 2001

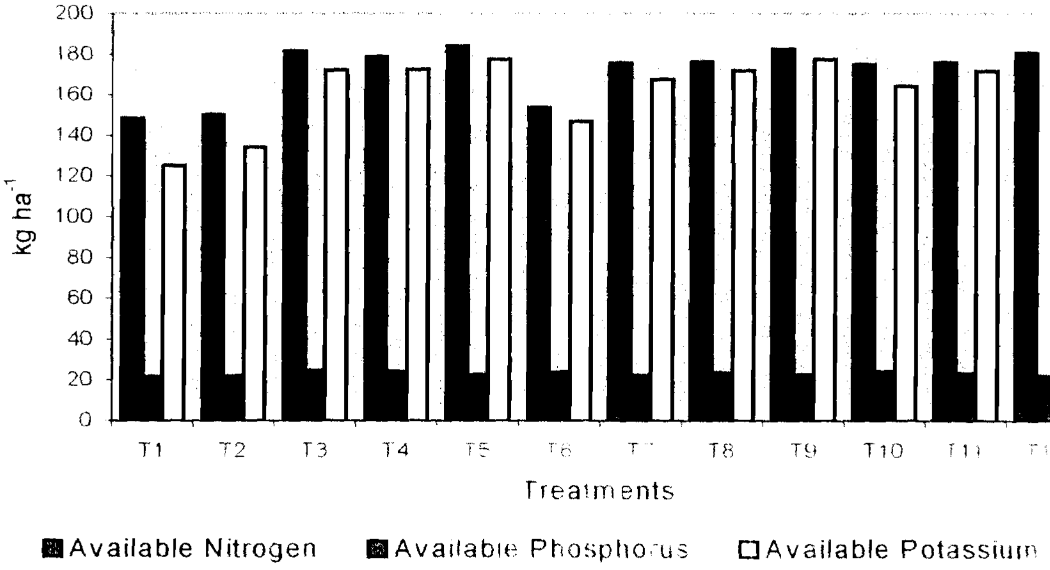


Fig 5.17a: Economics of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2000

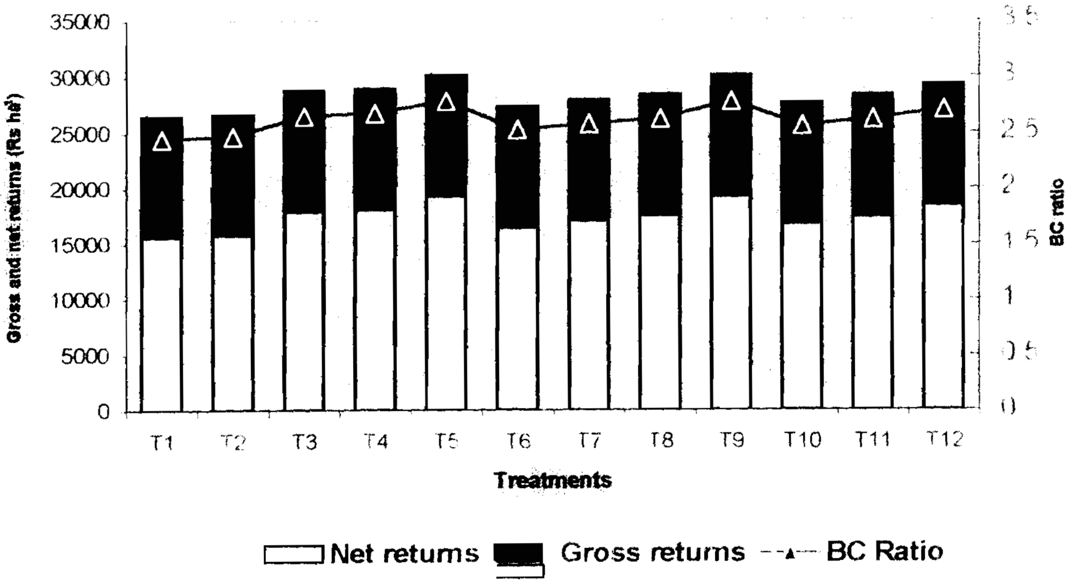


Fig 5.17b: Economics of groundnut as influenced by different nitrogen management practices to preceding rice - *rabi*, 2001

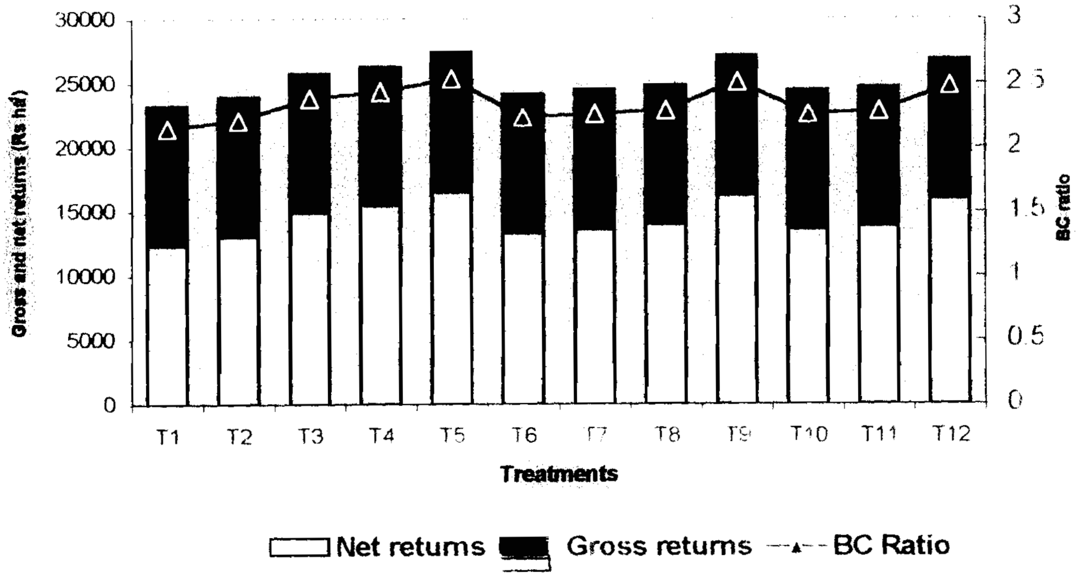
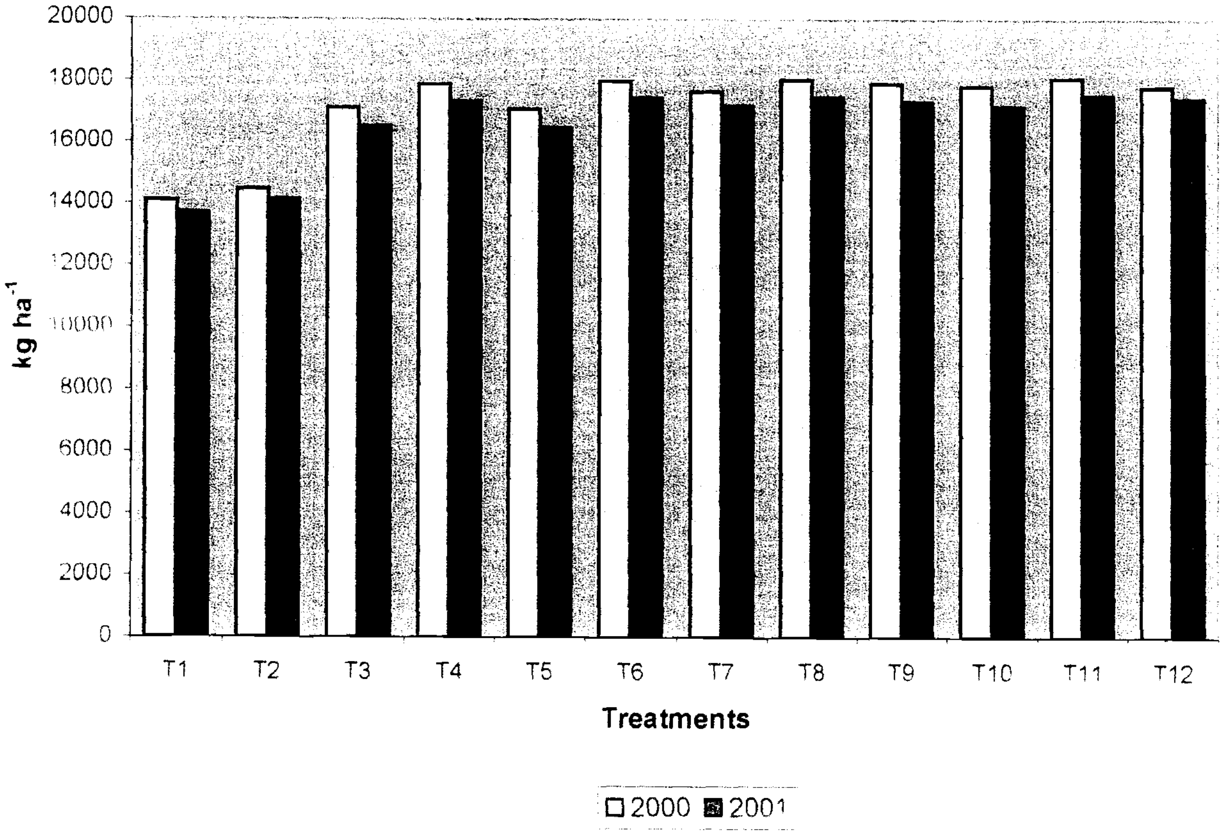


Fig 5.18: Total dry matter production (kg ha^{-1}) of rice-groundnut cropping system as influenced by different nitrogen management practices to rice



reflected in the higher dry matter production of both the crops in the cropping system. The deflated performance of rice crop with application N through exclusive organic sources has been compensated with superior performance of succeeding groundnut resulted from higher residual effect of the above treatments, thus the biological productivity of the entire cropping system as a whole with recommended N management practices was comparable with each other.

5.15 ECONOMIC YIELD OF THE RICE-GROUNDNUT CROPPING SYSTEM

Economic yield of the cropping system was altered to a noticeable extent by different N management practices imposed to *kharif* rice. Economic yield of the cropping system was expressed in terms of rice grain equivalent yield. The highest economic yield of the cropping system was recorded with FYM N_{50} + F N_{50} (T_9) (Fig 5.19), which was however, comparable with all the recommended N management treatments. This indicates that for the entire cropping system the economic yield realized with recommended N application through any source could meet the nutritional demand of the entire system equally. The lower yields of rice with the treatments of higher proportion of organic N has been compensated with higher yields of the succeeding groundnut by enhanced residual N by these treatments and vice versa, thus resulting in comparable realization of economic yield of the rice-groundnut cropping system with different N management practices to *kharif* rice.

5.16 ECONOMICS OF RICE-GROUNDNUT CROPPING SYSTEM

The highest gross returns (Fig. 5.20a & 5.20b) were recorded with FYM N_{50} + F N_{50} (T_9) applied to *kharif* rice, which were comparable with all the recommended N management practices. This was similar to the economic yield of the rice-groundnut cropping system.

Fig 5.19: Rice grain equivalent yield (kg ha^{-1}) of rice-groundnut cropping system as influenced by different nitrogen management practices to rice

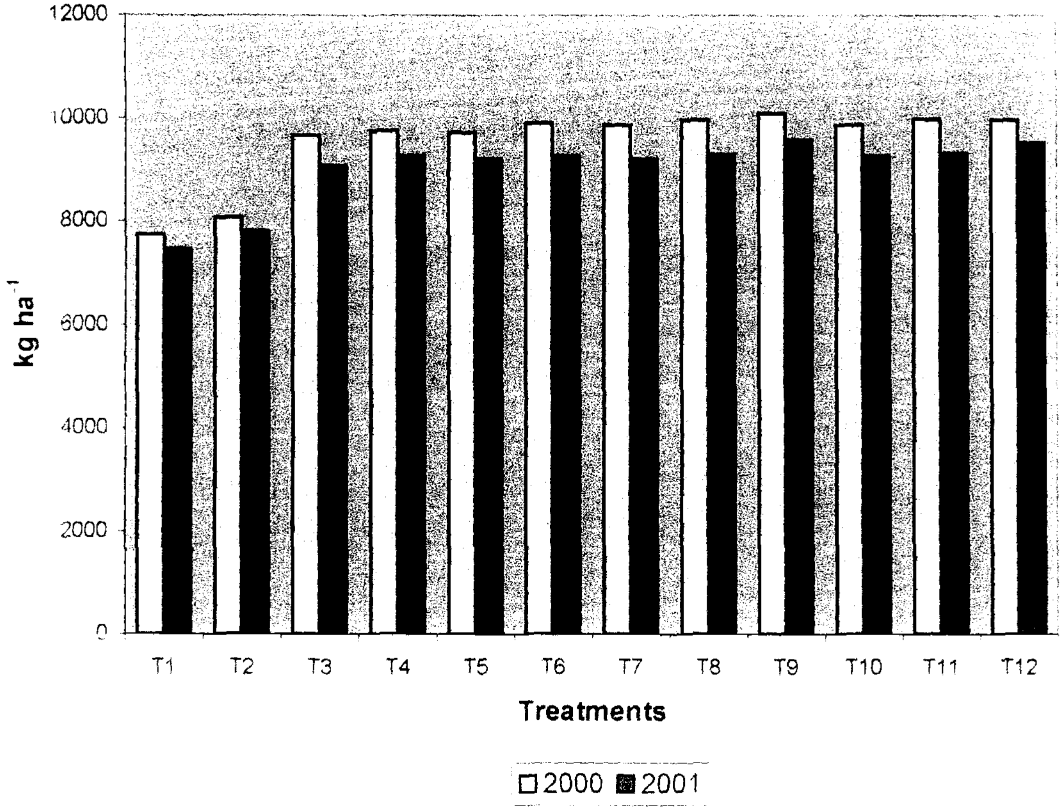


Fig 5.20a: Economics of rice-groundnut cropping system as influenced by different nitrogen management practices to rice - 2000

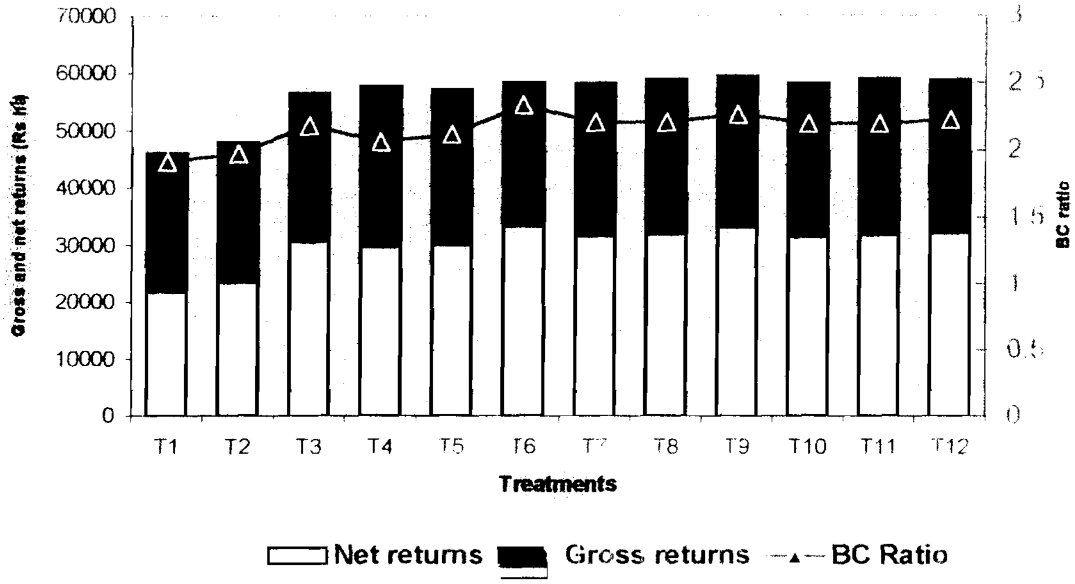
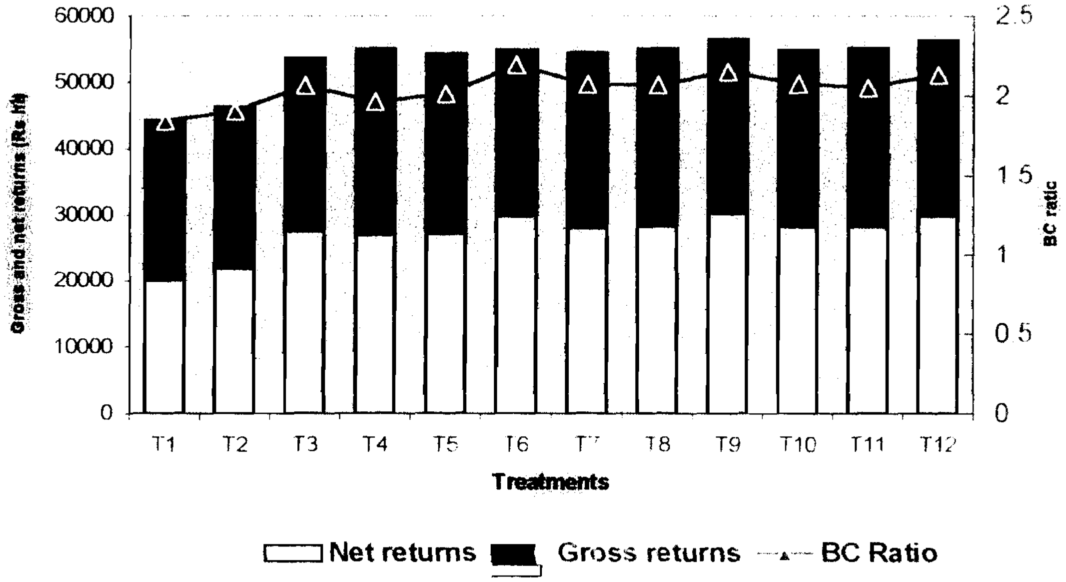


Fig 5.20b: Economics of rice-groundnut cropping system as influenced by different nitrogen management practices to rice - 2001



The highest net returns (Fig. 5.20a & 5.20b) of the cropping system were recorded with application of F N_{100} (T_6) during the first year and with FYM N_{50} + F N_{50} (T_9) during the second year, both of which were of course comparable with all the recommended N management practices, except GLM N_{100} (T_4) and FYM N_{100} (T_5). This was due to higher cost involved in procurement and application of exclusive organic source of N through neem leaf and FYM.

Application of 100 per cent N through fertilizer (T_6) to *kharif* rice has recorded the highest BC ratio (Fig. 5.20a & 5.20b), which was comparable with FYM N_{50} + F N_{50} (T_9) and FYM N_{50}+F N_{50}+*Azo.* (T_{12}). Higher economic yield of the cropping system with reasonable cost of the said N management practices, resulted in increased returns per each rupee invested.

5.17 SOIL FERTILITY DYNAMICS OF RICE-GROUNDNUT CROPPING SYSTEM

The soil organic carbon content tended to increase with each crop of rice and groundnut of the cropping system (Fig. 5.21). The available nitrogen (Fig. 5.22), phosphorus (Fig. 5.23) and potassium (Fig. 5.24) content of the soil tended to increase with the raising of rice crop and decrease marginally with the raising of groundnut crop, with the exception of no N (T_1) and *Azospirillum* alone (T_2), with regard to nitrogen dynamics of soil. The nitrogen balance in the cropping system was negative with the treatments of no N (T_1), *Azospirillum* alone (T_2) and F N_{100} (T_6) imposed to *kharif* rice. All other treatments recorded positive balance of soil available nitrogen in the cropping system, indicating a net gain of soil available nitrogen.

Fig 5.21: Dynamics of soil organic carbon (%) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system

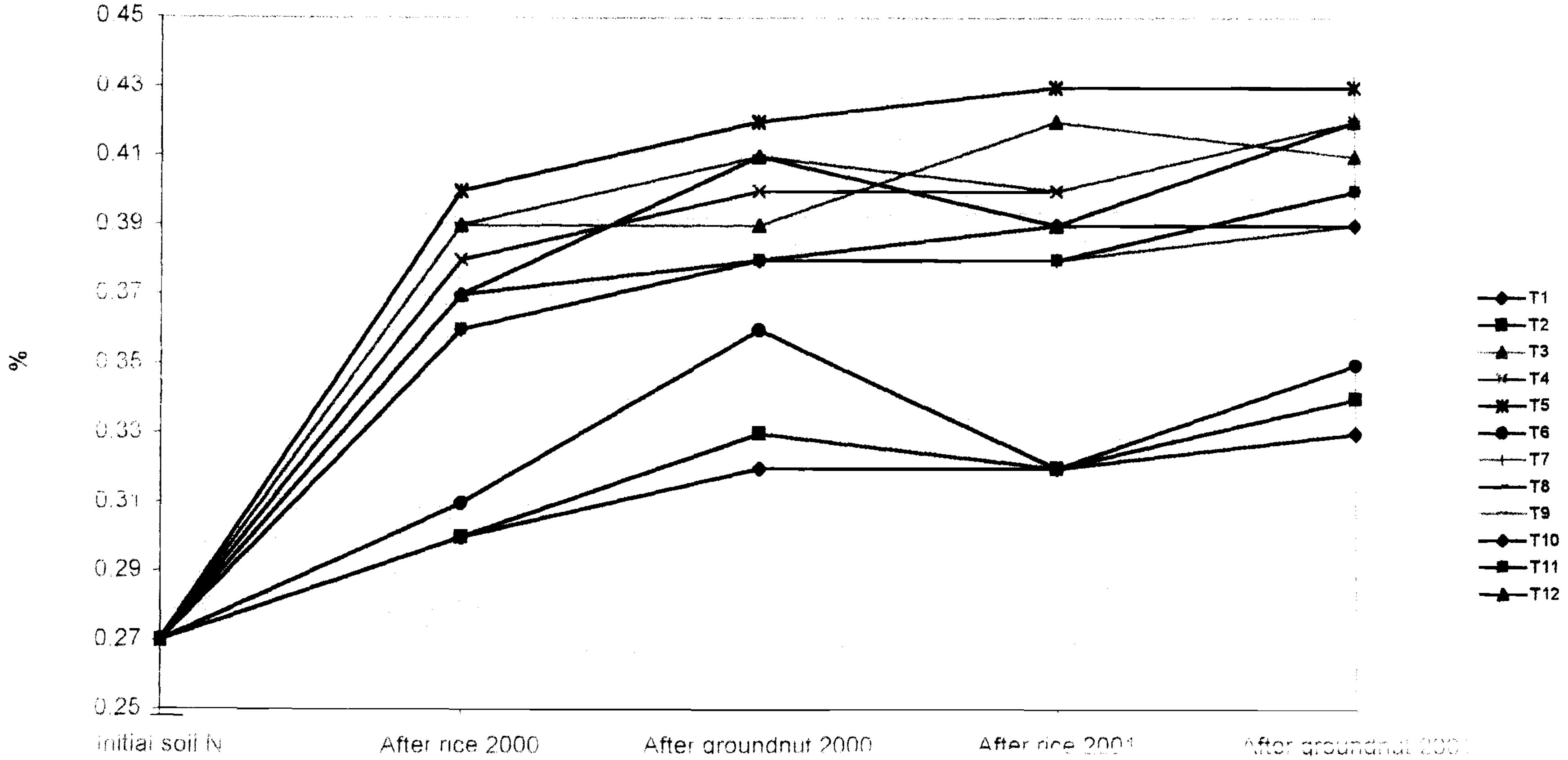


Fig 5.22: Dynamics of soil available nitrogen (kg ha^{-1}) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system

Fig 5.23: Dynamics of soil available phosphorus (kg ha^{-1}) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system

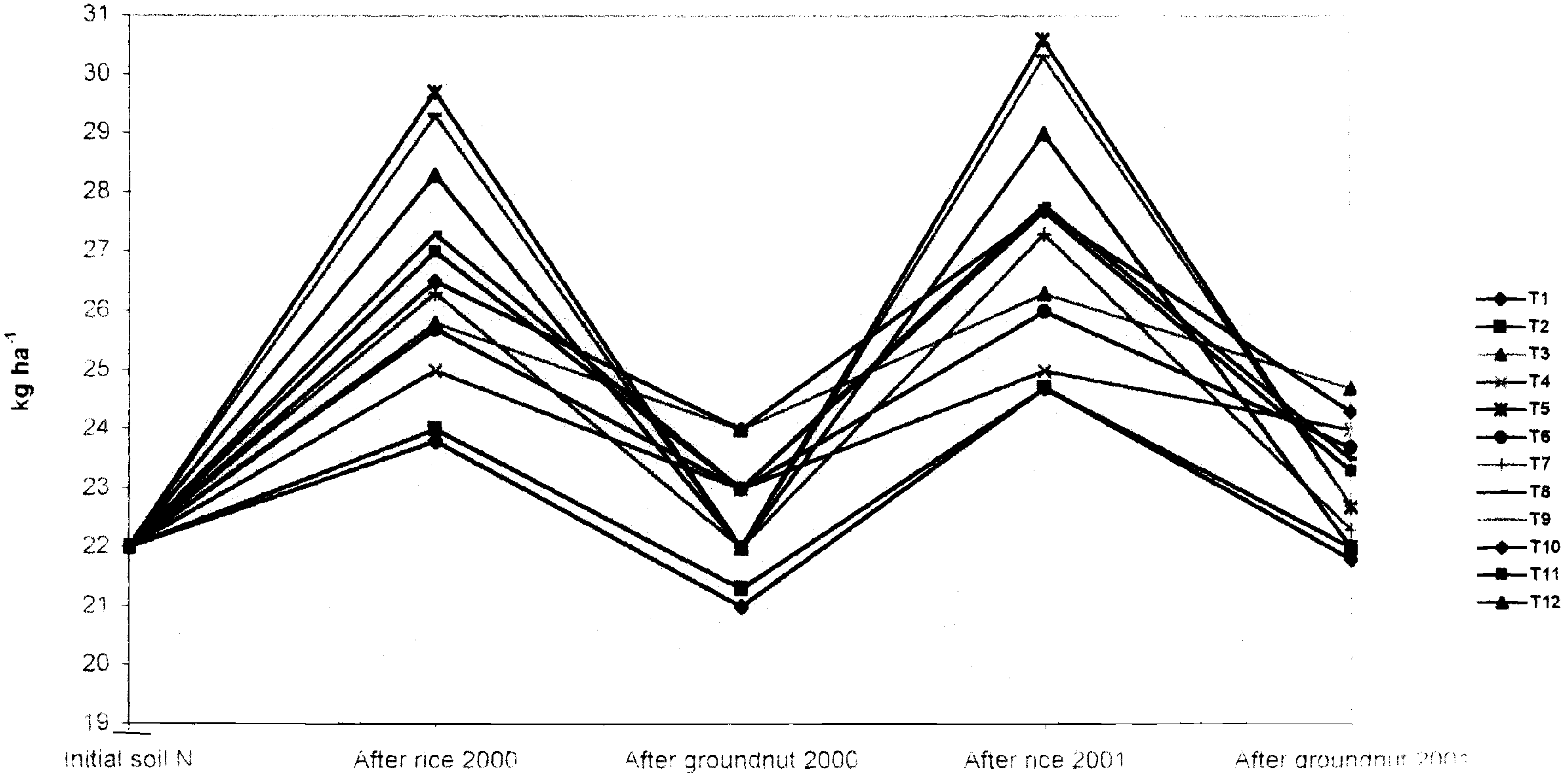
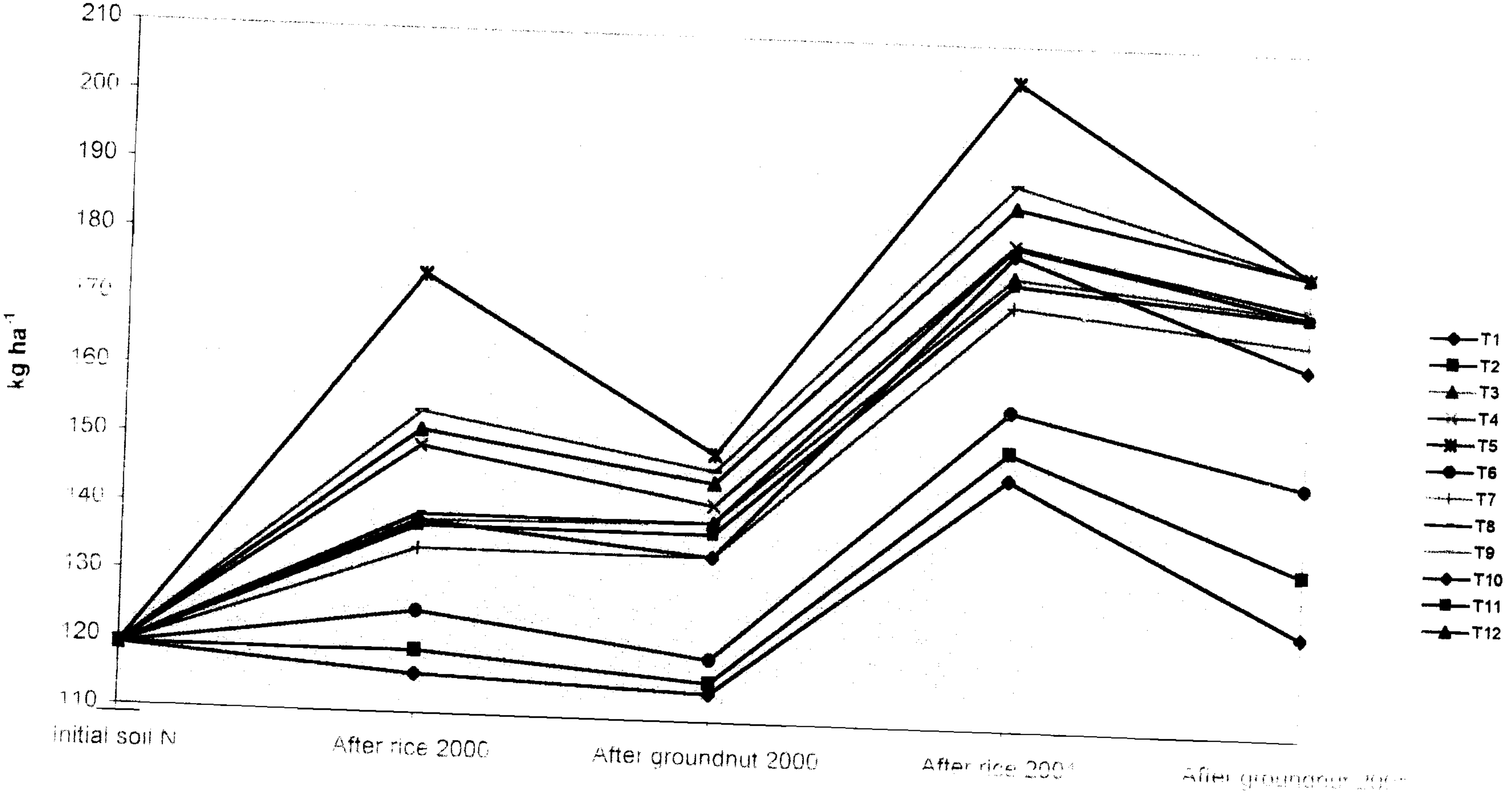


Fig 5.24: Dynamics of soil available potassium (kg ha^{-1}) as influenced by different nitrogen management practices to rice in rice-groundnut cropping system



Substitution of nitrogen through organic manures at higher proportions to rice would undergo decomposition slowly releasing N steadily to meet the crop requirement to certain extent. Even after the growing period of rice is completed, certain quantity of organic manures continue to mineralize nitrogen, which would add to the soil pool. Also, most of the N taken by the low land rice crop would be derived from native soil N pool, a well known fact and has been quoted by many researchers (Kai *et al.*, 1984; Manguiat *et al.*, 1994 and Ponnamperuma and Detruck, 1993). This might be the reason for the marginal increase in soil available nitrogen in the treatments of recommended N application after the harvest of rice crop.

In spite of the possible enrichment of soil with nitrogen due to root nodulation, there was a marginal decrease in available nitrogen after groundnut harvest. This might be due to utilization of nodulated nitrogen by the groundnut crop itself and the nodular efficiency might not have persisted till the later stages of crop growth and also the mineralization of residual organic matter applied to preceding rice might be completed by the time of harvest of groundnut crop. The increase in P and K availability with rice crop and decrease after groundnut crop might be due to reduced condition of soil under submergence with rice cultivation and their fixation with groundnut cultivation.

5.18 OVERVIEW

The present study of prospects of organic farming in rice-based cropping system was aimed at investigating the performance of lowland rice to organic manures and their combinations by adopting different N management practices and their residual effect on the succeeding crop of groundnut. The study revealed the following:

- Supply of 100 per cent N through fertilizer to rice has resulted in better performance of rice crop. However, similar magnitude of performance of rice was noticed with integration of 50 per cent N each through any of the organic sources and fertilizer.

- Application of dhaincha green manure has enriched the rhizo-ecosystem of soil to a greater extent, resulting in production of higher growth parameters at active tillering. However, the effect could not be continued for a long period of crop growth.

- Application of 100 per cent N through FYM has shown lower yield of rice crop and was however, comparable with 100 per cent N through dhaincha and neem leaf manuring, as well as all other N management practice tried.

- Biofertilization with *Azospirillum* did not show any striking impact on the performance of rice crop.

- Supply of 100 per cent N through FYM to *kharif* rice has resulted in better performance of groundnut crop than any other N management practices adopted to preceding rice crop.

- Soil fertility status was found maintained or improved with substitution of either 100 per cent or 50 per cent N through organic manures to rice.

- Drain in soil fertility due to cropping system of rice-groundnut was noticed, with non-supply of N, *Azospirillum* application alone and supply of 100 per cent N only through fertilizer to *kharif* rice.

- Productivity in terms of rice grain equivalent yield of the cropping system was at the best with 50 per cent N each through FYM and fertilizer to rice crop.

- The highest gross returns, net returns and BC ratio of rice were recorded with F N_{100}, while for groundnut, they were with FYM N_{100}. However, for the cropping system as a whole, the highest gross returns were realized with FYM N_{50} +.F N_{50}, the highest net returns were obtained with F N_{100}, during the first year and with FYM N_{50} + F N_{50}, during the second year and the highest BC ratio was recorded with F N_{100}, during both the years of study.

FUTURE LINE OF WORK

Exclusive dependence on high analytical fertilizers had resulted in an array of environmental problems like declining productivity, impoverishment of soil fertility and environmental pollution. The success of future agriculture depends upon the sustainability of production system and one of the important ways to achieve this is to arrest the decline and increase the soil organic matter status. Information presently available on the inclusion of organic manures as substitutes and supplements to fertilizers, in the cropping systems is rather insufficient. Some of the important areas which need to be thoroughly investigated in future are outlined below:

1. The extent of economy of mineral nitrogen to rice through different sources and their residual effect on the succeeding crops need to be quantified by radio-isotope studies.

2. The response of legumes to external as well as residual N and the contribution of N from symbiotic N fixation need to be quantified by radio-isotope investigations.

3. Potentiality of N fixation by different biofertilizers recommended to lowland rice has to be thoroughly researched.

4. The impact of various nutrient interactions especially that of micronutrients with the inclusion of organic manures in higher proportions needs an in depth study.

5. Soil fertility dynamics and nutrient balance has to be assessed under different N management practices with inclusion of various organic manures in rice-based cropping systems through long term studies.

6. Scarce information is available on nutrient recycling through crop residues left in the soil in intensive cropping systems. Fertilizer economy through crop residue management. needs critical analysis.

Chapter VI

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

An experiment on "Conjunctive use of organic and inorganic sources of nitrogen in rice-based cropping systems" was conducted during *kharif* and *rabi* 1999-2000 and 2000-2001 at College Farm, College of Agriculture, Rajendranagar, Hyderabad. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction, low in available nitrogen and phosphorus and medium in available potassium.

The experiment was conducted in a split-plot design with five nitrogen management practices to *kharif* rice *viz*., 25 per cent N through FYM + 75 per cent N through urea, 25 per cent N through FYM + 100 per cent N through urea, 25 per cent N through GLM + 75 per cent N through urea, 25 per cent N through GLM + 100 per cent N through urea and 100 per cent N through urea in main plots and four *rabi* crops (wheat, maize, soybean and groundnut) in sub-plots with four replications.

Observations on number of tillers, DMP, LAI, yield attributes and yield of *kharif* rice and DMP, yield attributes and yield of *rabi* crops were recorded. The economic yields of component crops in rice-based cropping systems were converted into rice grain equivalent yield for comparison. The net monetary returns, B:C ratio, carbohydrate, protein and energy equivalent yields of rice-based cropping systems were worked out. Soil physical (BD) and chemical properties (pH and EC), NPK uptake of component crops and NPK content of soil after *kharif* rice and *rabi* crops were estimated.

The results of the experiment obtained during both the years are summarised below:

- The grain and straw yield of *kharif* rice observed with application of 25 per cent N either through GLM or FYM + 100 per cent N through urea to rice was comparable and significantly higher over all other treatments. The grain and straw yield recorded with application of 100 per cent N through urea to rice was significantly greater than that of 25 per cent N through FYM + 75 per cent N through urea applied to rice.

- The DMP and 1000-grain weight of rice were significantly higher with application of 25 per cent N through GLM + 100 per cent N through urea as compared to 25 per cent N through FYM + 100 per cent N through urea, which inturn recorded significantly higher DMP and 1000-grain weight over that of application of 100 per cent N through urea to rice.

- The harvest index of rice did not vary significantly due to nitrogen management practices to rice.

- The nitrogen, phosphorus and potassium uptake at harvest with application of 25 per cent N through GLM + 100 per cent N through urea to rice was comparable with that of 25 per cent N through FYM + 100 per cent N through urea applied to rice and significantly higher over all other treatments to rice. On the other hand, application of 25 per cent N through FYM + 75 per cent N through urea to rice recorded significantly lower uptake of nitrogen, phosphorus and potassium by rice.

- Significantly higher soil available nitrogen, phosphorus and potassium after harvest of *kharif* rice from the initial soil status was observed with application of 25 per cent N through GLM + 100 per cent N through urea to rice as compared to application of 25 per cent N through FYM + 100 N through urea.
- Soil pH and EC after harvest of *kharif* rice (1999 and 2000) did not differ significantly among N management practices to rice.
- Significantly higher bulk density was observed after harvest of *kharif* rice (2000) with application of 100 per cent N through urea as compared to conjunctive use of organic and inorganic sources of nitrogen to rice. However, the bulk density recorded with application of 25 per cent N either through GLM or FYM + 100 per cent N through urea and 25 per cent N either through GLM or FYM + 75 per cent N through urea to rice was comparable.
- Significantly higher yield of wheat and groundnut were observed with application of 25 per cent N either through GLM or FYM + 100 per cent N through urea as compared to application of 25 per cent N through GLM + 75 per cent N through urea to rice. On the other hand, application of 25 per

cent N through GLM + 100 per cent N through urea resulted in significantly higher yield of maize and soybean as compared to 25 per cent N through FYM + 100 per cent N through urea and 100 per cent N through urea to rice. Application of 25 per cent N through FYM + 75 per cent N through urea to rice recorded significantly lower yield of wheat and maize as compared to application of 25 per cent N through GLM + 75 per cent N through urea to rice. However, it was comparable with 25 per cent N through GLM + 75 per cent N through urea applied to rice in case of soybean and groundnut.

- Application of 25 per cent N either through GLM or FYM + 100 per cent N through urea to rice resulted in significantly higher nitrogen, phosphorus and potassium uptake by wheat, maize, soybean and groundnut as compared to application of 100 per cent N through urea to rice. Application of 25 per cent N through FYM + 75 per cent N through urea to rice recorded significantly lower nitrogen, phosphorus and potassium uptake by wheat, maize, soybean and groundnut as compared to application of 25 per cent N through GLM + 75 per cent N through urea to rice.

- After harvest of *rabi* crops, significantly higher soil available nitrogen, phosphorus and potassium were observed with application of 25 per cent N through GLM + 100 per cent N through urea to rice as compared to application of 25 per cent N through FYM + 100 per cent N through urea to rice which inturn recorded significantly higher soil available NPK over that of 25 per cent N either through GLM or FYM + 75 per cent N through urea and 100 per cent N through urea applied to rice. Significantly lower soil available nitrogen, phosphorus and potassium were observed with application of 100 per cent N through urea to rice as compared to 25 per cent N through FYM + 75 per cent N through urea applied to rice.

- After harvest of *rabi* crops, significantly higher soil available nitrogen, phosphorus and potassium were observed in groundnut over rest of the crops. On the other hand, significantly lower soil available nitrogen was recorded in maize during 1999-2000 and in wheat during 2000-2001 as compared to soybean, while, significantly lower soil available phosphorus and potassium were recorded in wheat as compared to maize and soybean during both the years.
- The soil pH after harvest of *rabi* crops was not significantly influenced by *kharif* rice treatments and *rabi* crops. In 1999-2000, the EC after harvest of *rabi* crops did not differ significantly due to N management treatments to *kharif* rice and *rabi* crops. In 2000-2001, after harvest of *rabi* crops, comparable EC was observed with application of 25 per cent N through FYM + 75 per cent N through urea and 25 per cent N either through FYM or GLM + 100 per cent N through urea to rice.

Significantly higher EC was observed with application of 100 per cent N through urea than that of application of 25 per cent N either through GLM or FYM + 75 or 100 per cent N through urea to rice. The EC values of soil noticed after harvest of groundnut and soybean were comparable and significantly lower than those after wheat and maize.

- After harvest of *rabi* crops, significantly higher bulk density was recorded with application of 100 per cent N through urea to rice over rest of the treatments to rice. The bulk density did not vary significantly with application of 25 per cent N either through GLM or FYM + 75 or 100 per cent N through urea applied to rice. On the other hand, significantly lower bulk density was noticed with application of 25 per cent N through FYM + 75 per cent N through urea to rice. The bulk density observed after harvest of groundnut and soybean was comparable and significantly lower than that observed after harvest of wheat and maize.
- Significantly higher net monetary returns, B:C ratio and rice grain equivalent yield were obtained in rice-maize cropping system as compared to rice-groundnut with application of 25 per cent N through GLM + 100 per cent N through urea than that of 25 per cent N through FYM + 100 per cent N through urea and 100 per cent N through urea applied to rice. On the other hand, significantly lower net monetary returns, B:C ratio and rice grain equivalent yield were recorded in rice-soybean cropping system

as compared to rice-wheat with application of 25 per cent N through FYM + 75 per cent N through urea as compared to 25 per cent N through GLM + 75 per cent N through urea to rice.

- The rice-maize cropping system recorded significantly higher carbohydrate and energy and protein equivalent yields, respectively over rice-wheat and rice-groundnut cropping systems with application of 25 per cent N either through GLM or FYM + 100 per cent N through urea over that of 100 per cent N through urea to rice. On the other hand, significantly lower carbohydrate and energy and protein equivalent yields were noticed in rice-soybean and rice-wheat cropping systems, respectively as compared to rice-groundnut and rice-soybean cropping systems with application of 25 per cent N through FYM + 75 per cent N through urea than that of 25 per cent N through GLM + 75 per cent N through urea applied to rice.

Conclusion:

The results obtained from the investigation indicated that application of 25 per cent N through GLM + 100 per cent N through urea to *kharif* rice and growing maize during *rabi* with recommended dose of fertilizer was more remunerative (in terms of net returns, B:C ratio and rice grain equivalent yield) and sustains soil fertility without depletion. The rice-groundnut cropping sequence showed significant effect in increasing soil fertility over initial soil status and found second best economic crop sequence.

LITERATURE CITED

LITERATURE CITED

Agarwal S K and Sharma S D 1992 Effect of sources of nitrogen on the production of rice. Indian Journal of Agricultural Research 26(2) : 71-76.

Antil R S, Singh D, Kumar V and Singh M 1989 Effect of preceding crops on yield and nitrogen uptake by rice. Indian Journal of Agronomy 34(2) : 213-216.

Aulakh M S and Khera T S 1986 Rice-wheat production with green manuring. In National Seminar on organic farming and sustainable agriculture, University of Agricultural Sciences, Bangalore 122-123.

Badanur V P, Poleshi C M and Naik B K 1990 Effect of organic matter on crop yield and physical and chemical properties of a vertisol. Journal of the Indian society of soil science, 38(3) : 426 – 429.

Balasubramanian P and Palaniappan S P 1991 Effect of high density and fertilizer rate on growth and yield of low land rice. Indian Journal of Agronomy 36(1) : 10-13.

Balasubramanian P, Palaniappan S P and Francis H J 1991 Effect of green manuring and inorganic N and K fertilization on nutrient uptake and yield of lowland rice. Indian Journal of Agronomy 36(2) : 293-295.

Bellakki M A and Badanur V P 1997 Long-term effect of integrated nutrient management on properties of vertisols under dryland agriculture. Journal of the Indian Society of Soil Science 45(3) : 438-442.

Bhagat R K and Singh R S 1998 Crop management in rice-wheat cropping system. Journal of Research (BAU) 10(1) : 30-33

Bhagat R M, Kanwar B B, Verma T S and Minhas R S 1988 Nitrogen economy in low land rice. Oryza 25(3) : 255-260.

Bhandari A L, Sood A, Sharma K N, Rana D S and Anil Sood 1992 Integrated nutrient management in a rice-wheat system. Journal of the Indian Society of Soil Science 40(4) : 742-747.

Bharadwaj V and Omanwar P K 1994 Long term effects of continuous rotational cropping and fertilization on crop yields and soil properties-II. Effects on EC, pH, organic matter and available nutrients of soil. Journal of the Indian Society of Soil Scinece 42(3) : 387-392

Biswas B C, Yadav D S and Maheshwari S 1987 Fertilizer use in cropping system. Fertilizer News 32(3) : 23-35.

Black G R 1965 Bulk density. In: Methods of soil analysis ed by Black C A *et al.* Part-I Agronomy 9 : 374-390.

Blaise D and Rajendra Prasad 1996 Relative efficiency of modified urea fertilizers in wet land rice (*Oryza sativa*). Indian Journal of Agronomy 41(3) : 373-378.

*Boparai B S, Yadvinder Singh and Sharma B D 1992 Effect of green manuring with *Sesbania aculeata* on physical properties of soil and on growth of wheat in rice - wheat and maize - wheat cropping systems in a semi arid region of India. Arid - Soil - Research and Rehabilitation 6 : 135-143.

*Bouldin D R 1987 The effect of green manure on soil organic matter content and nitrogen availability to crops. Paper presented at the Symposium on Sustainable Agriculture, the role of green manure crops in rice farming system. May 25-29. International Rice Research Institute, Manila, Los Banos, Philippines pp. 105.

Brar B S, Dhillon N S and Milap Chand 1985 Effect of farm yard manure application on grain yield and uptake and availability of nutrients in rice (*Oriza sativa*) wheat (*Triticum aestivum*) rotation. Indian Journal of Agricultural Sciences 65(5) : 350-353.

Budhar M N and Palaniappan S P 1997 Integrated nutrient management in low land rice. Indian Journal of Agronomy 42(2) : 269-271.

Budhar M N, Palaniappan S P 1994 Effect of method of incorporation of green manure in low land rice. Indian Journal of Agronomy 39(3) 459-461.

Budhar M N, Palaniappan S P and Rangaswamy A 1991 Effect of farm wastes and green manures on low land rice. Indian Journal of Agronomy 36(2) : 251-252.

Buresh R J and De Datta S K 1991 Nitrogen dynamics and management in rice-legume copping systems. Advances in Agronomy 45 : 1-59.

Chakravorti S P and Chalam A B 1992 Integrated management of organic and urea nitrogen for rice (*Oryza sativa*) under flooded condition. Indian Journal of Agricultural Sciences 62(8) : 535-539.

Chaphale S D and Badole W P 1999 Effect of green manuring and NPK combinations on soil health and yield of rice. Indian Journal of Agronomy 44(3) : 448-451.

Chaudhary M L and Bathla 1985 Phosphate management for higher productivity. In: University Professors (IFFCO Chair) meet, Udaipur, 26 August, pp. 1-12.

Chaudhary M L, Singh J P and Narwal R P 1981 Effect of long term application of P, K and FYM on some soil chemical properties. Journal of the Indian Society of Soil Science 29 : 81-85.

Chhonkar P K and Rattan R K 2000 Soil fertility management for sustainable agriculture. Indian Farming 50(2) : 26-31.

Darra BL, Jain S V and Uzzaman Q 1968 The influence of different green manure crops on soil structure and wheat yield. Indian Journal of Agronomy 13(3) : 162-164.

Das P C 1999 Manures and fertilizers. Kalyani Publishers, Ludhiana-141 008.

Dastane N G 1972 A practical manual for water use research in agriculture. Navabharat Prakasham, Poone.

Deka J C and Singh Y 1984 Studies on rice-based multiple crop sequence-II. Effect of crop rotations on fertility status of soil. Indian Journal of Agronomy 29(4) : 441-447.

Deshpande V 1985 Studies on properties of soil under upland crops following submerged paddy. M.Sc. (Ag) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Dhane S S, Khadse R R, Patil V H, Joshi R G and Savant N K 1991 Agroforestry approach of *Glyricidia* green manuring integrated with use of urea super granules for transplanted rice. Oryza 28(3) : 333-338.

Donahue R L, Miller R W and Shickluna J C 1977 Soil-An introduction to soils and plant growth. Prentice Hall, New York.

Duraisamy V K and Palaniappan S P 1989 Evaluation of urea-gypsum as a source of nitrogen to low land rice. Madras Agricultural Journal 76(8) : 440-453.

Dwivedi D K and Thakur S S 2000 Production potential of wheat (*Triticum aestivum*) crop as influenced by residual organics, direct and residual fertility levels under rice (*Oryza sativa*) – wheat cropping system. Indian Journal of Agronomy 45(4) : 641-647.

EIS 2000 Economic Intelligence Service. Centre for Monitoring Indian Economy Private Limited (CMIE), Mumbai 92-196.

Ganai B A and Singh C M 1988 Effect of farm yard manure applied in rice-wheat rotation on physico – chemical properties of soil. Indian Journal of Agronomy 33(3) : 327-329.

Gill H S, Singh Tarlok and Rana D S 1994 Integrated nutrient management in rice-wheat cropping sequence in semi-arid tropics. Indian Journal of Agronomy 39(4) : 606-608.

Gopalan C, Rama Sastri B V and Balasubramanian S C 1989 Nutritive value of Indian foods. National Institute of Nutrition. Indian Council of Medical Research, Hyderabad 47-58.

*Gu R S and Wen Q X 1981 Cultivation and application of green manure in paddy fields of China. In: Proceeding of Symposium on Paddy. Soil Science Press, Beijing, Springer - Verlag, New York. pp. 207-219.

*Guar A C 1984 Response of rice to organic matter - The Indian experience. In organic matter and rice. International Rice Research Institute, Los Banos, Philippines pp. 503-516.

*Guo Yi-Xian 1982 The rice-based cropping system and its development in China. In Report of a workshop on cropping systems research in Asia. International Rice Research Institute, Los Banos, Philippines pp 331-334.

Halepyati A S and Sheelavantar M N 1990 *Sesbania rostrata* a new green manure for rice. Indian Journal of Agronomy 35(3) : 279-282.

Halepyati A S and Sheelavantar M N 1992 Effect of phosphorus application to *Sesbania rostrata* and nitrogen substitution rate on NPK content of rice (*Oryza sativa*) soil. Indian Journal of Agronomy 37(1) : 22-25.

Halepyati A S and Sheelavantar M N 1993 Effect of incorporation of different densities of *Sesbania rostrata* and nitrogen substitution rates on growth and yield of rice. *Oryza* 30(1) : 67-72.

Hari Prasad M 1993 Relative efficiency of organics in a rice-legume cropping system. M.Sc.(Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Haroon A R M, Krishnasamy R, Velu V, Jawahar D and Ramaswami P 1992 Integrated N management for irrigated lowland rice. International-Rice-Research News Letter 17(2) : 19-20.

Hearn A B 1986 Effect of preceding crop on the nitrogen requirements of irrigated cotton (*Gossypium hirsutum* L.) on a vertisol. Field Crops Research 13(2) : 159-175.

Hegeman N R and Shrader W D 1979 Effects of crop sequence and N fertilizer levels on soil bulk density. Agronomy Journal 71(6) : 1005-1008.

IRRI 1984 International Rice Research Institute. Annual Report for 1984. Los Banos, Philippines pp. 414-415.

Jackson M L 1973 Soil Chemical Analysis. Prentice Hall of India Private Limited, New Delhi.

Jadhav A D, Talashilkar S C and Powar A G 1997 Influence of the conjunctive use of FYM, vermicompost and urea on growth and nutrient uptake in rice. Journal of Maharashtra Agricultural Universities 22(2) : 249-250.

Jana M K and Ghosh B C 1996 Integrated nutrient management in rice (*Oryza sativa*) - rice crop sequence. Indian Journal of Agronomy 41(2) : 183-187.

Jawale S M, Jadhav A S and Patil V G 1998 Productivity and economics of legumes winter sorghum (*Sorghum bicolor*) double cropping systems under tillage practices in western Maharashtra. Indian Journal of Agronomy 43(3) : 396-403.

Jena D, Pradhan N K, Pani B K and Senapati P C 2000 Long-term effect of integrated nutrient management on properties of an Alfisol and rice yield under dryland agriculture. Indian Journal of Dryland Agricultural Research and Development 15(1) : 37-41.

Jeyaraman S and Purushothaman S 1988 *Leucaena* as leaf manure for low land rice. International Rice Research News Letter 15(5) : 17-18.

*Jiao B, Gu and Zhang X 1986 Chinese green manure Publishing House of Agriculture, Beijing, China.

*Jin H H 1984 A preliminary discussion on the role of the green manure crop - rice - rice system in rice production. Shanghai Agricultural Science and Technology 1 : 28-29.

Johnkutty I and Anilakumaran K 1991 Integrated nutrient supply improves physical, electro-chemical and biological properties of submerged rice soils. Farmer and Parliament 26(12) : 11-12.

Joseph K, Menon P K G and Anilakumar K 1991 Studies on the comparative efficiency of nitrogen sources on lowland rice. Indian Journal of Agronomy 36(1) : 122-137.

*Kachapur M D 1997 Integrated nutrient management in cereals. Lecture delivered in a course on Role of Organics in Sustaining Soil Fertility and Crop Productivity. Directorate of Research, University of Agricultural Sciences, Dharwad 185-196.

Karunasagar G and Ramasubba Reddy G 1992 Effect of different forms of urea levels and time of application of nitrogen on growth and yield of rice. Oryza 29(4) : 376-378.

Khan G, Gupta S K and Banerjee S K 1984 Studies on the solubilization of phosphorus in presence of different city wastes. Journal of the Indian Society of Soil Science 29 : 123-124.

Khan S K, Mohanty S K and Chalam A B 1986 Integrated management of organic manure and fertilizer nitrogen for rice. Journal of the Indian Society of Soil Science 34(6) : 505-509.

Khoi B X, Sharma G L and Mahapatra B S 1999 Economic feasibility of rice-based cropping systems under different nitrogen management. Journal of Andaman Science Association 15(1) : 24-29.

*Kiselev A N 1955 Soil structure and the conditions of its formation. Pochvovedenie No. 10 : 11-22.

Krishna A and Reddy K A 1997 Production potential and economics of different rice (*Oryza sativa*) - based cropping systems in Andhra Pradesh. Indian Journal of Agricultural Sciences 67(12) : 551-553.

Kulkarni K R and Pandey R K 1988 Annual legumes for food and as green manures in a rice based cropping system. In: Sustainable agriculture green manure in rice farming: International Rice Research Institute, Manila, Philippines. pp. 289-299.

Kulkarni K S and Kulkarni M V 1982 Complementary use of farm yard manure and chemical fertilizers in intensive crop production. Fertilizer News 27(10) : 44-51.

Kulkarni K S, Shirwal A S and Kulkarni M V 1983 Economy of fertilizer through use of farm yard manure in rice-rice cropping system. Fertilizer News 28(3) : 27-29.

Kumar B V and Reddy K A 1991 Rice based cropping for Andhra Pradesh. International Rice Research News Letter 16: 23.

Kumar K A and Mathew J 1994 Timing of green leaf manuring in presence and absence of liming on growth, yield and nutrient uptake in transplanted rice (*Oryza sativa*). Indian Journal of Agronomy 39(4) : 630-633.

Kumar V J, Usha Kumari K, Nair C Sundaresan, Pushpakumari R and Nair V Ramachandran 1993 Economics of high intensity crop sequences in a rice-based cropping system. Oryza 30(4) : 302-304

*Liu C 1988 Integrated use of manure in rice fields in south China. In: Sustainable agriculture: green manure in rice farming. International Rice Research Institute, Los Banos, Manila, Philippines pp. 165-183.

Mahapatra B S and Sharma G L 1996 Contribution of *seshania* species to yield and nitrogen nutrition in low land rice (*Oryza sativa*). Indian Journal of Agronomy 41(2) : 226-229.

Mahapatra B S, Sharma K C and Sharma G L 1987 Effect of bio, organic and chemical N on yield and N uptake in rice and their residual effect on succeeding wheat crop. Indian Journal of Agronomy 32(1) : 7-11

Mahapatra B S, Sharma K C and Sharma G L 1991 Nitrogen fertility under rice - wheat - fallow system with integrated nitrogen management in lowland rice. Indian Journal of Agronomy 36(3) : 223-227.

Mahapatra I C, Pillai K G, Bhargavan P N and Jain H C 1981 Fertilizer use in rice - rice cropping system. Fertilizer News 26 : 3-15.

Mahapatra P, Panda M M, Chalam A B, Chakravorti S P and Mohanty S K 1997 Effect of green manuring and N fertilization on the yield and nitrogen use efficiency of wetland rice. Journal of the Indian Society of Soil Science 45(1) : 95-98.

Manguiat I J, Guinto D F, Perez A S and Pintor R M 1992 Response of rainfed low land rice to green manuring with *Sesbania rostrata*. Tropical Agriculture 69(1) : 73-75.

Mani S, Kothandaraman and Krishnamoorthy K K 1980 A note on the accumulation of organic matter in rice soils. Madras Agricultural Journal 67(11) : 767-768.

Maskina M S, Bijay Singh, Yadvinder Singh and Meelu O P 1989 Integrated N management with green manures in rice-wheat system. Oryza 26 : 358-362

Maskina M S, Yadvinder Singh and Singh B 1987 Wheat straw management for rice on a coarse textured soil. International Rice Research News Letter 12(2) : 40.

Matiwade P S and Sheelavantar M N 1994a Influence of green manuring of *Sesbania rostrata* on rice (*Oryza sativa*). Indian Journal of Agronomy 39(1) : 19-22.

Matiwade P S and Sheelavantar M N 1994b Growth analysis of rice as influenced by green manuring with *Sesbania rostrata*. Oryza 31(3) : 196-198.

Meelu O P and Morris R A 1984 Integrated nutrient management of plant nutrients in rice-based cropping system. Fertiliser News 29 : 65-70.

Meelu O P and Rekhi R S 1981 Fertilizer use in rice-based cropping systems in Northern India. Fertilizer News 26 : 16-22.

Mehta H D, Ahlawat I P S, Chaudhary P P and Jadhav Y R 1996 Effect of green - manuring on nitrogen management in lowland rice (*Oryza sativa*). Indian Journal of Agronomy 41(1) : 38-40.

Mirza W A and Reddy S N 1989 Performance of modified urea materials at graded levels of nitrogen under experimental and farmer's management conditions in low land rice. Indian Journal of Agricultural Sciences 59(3) : 154-156.

Mishra K and Sharma R B 1997 Effect of fertilizers alone and in combination with manure on physical properties and productivity of Entisol under rice based cropping systems. Journal of the Indian society of soil science 45(1) : 84-88

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

Mitra G N, Sahu S K and Parida S K 1992 Integrated nutrient management of rice - groundnut cropping system in Aeric Haplaquepts. Indian Journal of Agricultural Sciences 62 : 391-394.

Mohanty S K, Bhadrachalam A and Samantary R N 1992 Long term nutrient management effects on soil chemical properties and sustainability of rice-rice system. Paper presented in ICAR-IRRI Seminar on Long Term Nutrient Management Strategy for Sustainable Productivity of Rice-based Cropping Systems. Indian Agricultural Research Institute. New Delhi 14-17 December.

Muthuvel P, Kandaswamy P and Krishnamoorthy K K 1979 Soil pH, electrical conductivity and CEC under long term Fertilization. Madras Agricultural Journal 66(5) : 296-299.

Nanda K K and Roy P K 1991 Changes in some soil physical properties due to long term application of manures and fertilizers. Journal of Research (BAU) 3(2) : 145-150.

Narang R S, Cheema S S, Grewal D S, Grewal H S, Sharma B D and Dev G 1990 Yield, nutrient removals and changes in soil fertility under intensive rice-wheat cropping system. Indian Journal of Agronomy 35(1&2) : 113-119.

*Olsen S R, Cole C V, Watanabe F S and Dean L A 1954 Estimation of phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture, Circular 939, USDA, Washington DC.

Panda S C, Patro H, Panda P C and Reddy G M V 1999 Effect of integrated nitrogen management on rice yield and physico-chemical properties of soil. Crop Research 18(1) : 25-28

Pandian P S and Perumal R 1994 Integrated nitrogen nutrition in rice. Oryza 31(2) : 123-126.

Panjab Singh 2001 Fight hunger to reduce poverty – 2001. Indian Farming 51(7) : 4.

Panse V G and Sukhatme P V 1985 Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi.

Papi Reddy C H 1997 Studies on effect of pre-*kharif* sole/dual legume green manures and rice based cropping systems on soil fertility and physical aspects of substainable soil productivity. Ph.D. thesis submitted to Acharya N.G. Ranga Agricultural University, Hyderabad.

Parida R C, Sahoo D and Mitra G N 1995 Effect of nutrient imbalance on grain yield and protein content of wet land rice. Journal of Potassium Research 11(3-4) : 302-306.

Parihar S S, Shukla R K, Pandey D and Sharma R B 1996 Effect of method of tillage and soil amendments on yield of wheat in rice-based cropping system. Advances in Plant Sciences 2(9) : 121-123.

Patra A K, Nayak B C and Mishra M M 2000 Integrated nutrient management in rice-wheat cropping system. Indian Journal of Agronomy 45(3) : 453-457.

Patra G K, Mohanty K and Jena B K 1988 A role on relative efficiency of various rice-based cropping patterns at Bhubaneswar (Orissa). Journal of Farming Systems 4 : 96-98.

Paulraj N J and Velayudham K 1995 Direct and residual effect of Mussoorie rock phosphate, organic manures and phosphobacteria in rice – black gram system. Madras Agricultural Journal 82(3) : 220-221.

Pillai K G 1981 Agronomic practices to improve the nitrogen use efficiency of rice. Fertilizer News 26 : 3-8.

Piper C S 1966 Soil and Plant Analysis. Hans Publishers, Bombay.

Powar S L, Mehta V B and Patil K D 1995 Increasing nitrogen use efficiency in rice through modified urea materials in coastal saline soils. Current Agriculture 19(1-2) : 55-57.

Pradhan B K and Mondal S S 1997 Integrated nutrient management for sustaining productivity and fertility building of soil under rice (*Oryza sativa*)-based cropping system. The Indian Journal of Agricultural Sciences 67(6) : 307-310.

Prakash V, Singh P and Bhatnagar V K 1989 Rice-based cropping sequences for rainfed conditions in mid hills of Uttar Pradesh. International Rice Research News Letter 14(2) : 40-41.

Prasad B 1994 Integrated nutrient management for sustainable agriculture. Fertilizer News 39(9) : 19-25.

Prasad P V N 2000 Nitrogen management for rice-based cropping systems of coastal Andhra Pradesh. Ph.D. Thesis submitted to Acharya N.G. Ranga Agricultural University, Hyderabad.

Pratibha G, Pillai K G and Satyanarayana V 1998 Effect of tillage induced physical edaphic properties in relation to crops after puddled rice (*Oryza Sativa*). Indian Journal of Agricultural Sciences 68(2) : 62 - 65.

Purushotham S, Chandrasekharaiah A M and Kulkarni K R 1988 Fertilizer management in a crop sequence of paddy-paddy under irrigation in Chitradurga District. The Mysore Journal of Agricultural Sciences 22(3) : 314-317.

Purushothaman S, Jeyaraman S and Sudhakar P 1990 Effect of *Leucaena* and *Parthenium* as green manure on rice. The Mysore Journal of Agricultural Science 24(4) : 429-432.

Puste A M, Mandal N N and Ghosh A 1992 Influence of growth regulating substances and N levels on the yield of low land rice. Oryza 29(3) : 267-269.

Puste A M, Mandal S S, Bandopadhyay S and Sounda G 1996 Effect of integrated fertilizer management in conjunction with organic matter on the productivity of rainfed transplanted rice. Paper presented at the National Seminar on Organic Farming and Sustainable Agriculture, Bangalore, 9-11 October.

Rabeya Khanam, Sahu S K and Mitra G N 1997 Yield maximisation of rice through integrated nutrient management on aeric ustochrept. Journal of the Indian Society of Soil Science 45(2) : 396-397.

Rabindra B, Naidu B S, Devi G and Gowda N S 1989 *Sesbania rostrata* a low cost source of N for rice. International Rice Research Newsletter 14(2) : 27-29.

Radha Madhav M, Ravi Kumar A and Venkateswarlu B 1996 Effect of different sources of nitrogen on growth, yield and nutrient uptake of rice. The Andhra Agricultural Journal 43(2-4) : 119-122.

Rajendra Prasad T V P 1985 Management of pulses in rice-based cropping system. M.Sc. (Ag) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.

Rajeswari C 1990 Studies on the effect of seed rate and method of sowing two green manures on succeeding rice. M.Sc. (Ag) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.

Rajkhowa D J and Baroova S R 1994 Organic recycling in transplanted rice. Annals of Agricultural Research 15(1) : 120-121.

Rajput A L 1995 Effect of fertilizer and organic manure on rice (*Oryza sativa*) and their residual effect on wheat (*Triticum aestivum*). Indian Journal of Agronomy 40(2) : 292-294.

Rajput A L and Warsi A S 1991 Contribution of organic materials to nitrogen economy in rice (*Oryza sativa*) production. Indian Journal of Agronomy 36(3) : 455-456.

Raju R A and Reddy M N 2000 Sustainability of productivity of rice (*Oryza sativa*) rice sequential cropping system through integrated nutrient management in coastal ecosystem. Indian Journal of Agronomy 45(3) : 447-452.

Raju R A, Reddy K A and Reddy M N 1993 Integrated nutrient management in wet land rice (*Oryza sativa*). Indian Journal of Agricultural Sciences 63 : 786-789.

Ram D N and Zwernman P J 1960 Influence of management systems and cover crops on soil physical conditions. Agronomy Journal 52 : 473-476.

Ramaiah N V, Raghavaiah R, Reddy S N, Raju M S and Singh B G 1987 Effect of time of planting and nitrogen on growth, yield and uptake of nitrogen in rice. The Andhra Agricultural Journal 34(1) : 1-4.

Ramana V M 1994 Integrated nutrient management in wet land rice. Ph.D. Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Ramaseshaiah K, Yogeswara Rao Y and Bheemaiah G 1985 Fertilizer requirements of groundnut grown in sequence with rice. The Indian Journal of Agricultural Sciences 55 (1) : 25-27.

Rao K S 1983 Water management of light irrigated crops after *kharif* Paddy in light soils. Ph.D. Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Rathore A L, Chipde S J and Pal A R 1995 Direct and residual effect of bio-organic and inorganic fertilizer in rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system. Indian Journal of Agronomy 40(1) : 14-19.

Rathore A L, Patel S L and Pali G P 1993 Integrated nitrogen management with green manures in rice-chickpea cropping system. Journal of Agronomy and Crop Science 170(3) : 158-162.

Roy H K, Ajay Kumar, Sarkar A K, Prasad R, Dubey S C and Kumar A 1997 Yield, nutrient uptake, pest and disease incidence in upland rice as influenced by N, K and FYM application in acid sedentary soils. Journal of Potassium Research 13(2) : 131-136.

Sadanandan N and Mahapatra I C 1973a Studies on multiple cropping - balance sheet of nitrogen in various cropping patterns. Indian Journal of Agronomy 18 : 321-327.

Sadanandan N and Mahapatra I C 1973b Studies on multiple cropping - balance sheet of total and available phosphorus in various cropping patterns. Indian Journal of Agronomy 18 : 459-463.

Sadanandan N and Mahapatra I C 1974 Studies on multiple cropping - balance sheet of total and exchangeable potassium in soils in various cropping patterns. Indian Journal of Agronomy 19 : 138-140.

Sahu P N, Padhi A K and Hota A K 1988 A rice grain legume system for South Coastal Orissa, International Rice Research Newsletter 13 : 46.

Santhy P, Muthuvel P, Murugappan V and Selvi D 1998 Long term effects of continuous cropping and fertilization on crop yields and soil fertility status. Journal of the Indian Society of Soil Science 46(3) : 391-395.

Saravanan A, Velu V and Ramanathan K M 1987 Effect of combined application of bio-organic and chemical fertilizers on physio-chemical properties, nitrogen transformation and yield of rice in submerged soils of cauvery delta. Oryza 24(1) : 1-6.

Saravanan A, Velu V and Ramanathan K M 1986 Effect of combined application of bioorganic and chemical fertilizer on physio-chemical properties, nitrogen transformation and yield of rice in submerged soils of cauvery delta. Oryza 24 : 1-6.

Selvi S and Ramaswami P P 1995 Residual effect of integrated nutrient management in rice-rice-pulse cropping sequence. Madras Agricultural Journal 82(1) : 24-26.

Setty R A and Channabasavanna A S 1990 Fertilizer management in rice-rice sequence in Tungabhadra command area. Oryza 27(4) : 461-464.

SFI 1980 Soil and Fertilizer Institute. Guangdong Academy of Agricultural Sciences, Sesbania Publishing House of Agriculture, Beijing, China pp. 41-43.

Shankarnarayana H S and Mehta B V 1967 Soil structure studies in chambal-command area of Rajasthan. Journal of the Indian Society of Soil Science 15 : 77-88.

Sharma A R and Mittra B N 1990 Complimentary effect of organic, bio and mineral fertilizers in rice-based cropping system. Fertilizer News 35(2) : 43-44.

Sharma A R and Mittra B N 1992 Integrated nitrogen management in rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system. The Indian Journal of Agricultural Sciences 62(1) : 70-72.

Sharma G D and Sharma H L 1994 Utilization of weed plants as organic manure under different methods of rice (*Oryza sativa*) establishment. Indian Journal of Agricultural Sciences 64(3) : 184-186.

Sharma H L, Singh C M and Modgal S C 1987 Use of organics in rice-wheat crop sequence. The Indian Journal of Agricultural Sciences 57(3) : 163-168.

Sharma M P, Bali S V and Gupta D K 2001 Soil fertility and productivity of rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system in an Inceptisol as influenced by integrated nutrient management. Indian Journal of Agricultural Sciences 71(2) : 82-86.

Sharma R A 1992 Influence of integrated fertility management on productivity and water use efficiency of rainfed soybean. Crop Research 5 : 52-58.

Sharma R K, Shrivastava U K, Suresh S T, Tiwari P N and Yadav R P 1999 Nutrient management in soybean (*Glycine max*)-mustard (*Brassica juncea*) crop sequence. Indian Journal of Agronomy 44(3) : 493-498.

Sharma S N, Singh S and Prasad R 1990 Relative response of short and medium duration rice to rate and time of nitrogen application. Indian Journal of Agronomy 35(4) : 442-446.

Shashi Kumar G S, Reddy S N and Ikramullah Mohd 1995 Effect of age of seedling and nitrogen level on performance of rice under late planting. Indian Journal of Agricultural Sciences 65(5) : 354-355.

Shinde S N 1995 Effect of green manuring on yield, yield attributes and nitrogen economy in lowland rice. Journal of Maharashtra Agricultural Universities 20(3) : 482-483.

Singh G R, Prasad J and Parihar S S 1998 Integrated nutrient management in rice - wheat crop rotation. Advances in Plant Sciences 11(1) : 175-178.

Singh I D and Stoskopf N C 1971 Harvest index in cereals. Agronomy Journal 63(2) : 224-226.

Singh M P and Varma S C 1989 Effect of rate of nitrogen and slow release materials on yield and harvest index of dwarf indica rice variety Jaya. Annals of Agricultural Research 10(1) : 30-33.

Singh N T 1984 Green manures as sources of nutrients in rice production. In: Organicmatter and rice. International Rice Research Institute. Los Banos. Philippines pp. 217-218.

Singh S B, Srivastava R K, Giri S P and Yadav I S 1998 Path co-efficient analysis of indigenous rice (*Oryza sativa*) cultivars of Uttar Pradesh. Journal of Living World 5(2) : 38-43.

Singh Y, Chaudhary D C, Singh S P, Bhardwaj A K and Singh Dheer 1996 Sustainability of rice-wheat sequential cropping through introduction of legume crops and green manure crop in the system. Indian Journal of Agricultural Sciences 63(20) : 644-646.

Singha D D, Sarma N N and Sarma A 1993 Effect of rice (*Oryza sativa*)-based cropping sequences on soil-chemical properties and available nutrients. Indian Journal of Agricultural Sciences 63(10) : 644-646.

Sinsinwar B S 1995 Nitrogen management in rice-based food and fodder production system. Indian Journal of Agronomy 40(3) : 349-352.

Soni P N and Sikarwar H S 1983 Nitrogen substitution with farm yard manure in rice-wheat sequence. Indian Journal of Agronomy 28 : 392-396.

Subbiah B V and Asija G L 1956 A rapid procedure for estimation of available nitrogen in soils. Current Science 25 : 259-260.

Sujathamma P 1996 Nitrogen management in cereal legume cropping system. M.Sc.(Ag.) Thesis submitted to Acharya N.G. Ranga Agricultural University. Hyderabad.

Sujathamma P 2000 Sustainable nitrogen management in a rice-based cropping system. Ph.D. Thesis submitted to Acharya N.G. Ranga Agricultural University, Hyderabad.

Sushma Kumari P, Pillai, Bala Krishna K, Sunitha Kumari S and Vasavan M G 1989 Effect of organic matter on soil fertility. Agricultural Research Journal Kerala 27 : 23-26.

Syed Nazeer Peeran and Sree Ramulu U S 1995 Influence of urea, organic manures, *azospirillum* and growth regulators on the yield of rice. Oryza 32(1) : 28-32.

Tandon H L S 1990 Fertilizers and sustainable agriculture in soil fertility and fertilizers use. P R Department, Marketing Division IFFCO, New Delhi 4 : 15-27.

Tandon, H L S and Sekhon G S 1988 Potassium Research and Agricultural Production in India. FDCO, New Delhi.

Tanveer R A, Baroova S R and Rajkhowa D J 1993 Direct and residual effect of farm yard manure sources and levels of phosphorus in summer rice-rainy season rice cropping sequence. Indian Journal of Agronomy 38(3) : 457-459.

Thakur D S and Patel S R 1998 Response of split application of nitrogen in rice with and without farm yard manure in Inceptisols. Environment and Ecology 16(2) : 310-313.

Thakur R B 1993 Performance of summer rice to varying levels of nitrogen. Indian Journal of Agronomy 38(2) : 187-190.

Thakur R C, Bindra A D, Sood R D and Bhargava M 1995 Effect of fertilizer application and green-manuring on physico-chemical properties of soil and grain yield in rice (*oryza sativa*)-wheat (*Triticum aestivam*) crop sequence. Indian Journal of Agronomy 40(1) : 4-13.

Thimmegowda S 1993 Direct and residual effect of fertilization on yield and uptake of nutrients by pulses. Journal of the Indian Society of Soil Science 41(3) : 495-497.

Thimmegowda S and Devakumar 1994 Effect of residual fertility on yield of groundnut grown in rice fallows. Indian Agriculturist 38(4) : 287-290.

Tiwari C, Singh Y and Singh D 1995 Effect of *Sesbania* green manure and nitrogen fertilizer in rice (*Oryza sativa*)-wheat (*Triticum aestivam*) cropping system. Indian Journal of Agricultural Sciences 65(10) : 708-711.

Touchton J T, Rickerl D H, Walker R H and Snipes C E 1984 Winter legumes as a nitrogen source for no-tillage cotton. Soil & Tillage Research 4 : 391-401

Tripathi B N, Dixit V K and Chaubey C N 1990 Influence of fertilizers and FYM on dry matter and harvest of economic products in rice. Bharatiya Krishi Anusandhan Patrika 5(4) : 217-223.

Tyagi S C, Sharma D L and Nathani G P 1982 Effect of different cropping patterns on the physical properties of medium black soils of Rajasthan. Current Agriculture 6(3-4) : 172-176.

Udayasoorian C and Paramasivam P 1991 Changes in available NPK status after 8 years of continuous manuring and fertilization in rice-rice cropping system. Madras Agricultural Journal 78(5-8) : 204-206.

Udayasoorian C, Sree Ramulu U S and Paramasivam P 1989 Effect of continuous manuring and fertilization on the fractions of soil nitrogen. Madras Agricultural Journal 76(5) : 257-261.

Upadhyay P N and Patel G R 1992 Nitrogen management in rice. Journal of the Indian Society of Soil Science 40(4) : 383-385.

Vanaja M 2000 Integrated nutrient management in rice-sunflower cropping system on Alfisols. Ph.D Thesis submitted to Acharya N.G. Ranga Agricultural University, Hyderabad.

Vasanth Kumar T T 1996 Nitrogen management through green manuring and fertilizers in lowland rice. M. Sc. (Ag) Thesis submitted to Acharya N. G Ranga Agricultural University, Hyderabad.

*Ventura W, Mascarina G B, Furoc R E and Watanabe I 1987 *Azolla* and *sesbania* as bio-fertilizers for low land rice. Philippines Journal of Crop Science 12 : 61-69.

Verma T S and Bhagat R M 1994 Effect of organic amendments on electro-chemical and chemical kinetics and growth and yield of rice. Oryza 31(3) : 206-212.

Walkley A and Black C A 1934 Estimation of organic carbon by chromic acid titration method. Soil Science 37 : 29-38.

*Wang De-ren and Lu Wan-Tang 1988 Nutrient balance of nitrogen, phosphorus and potassium under tripple cropping systems - based on rice (China). Better Crops International 12(2) : 3-5.

Wani A G and Umrani N K 1992 Changes in soil fertility by intercropping of forages in *Leucaena leucocephale* under nitrogen fertilization. In: National Symposium on Resource Management for Sustained Crop Production, February 25-28. Rajasthan Agricultural University, Bikaner pp. 135.

*Watanabe I 1984 Use of green manures in North East Asia. Organic matter and rice. IRRI, Manila, Philippines, pp. 229-234.

Wen Q X 1991 Management of farm-grown sources for rice. Progress in irrigated Research Rice abstracts 14(3) : 138.

Wesley R A, Heltherley L G, Pringlf H C and Tupper G K 1988 Seed-bed tillage and irrigation effects on yield of mono and double crop soybean and wheat on silt loam. Agronomy Journal 13 : 9-143.

Yadvinder Singh, Bijay Singh, Maskina M S and Meelu O P 1995 Response of wet land rice to nitrogen from cattle manure and urea in a rice-wheat rotation. Tropical Agriculture 72(1) : 91-96.

Yamada M, Jariki T, Watanabe Y, Samepoulpon R, Sasiprapa V and Nordson boon C 1986 Multiple cropping on paddy field. Technical Bulletin, Tropical Agricultural Research Centre, Japan 20 : 168-185.

Yawalkar K S, Agarwal J P and Bokde S 1992 Manures and fertilizers. Agri-Horticultural Publishing House, Nagpur-440 010

Yoshida S 1981 Fundamentals of rice crop science. International Rice Research Institute, Los Banos, Philippines pp. 269.

---

* Original not seen

Note: The Literature Cited is as per the guidelines of Acharya N.G. Ranga Agricultural University Thesis presentation.

APPENDICES

Appendix - A

Decennial Averages of Meteorological Data Recorded at ARI, Rajendranagar, Hyderabad (1991-2000)

Months	Temperature (°C)		R.H (%)		Rainfall (mm)	No. of rainy days	Bright sunshine (hrs day^{-1})	Wind speed (km hr^{-1})	Evaporation (mm day^{-1})
	Max.	Min.	07.16 hrs	14.16 hrs					
January	29.2	13.4	80	34	7.3	0.5	9.2	2.7	3.3
February	31.9	15.7	75	29	3.3	0.3	9.9	3.1	4.4
March	34.7	19.4	66	26	10.3	0.5	10.2	3.3	5.5
April	38.0	23.0	62	26	20.6	1.9	9.7	3.6	6.3
May	39.2	25.5	58	28	47.9	3.1	9.7	5.3	7.5
June	34.7	24.3	75	46	106.0	6.7	6.5	8.5	6.3
July	31.2	23.1	82	57	166.2	9.6	4.9	11.5	4.4
August	30.0	22.6	85	62	189.2	10.9	4.5	8.0	3.6
September	30.7	22.3	84	56	123.8	6.5	6.3	4.4	3.9
October	30.7	20.3	84	52	120.6	6.0	7.2	2.7	3.6
November	29.5	16.4	83	46	38.1	1.6	8.2	2.6	3.3
December	28.1	11.8	81	36	6.4	0.5	8.6	2.4	3.0
Mean	32.3	19.8	76	41	839.8	48.0	7.9	4.8	4.6

Appendix - B

Weekly Meteorological Data Recorded at ARI, Rajendranagar, Hyderabad (*Kharif*, 1999)

Standard week	Period	Temperature (°C)		R.H. (%)		Rainfall (mm)	No. of rainy days	Bright sunshine (hrs day^{-1})	Wind speed (km hr^{-1})	Evaporation (mm day^{-1})	Mean temperature(°C)
		Max.	Min.	07.16 hrs	14.16 hrs						
26	25 JUNE - 01 JULY, 1999	32.4	23.5	81	52	15.8	1.0	9.5	7.5	5.9	28.0
27	02-08 JULY, 1999	32.8	23.7	85	54	71.9	3.0	7.2	4.9	5.5	28.3
28	09-15	30.0	23.2	87	73	34.2	4.0	4.4	6.6	3.8	26.6
29	16-22	30.2	23.2	88	59	60.8	4.0	4.6	7.0	3.9	26.7
30	23-29	29.4	23.0	87	66	16.6	2.0	4.6	9.9	4.4	26.2
31	30 JULY - 05 AUG. 1999	28.0	22.7	89	74	67.7	3.0	2.8	7.5	3.3	25.2
32	06-12	28.8	22.8	82	68	8.8	2.0	4.0	7.0	3.4	25.8
33	13-19	30.7	23.0	89	68	40.6	1.0	6.7	3.9	4.0	26.9
34	20-26	30.3	23.4	87	64	50.3	1.0	5.0	3.3	4.1	26.9
35	27 AUG - 02 SEP. 1999	29.1	22.7	88	65	24.6	3.0	2.5	5.1	3.6	25.9
36	03-09	29.6	22.3	88	66	28.4	2.0	5.3	6.4	4.5	26.0
37	10-16	28.6	22.8	87	67	1.9	0.0	4.4	5.4	3.4	25.7
38	17-23	31.4	23.0	80	53	1.8	0.0	7.0	4.4	5.3	27.2
39	24-30	31.7	23.1	94	66	23.4	4.0	5.7	1.9	2.9	27.4
40	01-07 OCT. 1999	31.1	22.9	88	62	14.6	1.0	8.6	3.0	3.7	27.0
41	08-14	31.5	22.4	92	52	8.4	1.0	8.6	2.3	3.6	27.0
42	15-21	31.1	20.2	90	49	3.2	1.0	7.5	2.1	4.1	25.7
43	22-28	31.2	19.8	82	51	42.4	1.0	7.9	2.2	3.3	25.5
44	29 OCT - 04 NOV. 1999	31.0	18.1	76	39	0.0	0.0	9.1	2.2	4.3	24.5

Appendix - C

Weekly Meteorological Data Recorded at ARI, Rajendranagar, Hyderabad (*Rabi*, 1999-2000)

Standard week	Period	Temperature (°C)		R.H. (%)		Rainfall (mm)	No. of rainy days	Bright sunshine (hrs day^{-1})	Wind speed (km hr^{-1})	Evaporation (mm day^{-1})	Mean temperature(°C)
		Max.	Min.	07.16 hrs	14.16 hrs						
46	12-18 NOV, 1999	30.3	11.9	77	26	0.0	0.0	10.1	20.3	4.0	21.1
47	19-25	28.8	13.8	80	36	0.0	0.0	8.0	2.5	3.7	21.3
48	26 NOV - 02 DEC, 1999	30.0	12.8	86	31	0.0	0.0	9.6	1.7	3.5	21.4
49	03-09	28.6	12.0	84	34	0.0	0.0	9.5	1.1	3.0	20.3
50	10-16	28.1	10.2	83	33	0.0	0.0	9.2	1.3	3.1	19.1
51	17-23	28.0	10.8	82	35	0.0	0.0	9.5	1.7	3.0	19.4
52	24-31	28.1	12.3	88	38	0.0	0.0	9.4	1.7	3.0	20.2
01	01-07 JAN, 2000	27.4	10.3	83	31	0.0	0.0	9.4	1.5	2.9	18.8
02	08-14	29.7	12.4	84	32	0.0	0.0	9.7	1.9	3.3	21.1
03	15-21	31.6	14.7	86	30	0.0	0.0	9.3	1.8	3.5	23.2
04	22-28	32.1	14.6	87	30	0.0	0.0	10.0	2.1	4.3	23.4
05	29 JAN - 04 FEB, 2000	31.2	13.0	84	29	0.0	0.0	10.2	2.0	4.3	22.1
06	05-11	32.6	18.0	84	34	0.0	0.0	9.7	1.9	4.9	25.3
07	12-18	31.8	18.5	78	43	0.0	0.0	8.9	2.8	5.0	25.2
08	19-25	30.8	19.9	84	55	3.0	1.0	7.0	4.8	4.2	25.4
09	26 FEB - 04 MAR, 2000	32.0	16.7	77	48	22.2	6.0	8.6	2.7	4.5	24.3
10	05-11	34.8	16.7	73	43	0.0	0.0	10.7	2.1	6.5	25.8
11	12-18	36.0	18.2	72	43	0.0	0.0	10.5	1.9	6.7	27.1
12	19-25	36.3	19.9	73	38	0.0	0.0	10.1	2.7	7.1	28.1
13	26 MAR - 01 APR, 2000	35.6	19.9	69	43	0.0	0.0	10.0	2.9	6.7	27.8
14	02-08	38.4	23.1	72	46	0.0	0.0	10.4	3.7	7.9	30.8
15	09-15 APR, 2000	40.1	24.0	68	45	2.2	0.0	9.3	2.3	7.6	32.0

Appendix - D

Weekly Meteorological Data Recorded at ARI, Rajendranagar, Hyderabad (*Kharif*, 2000)

Standard week	Period	Temperature (°C)		R.H. (%)		Rainfall (mm)	No. of rainy days	Bright sunshine (hrs day^{-1})	Wind speed (km hr^{-1})	Evaporation (mm day^{-1})	Mean temperature(°C)
		Max.	Min.	07.16 hrs	14.16 hrs						
26	25 JUNE - 01 JULY, 2000	29.9	23.0	80	68	66.1	4.0	1.5	6.9	3.3	26.4
27	02-08 JULY, 2000	29.7	25.0	86	74	25.2	2.0	3.6	5.3	3.1	27.4
28	09-15	27.9	23.1	85	75	29.1	2.0	2.0	10.5	3.6	25.5
29	16-22	29.6	23.0	81	61	1.9	0.0	5.0	9.3	4.7	26.3
30	23-29	31.7	23.3	75	53	0.6	0.0	8.2	3.5	5.1	27.5
31	30 JULY - 05 AUG. 2000	33.6	24.1	77	51	2.7	1.0	8.3	2.6	5.0	28.9
32	06-12	28.1	22.7	88	77	95.0	4.0	2.3	5.4	3.2	25.5
33	13-19	30.2	23.3	87	62	49.7	3.0	6.6	4.2	3.8	26.8
34	20-26	28.0	23.0	91	77	164.9	4.0	2.0	5.9	3.4	25.5
35	27 AUG - 02 SEPT. 2000	27.8	22.7	87	73	19.9	3.0	2.3	8.2	2.8	25.3
36	03-09	30.0	22.8	83	57	1.2	0.0	7.0	3.8	3.8	26.4
37	10-16	31.7	22.2	84	55	48.6	4.0	7.7	2.1	4.2	27.0
38	17-23	30.9	22.6	87	64	35.6	2.0	6.5	1.9	4.0	26.7
39	24-30	31.8	22.4	87	59	10.0	1.0	7.7	2.1	3.9	27.1
40	01-07 OCT. 2000	33.0	21.8	78	43	0.0	0.0	8.6	1.7	4.4	27.4
41	08-14	32.5	21.4	89	58	8.4	1.0	6.7	1.1	2.9	27.0
42	15-21	31.6	21.1	86	49	12.8	2.0	6.0	1.9	3.4	26.3
43	22-28	33.4	17.6	80	34	0.0	0.0	9.4	1.5	4.7	25.5
44	29 OCT - 04 NOV. 2000	31.4	17.5	80	44	0.8	0.0	8.0	1.8	3.4	24.5

Appendix - E

Weekly Meteorological Data Recorded at ARI, Rajendranagar, Hyderabad (*Rabi*, 2000-2001)

Standard week	Period	Temperature (°C)		R.H. (%)		Rainfall (mm)	No. of rainy days	Bright sunshine (hrs day^{-1})	Wind speed (km hr^{-1})	Evaporation (mm day^{-1})	Mean temperature(°C)
		Max.	Min.	07.16 hrs	14.16 hrs						
46	12-18 NOV. 2000	30.4	13.7	79	37	0.0	0.0	10.0	2.2	3.8	12.0
47	19-25	31.0	14.4	80	35	0.0	0.0	9.1	1.6	3.5	22.7
48	26 NOV - 02 DEC. 2000	30.2	16.3	81	48	0.6	0.0	7.2	2.7	3.5	23.2
49	03-09	29.6	9.2	78	24	0.0	0.0	8.7	2.3	4.0	19.4
50	10-16	30.0	8.1	75	20	0.0	0.0	9.5	1.9	3.7	19.0
51	17-23	29.5	8.2	76	23	0.0	0.0	9.3	2.3	3.9	18.8
52	24-31	29.4	9.8	84	28	0.0	0.0	9.2	2.8	3.6	19.6
01	01-07 JAN. 2001	27.6	14.2	83	45	1.0	0.0	5.2	2.2	2.9	20.9
02	08-14	30.6	14.4	82	29	0.0	0.0	8.7	2.8	4.2	22.5
03	15-21	30.5	14.1	89	30	0.0	0.0	8.3	3.0	4.3	22.3
04	22-28	30.4	9.7	78	18	0.0	0.0	8.7	2.0	4.2	20.1
05	29 JAN - 04 FEB. 2001	31.9	11.2	79	21	0.0	0.0	8.9	2.0	4.4	21.6
06	05-11	34.2	11.4	78	17	0.0	0.0	9.9	2.3	5.5	22.8
07	12-18	34.2	14.1	77	20	0.0	0.0	10.1	2.8	5.4	24.2
08	19-25	35.5	15.1	63	17	0.0	0.0	10.0	2.5	6.1	25.3
09	26 FEB - 04 MAR. 2001	35.9	17.1	70	22	0.0	0.0	9.9	3.4	6.8	26.5
10	05-11	34.4	19.8	74	29	0.0	0.0	7.5	3.7	5.8	27.1
11	12-18	34.7	18.9	74	31	0.0	0.0	7.1	3.1	5.7	26.8
12	19-25	37.1	21.8	65	22	8.4	1.0	6.8	2.5	6.2	29.5
13	26 MAR - 01 APR. 2001	37.9	21.0	58	24	0.0	0.0	9.0	3.0	7.7	29.5
14	02-08	36.7	21.7	67	33	7.8	1.0	8.3	3.6	7.2	29.2
15	09-15 APR. 2001	35.4	23.2	72	42	15.0	2.0	6.0	3.7	5.8	29.7

Appendix - F

Expenditure on nitrogen management in rice through organic manuring and urea (Rs ha^{-1})

Treatments	*Kharif* 1999					*Kharif* 2000				
	Cost of cultivation excluding FN and OM	Cost of organic manure	Cost of FN	Cost of P and K	Total cost of cultivation	Cost of cultivation excluding FN and OM	Cost of organic manure	Cost of FN	Cost of P and K	Total cost of cultivation
FYM N_{25} - FN_{75}	7020	985	684	1033	9722	6900	1020	690	1105	9715
FYM N_{25} - FN_{100}	7020	985	913	1033	9951	6900	1020	920	1105	9945
GLM N_{25} - FN_{75}	7020	679	684	1211	9594	6900	695	690	1202	9487
GLM N_{25} - FN_{100}	7020	679	913	1211	9823	6900	695	920	1202	9717
FN	7020	-	913	1513	9446	6900	-	920	1550	9370

Appendix - G

Cost of cultivation (Rs ha^{-1}) of *rabi* crops (1999-2000)

Details	Wheat	Maize	Groundnut	Soybean
1. **Input Cost**				
a) Seed	1000	650	1780	600
b) Fertilizers	2725	3092	1550	1604
c) Plant protection chemicals				
i) Insecticides	250	300	600	175
ii) Fungicides			250	-
d) Irrigation	250	350	380	250
2. **Labour Cost**				
a) Preparatory cultivation				
i) Tractor ploughing	400	400	400	400
ii) Human labour	180	180	180	180
iii) Cattle	100	100	100	100
b) Fertilizer application	120	120	120	120
c) Sowing	275	275	275	275
d) Gap filling and thinning	-	200	275	-
e) Weeding and intercultural operations	680	800	900	300
f) Application of plant protection chemicals	60	130	180	60
g) Irrigation	160	250	250	160
h) Bird scaring	-	250	325	-
i) Harvesting, threshing and winnowing, etc.				
i) Tractor	200	200	200	100
ii) Human labour	585	700	800	175
Total Cost of Cultivation	**6985**	**7997**	**8565**	**4499**

Appendix - H

Cost of cultivation (Rs ha^{-1}) of *rabi* crops (2000-2001)

Details	Wheat	Maize	Groundnut	Soybean
1. **Input Cost**				
a) Seed	1000	700	1680	550
b) Fertilizers	2775	3100	1500	1575
c) Plant protection chemicals				
i) Insecticides	300	350	550	150
ii) Fungicides			200	-
d) Irrigation	250	350	380	250
2. **Labour Cost**				
a) Preparatory cultivation				
i) Tractor ploughing	450	450	450	450
ii) Human labour	200	200	200	200
iii) Cattle	120	120	120	120
b) Fertilizer application	120	120	120	120
c) Sowing	275	275	275	275
d) Gap filling and thinning	100	250	250	100
e) Weeding and intercultural operations	700	900	850	275
f) Application of plant protection chemicals	50	130	150	50
g) Irrigation	150	250	250	150
h) Bird scaring	-	300	350	-
i) Harvesting, threshing and winnowing, etc.				
i) Tractor	250	250	250	150
ii) Human labour	600	750	768	150
Total Cost of Cultivation	**7340**	**8495**	**8343**	**4565**

Appendix - I

Date of sowing, harvesting and duration of different crops during *kharif* and *rabi* 1999-2000 and 2000-2001

Crop	Date of Sowing		Date of Harvesting		Duration (days)	
	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
Kharif						
Rice	30.06.1999	28.06.2000	03.11.1999	27.10.2000	127	122
Rabi						
Wheat	21.11.1999	16.11.2000	04.03.2000	01.03.2001	104	106
Maize	21.11.1999	16.11.2000	27.03.2000	21.03.2001	127	126
Soybean	21.11.1999	16.11.2000	02.03.2000	27.02.2001	102	104
Groundnut	21.11.1999	16.11.2000	11.04.2000	08.04.2001	142	144

* Sunnhemp (green leaf manure) was sown on 12.06.1999 in 1st year and on 10.06.2000 in 2nd year in a separate field and incorporated in rice field before transplanting at 45 DAS during both the years.

Appendix - J

Calender of Operations (*kharif* rice)

Operations		1999	2000
1. Nursery			
a.	Puddling	25.06.1999	23.06.2000
b.	Puddling and levelling	29.06.1999	27.06.2000
c.	Broadcasting of sprouted seed	30.06.1999	28.06.2000
2. Main field			
a.	First ploughing	02.07.1999	30.06.2000
b.	Second ploughing	10.07.1999	06.07.2000
c.	First puddling	15.07.1999	11.07.2000
d.	Trimming of bunds	17.07.1999	13.07.2000
e.	Final puddling and levelling with cattle drawn wooden plank	20.07.1999 to 21.07.1999	16.07.2000 to 17.07.2000
f.	Layout and bunding	22.07.1999 to 23.07.1999	18.07.2000 to 19.07.2000
g.	Incorporation of GLM and FYM	24.07.1999	20.07.2000
h.	Micro-levelling	28.07.1999	24.07.2000
i.	Basal application of fertilizers and transplanting	29.07.1999	25.07.2000
j.	Application of butachlor 50 EC	02.08.1999	28.07.2000
k.	First hand weeding	19.08.1999	15.08.2000
l.	First top dressing of nitrogen	20.08.1999	16.08.2000
m.	Application of carbofuran 3G	21.08.1999	17.08.2000
n.	Spraying of quinalphos 25EC	28.08.1999	24.08.2000
o.	Second hand weeding	07.09.1999	03.09.2000
p.	Second top dressing of nitrogen	08.09.1999	04.09.2000
q.	Harvesting of border rows	02.11.1999	26.10.2000
r.	Harvesting of net plots	03.11.1999	27.10.2000
s.	Threshing and winnowing	06.11.1999	30.10.2000
t.	Drying, weighing and bagging	07.11.1999 to 10.11.1999	31.10.2000 to 03.11.2000

Appendix - K

Calender of Operations (*rabi* crops)

	Operations	Wheat		Maize		Soybean		Groundnut	
		1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
1.	First ploughing	10.11.1999	05.11.2000	10.11.1999	05.11.2000	10.11.1999	05.11.2000	10.11.1999	05.11.2000
2.	Second ploughing	15.11.1999	11.11.2000	15.11.1999	11.11.2000	15.11.1999	11.11.2000	15.11.1999	11.11.2000
3.	Harrowing and levelling	18.11.1999	13.11.2000	18.11.1999	13.11.2000	18.11.1999	13.11.2000	18.11.1999	13.11.2000
4.	Layout and levelling of sub-plots	19.11.1999	14.11.2000	19.11.1999	14.11.2000	19.11.1999	14.11.2000	19.11.1999	14.11.2000
5.	Basal application of fertilizers	20.11.1999	15.11.2000	20.11.1999	15.11.2000	20.11.1999	15.11.2000	20.11.1999	15.11.2000
6.	Sowing and post-sowing irrigation	21.11.1999	16.11.2000	21.11.1999	16.11.2000	21.11.1999	16.11.2000	21.11.1999	16.11.2000
7.	Thinning and gap filling	30.11.1999	26.11.2000	02.12.1999	28.11.2000	30.11.1999	26.11.2000	11.12.1999	06.12.2000
8.	First hand weeding	12.12.1999	07.12.2000	13.12.1999	08.12.2000	12.12.1999	07.12.2000	21.12.1999	18.12.2000
9.	First top dressing of nitrogen	20.12.1999	15.12.2000	23.12.1999	18.12.2000	20.12.1999	15.12.2000	26.12.1999	21.12.2000
10.	Spraying of nuvacron 36 SL	22.12.1999	17.12.2000	-	-	14.12.1999	09.12.2000	-	-
11.	Application of carbofuran 3G in leaf whorls	-	-	26.12.1999	21.12.2000	-	-	-	-
12.	Spraying of monocrotophos 36 SL	06.01.2000	31.12.2000	28.12.1999	23.12.2000	06.01.2000	31.12.2000	05.01.2000	30.12.2000
13.	Spraying of Dithane M-45	-	-	-	-	-	-	10.01.2000	05.01.2001
14.	Second hand weeding	08.01.2000	03.01.2001	09.01.2000	04.01.2001	08.01.2000	03.01.2001	22.01.2000	18.01.2001

Contd....Appendix - K

	Operations	Wheat		Maize		Soybean		Groundnut	
		1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
15.	Second top dressing of nitrogen	19.01.2000	16.01.2001	23.01.2000	19.01.2001	19.01.2000	16.01.2001	04.02.2000	29.01.2001
16.	First irrigation	30.11.1999	26.11.2000	30.11.1999	26.11.2000	30.11.1999	26.11.2000	21.11.1999	16.11.2000
17.	Second irrigation	13.12.1999	09.12.2000	13.12.1999	09.12.2000	13.12.1999	09.12.2000	30.11.1999	26.11.2000
18.	Third irrigation	28.12.1999	24.12.2000	30.12.1999	22.12.2000	28.12.1999	24.12.2000	13.12.1999	09.12.2000
19.	Earthing up	-	-	11.01.2000	05.01.2001	-	-	-	-
20.	Fourth irrigation	10.01.2000	09.01.2001	12.01.2000	06.01.2001	10.01.2000	09.01.2001	02.01.2000	30.12.2000
21.	Fifth irrigation	23.01.2000	20.01.2001	01.02.2000	24.01.2001	23.01.2000	20.01.2001	23.01.2000	20.01.2001
22.	Sixth irrigation	-	-	20.03.2000	13.03.2001	-	-	20.02.2000	18.02.2001
23.	Seventh irrigation	-	-	05.03.2000	27.02.2001	-	-	06.03.2000	03.03.2001
24.	Eigth irrigation	-	-	17.02.2000	10.02.2001	-	-	23.03.2000	20.03.2001
25.	Ninth irrigation	-	-	-	-	-	-	08.04.2000	05.04.2001
26.	Harvesting, threshing, winnowing and drying	04.03.2000 to 07.03.2000	01.03.2001 to 04.03.2000	27.03.2000 to 01.04.2000	21.03.2001 to 26.03.2001	02.03.2000 to 05.03.2000	27.02.2001 to 30.02.2001	11.04.2000 to 16.04.2000	08.04.2001 to 13.04.2001

Appendix - L

Cost of inputs (Rs kg^{-1})

Inputs	Cost (Rs kg^{-1})
Sunnhemp (green leaf manure)	0.10
Farm yard manure	0.25
Urea fertilizer	4.60
Single super phosphate	2.70
Muriate of potash	4.40

Appendix - M

Nutrient content (%) of organic manures

Organic manures	1999			2000		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Sunnhemp (on dry weight basis)	2.52	0.16	0.51	2.47	0.19	0.53
Farm yard manure	0.64	0.28	0.58	0.61	0.27	0.53