SOURCE - EFFICACY RELATIONS OF ORGANICS IN WETLAND RICE CULTURE

By

RAJAGOPAL PRASHANT

THESIS

Submitted in partial fulfillment of the
requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2002

DECLARATION

I hereby declare that the thesis entitled **"SOURCE – EFFICACY RELATIONS OF ORGANICS IN WETLAND RICE CULTURE"** is a bonafide record of research work done by me during the course of research and, that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
24-12-2002

RAJAGOPAL PRASHANT
(99-11-45)

CERTIFICATE

Certified that this thesis entitled **"SOURCE – EFFICACY RELATIONS OF ORGANICS IN WETLAND RICE CULTURE"** is a record of research work done independently by **Mr. Rajagopal Prashant**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikkara.
24-12-2002

Dr. P.S John
Major Advisor, Advisory Committee
Associate Professor and Head
Cashew Research Station
Madakkathara

CERTIFICATE

We, the undersigned members of the advisory committee of Mr. Rajagopal Prashant, a candidate for the degree of **Master of Science in Agriculture** with major field in **Agronomy**, agree that the thesis entitled **"SOURCE – EFFICACY RELATIONS OF ORGANICS IN WETLAND RICE CULTURE"** may be submitted by Mr. Rajagopal Prashant, in partial fulfillment of the requirement for the degree.

31/12/2002

Dr. P.S John
Major Advisor, Advisory Committee
Associate Professor and Head
Cashew Research Station
Madakkathara

Dr.C.T Abraham
Associate Professor &Head
Department of Agronomy
College of Horticulture
Vellanikkara

Dr. Mercy George
Associate Professor
Department of Agronomy
College of Horticulture
Vellanikkara

31/12/02

Dr.V.K.G Unnithan
Associate Professor &Head
Department of Agricultural Statistics
College of Horticulture
Vellanikkara

31.12.02

External Examiner
Dr. N. SANKARAN
Prof & Head
Dept. of Agronomy
T.N.A.U. COIMBATORE-3

ACKNOWLEDGEMENT

It is with great pleasure I place here on record my heartfelt gratitude and sincere thanks to **Dr. P.S. John**, Associate Professor and Head, Cashew Research Station, Madakkathara, and Chairman of my Advisory Committee, for his expert guidance, sustained interest and unfailing help throughout the course of this investigation. But for his constant encouragement and prodding this venture would not have been completed successfully.

I would like to place on record my deep sense of gratitude and indebtedness to **Dr. C.T. Abraham**, Associate Professor and Head, Department of Agronomy, for his constructive criticism and valuable and timely suggestions which has immensely contributed to the success of this venture.

The valuable advice and encouragement provided to me not only during the course of this investigation but also throughout the academic phase of the programme by **Dr. Mercy George**, Associate Professor, Department of Agronomy, is acknowledged with deep sense of gratitude.

I am deeply obliged to **Dr. V.K.G. Unnithan**, Associate Professor and Head, Department of Agricultural Statistics, for the his valuable suggestions and generous help accorded to me during the preparation of thesis, especially with regard to statistical analysis of data and interpretation of results.

It is my pleasant privilege to express my utmost gratitude to **Dr. N.N. Potty**, Professor, and former Head, Department of Agronomy, for his constant help, never ending encouragement, valuable suggestions and whole-hearted co-operation towards the satisfactory fulfillment of this endeavour.

I am extremely grateful to Dr. U. Jaikumaran, Associate Professor and Head, Agricultural Research Station, Mannuthy, for providing the facilities to conduct the research work at the station.

The help accorded by Dr P.K. Rajeevan, Associate Professor and Head and Dr P.K. Valsalakumari, Associate Professor, Department of Pomology and Floriculture, is gratefully acknowledged.

I also place on record my sincere gratitude to Sri. S. Krishnan, Associate Professor, Department of Agricultural Statistics, for the kind co-operation and help extended.

The constant encouragement and motivation provided by Dr. P. Indira Devi, Associate Professor, Department of Agricultural Economics and Dr E. Soman Department of Physical Education, are fondly remembered.

My gratefulness and personal obligation go without any reservation to each and every member of the Department of Agronomy for extending all possible help in the proper conduct of this research work.

The assistance and co-operation rendered to me by the staff members and labourers of the Agricultural Research Station, Mannuthy, and Cashew Research Station, Madakkathara are very much appreciated and I thank them sincerely for their unconditional and ever present help.

I wish to thank the staff of NIO - RC Kochi for having conducted an accurate analysis of micronutrients and also for offering very valuable suggestions in this regard.

The untiring and timely help and support provided by Joby, Jinesh, Sunil, Ashith, Sameer, Sajnanath, Rajiv, Arun, Anees, Sajid, Neel, Roopa and Glenda throughout the conduct of the experiment is gratefully acknowledged. Words fail in expressing my deep indebtness to Pratheesh, Rajesh, Shinoj, Nandan, Suresh (K), Biju and Santhosh and Jeo (C.C) for the help provided in preparation of the manuscript.

I would especially like to thank Sri. S. Vallalkannan, Ph.D Scholar for his meticulous and thorough perusal of the manuscript and valuable contributions. Without the help of my seniors, classmates and juniors in the Department of Agronomy this venture would have certainly not been successful and I am immensely grateful to them.

I would like to take this opportunity to thank Mr. Ghanashyam for his painstaking efforts in neatly typing the entire manuscript and also preparation of the tables and illustrations. The support extended by Smt. Ajitha in preparation of the slides is also gratefully remembered.

I am forever beholden to my parents and brother for their boundless affection and constant encouragement in all my endeavours.

The Award of KAU Junior Research Fellowship during the period of my study is gratefully acknowledged.

Rajagopal Prashant

Out of the night that covers me,
Black as the pit from pole to pole,
I thank whatever gods may be
For my unconquerable soul.

In the fell clutch of circumstance,
I have not winced nor cried aloud.
Under the bludgeonings of chance,
My head is bloody, but unbowed.

Beyond this place of wrath and tears
Looms but the Horror of the shade,
And yet the menace of the years
Finds, and shall find, me unafraid.

It matters not how strait the gate,
How charged with punishments the scroll,
I am the master of my fate:
I am the captain of my soul.

Contents

Page No.

List of Tables

List of Figures

INTRODUCTION

1. Introduction

Rice, which is the staple food of majority of people in Asia, is the sustenance of more than half of the world population and the backbone of most agrarian economies. Globally, population is increasing by about 80 million people per year and by 2050 AD, the world is likely to be inhabited by between 8 and 11 billion people, which will eventually require a substantial increase in rice production to meet the demands. If the technologies that affect nutrient utilization by the rice crop remain unchanged, this production increase will require almost 300 per cent more than the present application rate of nitrogen alone (Fisher and Heilig, 1998).

In developing countries, where the amount of arable land *per capita* is steadily decreasing, inherently sustainable local practices and knowledge adopted before the Green Revolution era have been systematically replaced. For instance, the subsistence agriculture of the pre-chemical era that efficiently sustained the N status of soils by maintaining a balance between N lost with the grain harvest and N gain from biological N fixation and decomposition of residues has been replaced by agriculture of the modern chemical era, which concentrates on maximum output but overlooks input efficiency. Likewise, the traditional, less intensive wet-dry rotation of rice culture has been gradually replaced by intensive continuous wetland rice culture, leading to a lower available soil N pool (Kundu and Ladha, 1995).

Stresses (deficiencies and toxicities) due to availability, acquisition and utilization of nutrients are becoming increasingly widespread in many soils, leading to low crop productivity. For example, the yield potential of cropping systems on acid soils, which cover about 395 billion hectares of the earth's surface, is restrained by deficiencies of phosphorus, calcium, magnesium, and potassium, and by toxicities of aluminium, manganese, and iron (Salazar *et al.*, 1997).

Conventionally, fertilizers or soil amendments are used to counter such stresses. However, total dependence on fertilizer is neither economical nor pragmatic because of (a) the inability of many farmers to buy enough fertilizer, and (b) the capacity of many soils to fix applied nutrients into forms unavailable to plants (Sanchez and Uehara, 1980).

There is also increasing evidence that fertilizer alone cannot sustain yields for long periods. In continuous rice cropping with two to three crops grown annually, the use of fertilizer N was increased with time but the yields often remained stagnant (Cassman and Pingali, 1995). This reflects a higher fertilizer requirement to produce the same yields, implying a decline in yield response to nutrients, possibly because of an overuse of fertilizer.

Research on nutrient acquisition and management in cropping systems is entering a critical phase. While developed countries are mainly concerned about the adverse impacts of intensive cropping systems on the environment (soil, water and air) and society, developing countries are confronted with an ever-growing demand for greater agriculture production, while needing to sustain their already fragile resource base (Sanchez *et al.*1997). Although the concept of sustainability originated mainly in response to pressure from environmentalists in developed countries, concern over the long-term viability of cropping systems is felt for all scales of farming and in all agro-ecological zones. Nutrient-use efficiency of rice cropping systems must be improved, along with yield potential of cultivars; in order to improve profitability of rice production and prevent environmental degradation in irrigated areas (Fisher, 1998).

Thus, in the present scenario, where the environment is being extensively damaged to obtain a marginal increase in production, it becomes worthwhile to consider the possibility of substituting a sizeable quantity of the chemical fertilizers with organic nutrient sources of both plant and animal origin.

An alternate environmentally benign approach is to reduce the need for fertilizer through more efficient management of nutrient cycles and precise applications of fertilizers. Such practices include application of organic waste residues from animals and crops, green manures, green leaf manuring, crop rotations with legumes, improvement of crop health that may result in better use of nutrients, and split applications of fertilizers. The current conventional approach is to apply nutrients in the form of fertilizers at levels needed for maximum profitability. Swaminathan (1987) suggested that an integrated nutrient supply through a judicious combination of organic and biological sources along with inorganic fertilizers has a large number of agronomic and environmental benefits over inorganic sources alone and it is a concept that is ecologically sound leading to sustainable agriculture.

This can be achieved to certain extent by the use of loppings of commonly available trees and also easily obtainable animal manures, which have the ability to supply a sufficient amount of major and minor nutrients. Hence, the present investigation was undertaken with the following objectives,

(a) To assess the efficacy of various sources of green leaf and organic manures in relation to nutrient accretion, rice growth and yield

(b) To elucidate the effect of decomposition products on soil and plant chemical composition, rice growth, and yield, and

(c) To study the nitrogen mineralization pattern of the organic sources.

REVIEW OF LITERATURE

2. Review of literature

The role of manures of both plant and animal origin, in improving soil fertility and enhancing production in agriculture, has been well recognized and been in practice for many years. The green manures, green leaf manures, plant residues and animal wastes have the ability to release the nutrients present in them over an extended period of time, and make it available to the plants. In addition to the chemical changes brought about, application of organic manures can also enhance the physical properties of the soil making it more conducive to plant establishment and growth.

The use of organic manures is now achieving prime importance especially due to the ill effects of chemical fertilizers and also the inability of synthetic fertilizers to supply a range of nutrients, or to improve the soil fertility.

Organic manuring also improves the physical and microbial conditions of soil and enhances fertilizer use efficiency when applied in conjunction with mineral fertilizers. Thus, all the major sources of plant nutrients such as soil, mineral, organic and biological should be utilized in an efficient and judicious manner for sustainable crop production in a rice cropping system.

This review focuses on the fate of various organics applied in a wetland rice system, their impact on soil fertility and crop productivity and also the possibility of an integrated nutrient management strategy.

2.1 Manuring in rice

Though no major expansion of area under lowland rain fed rice is being anticipated in the foreseeable future, total rice production must increase by 60 – 70 percent by 2025 AD. It is estimated that rain fed lowland rice alone will have to contribute 25 – 30 per cent of this increased production which will necessitate the development of better production technology, including integrated nutrient management (Hossain and Fisher, 1995). In the wake of the present energy crisis and increased cost of fertilizers, it becomesnecessary to lay emphasis on the use of renewable environmental resources for sustainable development.

Increased prices and limited availability of fertilizers entails a search for alternative organic sources to supplement the nutrient requirements of crops including rice (Gaur, 1982). A combination of organic and inorganic nutrient sources is a necessary part of any management strategy to sustain rice yield particularly in areas with limited resources (Kundu and De Datta, 1988).

In Kerala, the gap between demand and local production of rice is widening primarily due to the continuous pace at which rice cultivated areas are giving way to urbanization. Problems of multi-nutrient deficiencies coupled with the fast declining grain yield response to NPK fertilizers applied alone, point to the fact that ecological recovery of a soil can be achieved through a balanced use of organic manures and chemical fertilizers in judicious combination (Pillai and Kundu, 1990).

In sustained rice production, organic manuring plays an important role. The combination of organic manures and inorganic fertilizers is considered to be more productive. Liu and Shen (1992) observed that mixed application of inorganic and organic fertilizer compared to no fertilizer or inorganic fertilizers not only increased soil organic matter content but also improved its quality. This resulted in an increase in acid hydrolysable N and improved soil structure.

The advantages of using organic sources of nutrients is that they can provide a wide range of nutrients, whereas, inorganic fertilizers only release a single nutrient.(eg. Urea N) or a few (eg. Compound NPK). In addition to the ability to combat multi nutrient deficiencies, organic sources also provide bulk matter that is important in the sustenance of soil organic matter (Dobermann and Fairhurst, 2000).

2.2 Green manuring and green leaf manuring

The use of green manures to increase crop yields is an age-old practice. By as early as 500 BC, the importance of green manuring had been recognized in India (Kadke, 1965).

Though, the use of green manures was an accepted practice in many countries other than India and citations in various ancient texts show that incorporation of plants or plant parts as a source of nutrients has a positive influence on the crop grown. Bin (1983) cited ancient Chinese literature *viz.,* a 3000-year-old book of songs in which a reference to green manuring has been made as "Bitter vegetable and knot weed rot, broom corn millet and millet flourishes".

An evaluation of the use of green manures in the middle of the 20th century has been carried out (Raju, 1952) and the extensive surveys that were conducted by Vachhani and Murthy (1964) on about 100 leguminous green manure crops in India were some of the early records of activities worth to be considered. They recommended several suitable reasons for rice culture using organic manures among which *Sesbania aculeata* and *Crotolaria juncea* were found to be more acceptable to the farmers of India.

The continuous application of manures can modify, in addition to supply of plant nutrients, the soil physical properties. Bulky organic manures in particular help in the improvement and maintenance of soil physical conditions (Biswas *et al.*, 1970). Also they were considered as an expedient to increase organic matter content of soil (Singh, 1962).

A survey of rice farmers of Sri Lanka showed that most farmers used green leaves and tender branches of selected plant species mainly because of their rapid decomposition and manurial value (Gunapala and Amarasiri, 1989).

Though in terms of nutrient value, green manures were on par with animal manures, they were never looked upon as a substitute for animal manures, rather a conjoint use of the two, to supplement nutrient requirements of different crops including rice was followed (Gaur, 1982).

Evans and Rotar (1987) reported that *Sesbania* sp. are well adapted for use as green manure because of their ability to withstand water logging and flooding and grow on fine textured soil and tolerate soil salinity.

Budhar *et al.*, (1991) experimented with neem leaves as a source of nutrients and observed that it was capable of releasing nutrients in sufficient quantities to enable satisfactory growth of rice seedlings. Samad and Sahadevan (1952) and Raju (1952) listed a number of tree species and other plants used extensively as green manure in southern States with Neem and Gliricidia as important ones.

Gurung and Sherchan (1996) reported a significant increase in grain yield of rice with green mauring using *Sesbania aculeata*. *Sesbania aculeata* grown as a sole crop and green manured to rice increased rice grain yield from 30-49 per cent. It was suggested that rice should be transplanted immediately after incorporation of *S. aculeata* green manure in the field.

Leaves of Jack (*Artocarpus integrifolius*), Acacia (*Acacia auriculiformis*), Macaranga (*Macaranga peltata*) and Terminalia (*Terminalia paniculata*) were also used as potential green manures in rice to supply various nutrient sources.

2.3 Influence of green manuring on productivity of rice

Green manuring has a pronounced effect on the productivity of rice and application of *Gliricidia* gave grain yield of 2.73 t /ha compared to control yield of 1.49 t/ha (Bal *et al.*, 1993). In field trials with different doses of N and *Gliricidia maculata* green manure, highest grain yield (5.21t/ha) was obtained with 50 kg N + 8 tonnes of *Gliricidia maculata*. However, similar yields were also obtained with 25 kg N + 8 tonnes of *Gliricidia*, 50 kg N + 6 tonnes of *Gliricidia*, 100 kg N or 10 tonnes *Gliricidia* / ha (Shinde, 1995).

Turkhede *et al.*, (1996) observed that incorporation of *Gliricidia* leaves as a green manure at 5 t /ha at the time of transplanting significantly increased the grain and straw yields of paddy. Incorporation of *Gliricidia* leaf foliage at the same site for five years recorded increase in grain and straw yield over control plot (Chaphale and Badole, 1999).

Dwivedi and Thakur (1999) reported that green manuring with prickly sesban or dhaincha gave significantly higher grain yield (47.7 and 40.4 q/ha). Among the various organic sources tried, *in situ* incorporation of dhaincha gave remarkably increased grain (18 per cent) and straw (16 per cent) yields (Hemalatha *et al.*, 2000).

When a 60 day old Dhaincha (*Sesbania aculeata*) crop was incorporated 10 days before transplanting rice, highest grain yield (8.79 t/ha) was obtained when compared to the incorporation of a 40 day old and 50 day old Dhaincha crop. Highest rice grain yield (3.3t /ha) was produced by the application of *S. aculeata* alone while urea alone produced 3.1 t /ha in the second crop season in rice (Haroon *et al.*, 1992).

Mohopatra and Jee (1993) reported that green manuring with Dhaincha alone gave yields of 3.48 tonnes whereas, green manuring + 20kg N/ha top-dressed at panicle initiation gave 3.81 t/ha which was on par with 60 kg N/ha as prilled urea.

Mehla *et al.* (1997) observed that manuring with green manures and farmyard manures increased mean grain yields to 6.89 and 6.74 t/ha as compared to 5.43 t/ha in control treatment. Sarmah (1997) showed that rice grain yield and P uptake were increased by application of green manure and phosphatic fertilizers. Phosphorus applied to green manure crops gave better rice yield response than when applied directly to rice crops.

Mahapatra and Sharma (1996) observed that yield of rice was increased significantly and was on par with highest dose of N (120 kg N/ha), with application of 5-6 t/ha of green manures (*S. cannabina, S. aculeata and S. rostrata*). The yield increase was attributed to significant variations in number of panicles/ m ^{2}, 1000 grain weight and N uptake of the crop. These yield attributes and rice yield had a significant correlation with wet soil NH_4^+ N, which was increased by green manuring with *Sesbania rostrata.*

Hiremath and Patel (1996) showed that incorporation of green manures sown early with higher sowing rates recorded highest grain yield of rice. Rice grain yield with incorporation of *S. aculeata*, sown in second crop season using 100kg seed/ha was comparable to application of 100kg N.

Adopting low cost technology for green manuring with *Sesbania* (Dhaincha) raised the productivity of lowland rice by nearly 1.0 tonne rice /ha (37per cent increase). Supplementing green manuring with moderate doses of 20 kg N/ha (urea) at incorporation resulted in a further increase of 0.5t rice /ha (Behera and Jha, 1997).

Rice yield significantly responded to green manuring whereas response of succeeding wheat crops to the residual effect was only marginal. Also manuring with *dhaincha* significantly improved productivity of rice over some other sources (Thakur *et al.*, 1999). Hemalatha *et al.* (1999) observed that grain quality of rice was greatest with *Sesbania aculeata* and 50per cent N + Azospirillum.

Sharma and Ghosh (2000) suggested that direct seeded rice when intercropped with *dhaincha* is beneficial in substituting urea fertilizer up to 40 kg N ha^{-1} and augmenting crop productivity under flood prone lowland conditions. Khan *et al.* (2000) found that green manuring with *Sesbania aculeata* increased rice yields by 0.7 t/ha.

Neem leaves were recommended as suitable manure for rice due to its nutrient value (Gunapala and Amarasiri, 1989). Budhar *et al.* (1991) observed that plant height and tiller number in plots into which neem leaves had been incorporated were comparable to the same from poultry manure incorporated plots.

2.4 Influence of green manuring on soil fertility

Green manures have the capability to increase organic matter content and also physical properties of the soil (Singh, 1962). Green manuring benefitted the soil by mobilization of plant nutrients absorbed by the green manures and released during subsequent decomposition increased soil fertility (Paturde and Patankar, 1998).

The ability of green manures to improve soil physical properties and fertility was reported by Biswas *et al.* (1970). The application of green manures at 22.5 per cent – 30 t/ha for five years increased the soil organic matter content by 7.3 per cent – 33.6 per cent compared to control. Also it improved soil organic matter, increased active organic matter content, organic complex formation and total humus content by 17.4 per cent, 52.1 per cent and 6.1 per cent respectively (Chen and Wang, 1987).

Green manuring contributed about 60 kg N per ha to rice showed no residual effect on succeeding wheat crop but an increased uptake of Zn, Fe and Mn was observed. Soil available P and K were either equal to or higher than initial values at the end of two year cropping sequence involving green manuring (Narang *et al.*, 1990).

It was observed by (Budhar *et al.*, 1991) that post harvest soil N and K contents were highest after application of *Sesbania* and P content was highest on application of *Pongamia glabra.* Plant uptake of N, P and K was generally increased by green manures and N fertilizer application (Balasubramaniyam *et al.*, 1993).

Nitrogen release from *Sesbania* and *Gliricidia* was roughly equal to 21.5 per cent and 32 per cent respectively, of that from urea, while agronomic efficiency of *Sesbania* and *Gliricidia* was found to be 42 per cent and 66 per cent respectively of that of urea N. Green manures that attain peaks of their nitrogen release between fourth and fifth weeks after transplanting rice, were found to be the most productive and useful source of N for transplanted rice (Kundu *et al* .,1990).

Budhar *et al.*, (1991) experimented with neem leaves as a source of nutrients and observed that it was capable of releasing nutrients in sufficient quantities to enable satisfactory growth of rice seedlings.

The benefits of green manuring include increase in available plant nutrients and organic matter content, improvement in physical and biological properties of soil and an overall increase in crop production (Singh, 1962). Budhar *et al.*, (1991) observed that P and K content of soil were higher in plots manured with *Pongamia glabra*, poultry manure and *Sesbania rostrata.*

Though the major effect is through N contribution, the favourable effects of organic matter addition and availability of other nutrients cannot be overlooked. Balasubramaniyam *et al.* (1993) reported that green manure treatments using *Pongamia glabra* or *Crotolaria juncea* @ 12.5 t/ha led to an increase in grain yield in two or three seasons. Also the plant uptake of N, P and K was increased by green manure and fertilizer N application.

Marinikumar *et al.* (1990) studied the effect of *Pongamia* leaf on soil microorganisms and showed that it had a positive influence on soil microbial population. Balasubramaniyam *et al.* (1993) used leaves of *Pongamia glabra* as a potential source of plant nutrients. . Also there was significant residual effect of green manure with regard to soil organic matter and total N (Gurung and Sherchan, 1996).

Joseph *et al.* (1991), Bal *et al.* (1993), Shinde (1995), Turkhede *et al.* (1996), Powar and Mehta (1997) and Chaphale *et al*. (2000) have all explored the possibility of using the leaves of *Gliricidia maculata* as a potential green leaf manure for rice.

In addition to this the use of neem (*Azadirachta indica*) leaves as green manure was investigated. It is reported that farmers in South India puddle leaves into the field before transplanting as it serves as an efficient nutrient source.The decompostion of Acacia leaves was studied in depth by Hegde (1995) and Konboon *et al.* (1998) and it was reported that long term addition brought about changes in soil carbon content.

Medhi and De Datta (1997) suggested that P uptake was improved with green manuring. The extent and rate of P adsorption declined with P application and green manuring while cropping increased it. Phosphorus application and green manuring also resulted in decrease in adsorption maxima in all soil types.

The P content of green manure crops and presence of crop are important factors worthy of consideration in P adsorption studies and better P management of soil (Bahl *et al.*, 1998).

Green manuring with *Sesbania aculeata* under submerged conditions led to decrease in soil solution pH, pE and increase in CO_2, partial pressure and Mn concentration (Sadana *et al.*, 1990). Addition of plant residues enhanced the rate of P release in anoxic soil (Hundal *et al.*, 1991). Manguiat *et al.* (1992) observed that available soil N was greatest with green manuring + N application and reached a maximum at 4 weeks after *Sesbania* incorporation.

Swarup (1991) reported that *Sesbania aculeata* green manure contributed 110 kg N / ha. He also observed that over four years, rice and wheat grain yields were increased on an average by 1.48 and 0.66 t/ha respectively with green manuring.

Application of green manure (*Sesbania aculeata*) to wet land rice increased the water table aggregates between 0.1 and 0.55 mm size by 62 per cent, reduced the soil bulk density and increased infiltration rate. After the crop, the soil water content in the 15-90 cm profile was higher in green-manured plots than in unmanured plots. Incorporation of green manure increased root density and grain yield and also improved the physical properties of soil under wetland rice (Boparai *et al.*, 1992).

According to Watanabe and Ventura (1992), grain production per unit weight of absorbed N was lower with green manure than with urea. Residual effects were observed with green manure but not with urea.

Treatment with urea produced significantly higher NH_4^+ N throughout the period of study (30 days) compared with control and treatments receiving *Sesbania* alone. In all treatments involving urea with or without *Sesbania,* NH_4^+ N released from *Sesbania* increased upto 7th day after fertilizer application and 40 day old *Sesbania* behaved similar to 60 day old *Sesbania* (Biswas and Goswami, 1995).

Sesbania green manuring enriched soil fertility by increasing organic matter level and P, K and S availability in soils (Pervin *et al.*, 1995). Wet soil NH_4^+ N increased by green manuring with *Sesbania* (Mahapatra and Sharma 1996).

Mahapatra *et al.* (1997) observed that applications of 80 kg N/ha as green manure a week before transplanting rice or substituting the basal dose of 50per cent N through green manuring plus 50per cent through prilled urea gave highest yield, and maintained higher available NH_4^+ N in soil and decreased losses of N through leaching and volatilization.

Ahmed *et al.* (1998) reported that incorporation of urea or manures alone or in combination with urea resulted in significantly higher leaching loss of N than control. Amongst organic manures, FYM, *S. aculeata* and *S. rostrata* leaching loss did not differ significantly. The effect of green manure (*Sesbania*) on Fe uptake was equivalent to application of 10 ppm of Fe (Chahal *et al.*, 1998).

Green manuring with *Sesbania* or incorporation of Moong bean residue resulted in recycling of 77 – 113 kg N / ha and increased plant uptake of N by 12 – 35 kg / ha (Sharma and Prasad 1999).

Abdul *et al.* (1999) reported that soil available N was greatest with sunnhemp followed by *dhaincha* and also P decreased the availability of N. Significantly higher NPK and protein contents were recorded with application of *dhaincha* green manure. Total nutrient uptake was significantly influenced with *dhaincha* green manure and higher fertilizer application (Dwivedi and Thakur, 1999).

Vendan and Rajeswari (1999) observed that incorporation of *S. aculeata* seeded at a higher seed rate and 100 kg inorganic N/ha increased post harvest soil total N, available N, available P and organic carbon content but there was a slight decrease in available K content.

Hemalatha *et al.* (2000) observed that organic manures like *dhaincha,* sunnhemp and FYM improved the yield, quality and soil fertility, with *dhaincha* incorporation resulting in pronounced increase of organic carbon content, available soil N, P and K.

Chakraborty *et al.* (2001) observed that grain and straw yields, N uptake and P recovery of rice and agronomic efficiency of P of rice was highest when *S. aculeata* was incorporated followed by fertilizer application @ 30, 15, 15 kg N, P and K/ha as basal dose to rice.

Gliricidia foliage application over a period of 5 years led to increase in organic carbon, total nitrogen, available N, P, K and water holding capacity and a reduction in bulk density in comparison to control (Chaphale *et al.*, 2000).

2.5 Crop residues and animal wastes

In sustaining agricultural production, the role of crop residues like rice and wheat straw and animal wastes like cow dung and poultry manure, is of immense importance. These unlike green manure or green leaf manures do not have to be grown specially rather they are easily available as by – products.

Organic manures including animal manures, crop residues, green manures and composts were traditionally and preferentially used in developing countries until 1960's when inorganic chemical fertilizers began to gain popularity due to their easy availability less of bulk and thus easiness in transport handling and storage (Dahama, 1996).

However, over four decades of inorganic fertilizer use has left the soil depleted and the environment polluted and now farmers are turning back to organic farming practices. The use of animal wastes and crop residues become as important if not more than, green manures as they are bulky organic manures and can supply large quantities of organic matter but small quantities of plant nutrients in comparison to inorganic fertilizers (Smaling *et al.*, 1997).

Farmyard manure of good quality is perhaps the most valuable organic matter applied to a soil and is the most commonly used organic manure in most countries of the world. Poultry manure is rich in plant nutrients and the content of N, P and K is double than that in farmyard manure (Dobermann and Fairhurst, 2000).

Another easily available by - product that has the potential to be organic manure in the rice farming tracts of the world is rice straw. It is the only organic material available in significant quantities to most rice farmers (Dobermann and Fairhurst, 2002)

Though a substantial amount of the straw produced is used as fodder, the possibility of incorporating both fresh straw or composted straw or even ash obtained from straw burning has been explored and the advantages of each have been studied by Ponnamperuma (1984), Qi- Xiao (1984) and Verma and Bhagat (1992).

The benefits of rice straw addition are recycling of nutrients, improving re – oxidation of topsoil layer and increase in water holding capacity (Brandon *et al.*, 1997).

2.6 Influence of crop residues and animal wastes on productivity of rice

Rice straw application in soils with high N levels did not become effective in improving the growth and yield of paddy till the fourth year whereas, in soils with low N, application of straw resulted in initial retardation of growth but was restored by the time the crop reach panicle initiation stage, however yield obtained was lesser than soil supplied with chemical fertilizer (Anzai *et al.*, 1989).

Application of rice straw increased straw and grain yields of rice variety IR-36 (Yodkeaw and De Datta, 1989). Also the incorporation of rice straw increased rice yields in the no- P plots (Kwak *et al.*, 1990). Jha *et al.* (1992) reported high rice grain yield with fresh rice straw + green manure and with 60kg N in three split applications. Grain yield of the following wheat crop was also highest in plots where rice had been incorporated along with green manuring.

Stable rice growth and yields would be obtained if rice straw is ploughed in during early autumn @ 60 kg to wet field and 100 kg to semi wet field, together with nitrogen basal dressings of 0.3-0.4 and 0.5 kg respectively (Kubota, 1992). In an experiment involving the use of organic manures in rice production, the highest grain yield was obtained by the use of poultry manure at 12.5 t / ha. (Budhar *et al.*, 1991).

Gupta *et al.* (1995) observed that highest rice yields were obtained with combined application of poultry manure and P. In addition, the concentration of phosphorus in rice tissue at different stages and P uptake at maturity increased with the application of P and, or manure.

Poultry manure did not perform better than urea in the first year of application, but by second and third years 120 kg and 180 kg as poultry manure produced significantly higher grain yields than the same rates as urea. Yields decreased with the use of urea, but poultry manure sustained the grain yields of rice (Singh *et al.*, 1996).

Farmyard manure (FYM) is the most widely used organic nutrient source in India and possibly the world over, the advantage being that it is readily available in sizeable quantities (Sharma and Mittra, 1991). Singh *et al.* (1996) reported that significantly higher grain and straw yields of rice and wheat were obtained with application of 10 t/ha of farmyard manure.

Rice grown with annual application of either 10 or 20 t FYM / ha gave average unpolished grain yield of 3.66 t / ha with 10 t FYM and 3.53 t with 20 t FYM / ha (Kobayashi *et al.*, 1989). Average yields of rice over a period of 20 years increased from 5.2 t with no FYM to 6.0 t with 20 t FYM and 5.89 t with 30 t / ha of FYM and in a similar trial rice yield of 6.6 t / ha was obtained with 40 t FYM / ha (Ohyama, 1989). Ikarashi *et al.* (1990) reported that plant height was the greatest with lower plant density and without FYM while leaf area index (LAI) was greater with FYM application.

Straw yields per plant and per sq m, were increased by FYM application, as was panicle straw ratio. The proportion of heavily diseased panicle was lower with FYM and higher plant density. Farm yard manure at 10 t / ha without inorganic fertilizers produced 3.54 t of grains / ha and gave the highest value of input cost ratio (Hussain *et al.*, 1991).Applying 10 t of FYM at transplanting increased grain yield of rice as much as applying 30 kg N / ha (Sharma and Mittra, 1991).

Chandrakar *et al.* (1990) reported maximum rice grain yield with 5.3 t/ha sunnhemp + 40kg N/ha in 1987 and with 8t/ha FYM + 40kg N/ha in 1988. Application of 80kg N/ha was on par with 40kg N/ha + 8t/ha FYM.

Application of FYM or wheat straw @ 10t/ha saved 50kg N/ha and gave maximum yield of rice. The carry over effect of FYM on wheat also had the trend similar to rice. The benefit cost ratio was maximum with FYM @ 10t/ha + 100 kg N/ha treatment in wheat and FYM alone in case of rice (Rajput and Warsi, 1992).

In tall indica rice cultivars, applications of cattle manure + NPK fertiliser and cattle manure + green manuring + NPK gave highest grain yield in the kharif and rabi season crops respectively (Anilakumar *et al.*, 1993). Bal *et al.* (1993) reported that application of N fertilizer, green manure and FYM increased N content and uptake.

Heavy application of cattle manure increased the plant height, number of tillers and grains/panicle but decreased the 1000 grain weight and total yield (Jin *et al.*, 1996). Green manuring with *Sesbania aculeata* or application of 20 t FYM/ha gave the highest yields in both consecutive years (Misra *et al.*, 1996).

Raman *et al.* (1996) found that in the first year of a trial, yield was highest with inorganic fertilizers only. After two-three years, the combination of organic and inorganic fertilizers gave similar yields to the inorganic treatments, while after another three-four years; the combined fertilizer treatments started giving higher yield than the inorganic sources. Farmyard manure was a more effective organic nutrient source than wheat straw and green manuring.

In trials with rice cultivars, Jaya and Byrnellu and hybrid KRH-1, yields were highest with 5t FYM followed by 10t FYM (Reddy and Shivaraj, 1999).

2.7 Influence of crop residues and animal wastes on soil fertility

Application of rice straw increased the uptake of Fe and Mn at different stages of growth but pH and Eh values of the soil decreased rapidly with decreasing rice straw addition (Yodkeaw and De Datta, 1989).

Successive application of rice straw resulted in marginal increase in yields in second and third seasons and also increases in uptake of silicic acid and potassium were observed. The pH of the topsoil was lowered along with the amount of exchangeable calcium and magnesium, however there was a gradual increase in the amount of exchangeable potassium. In the subsoil, the amounts of exchangeable Ca and Mg and available silicic acid were increased. The amounts of total nitrogen and carbon in subsoil did not increase with application of rice straw in spite of their increase in topsoil (Seki *et al.*, 1989).

Luo and Huang (1990) reported that addition of large quantities of rice straw reduced efficiency of applied N. Shiga *et al.* (1990) studied the uptake of N by rice from a gley paddy soil that had received continuous straw application for 10 years and calculated that the limit for continuous application of rice straw at an annual rate of 5 t/ha, was 7 years.

Li (1991) suggested the adoption of rice straw manuring to sustain better soil nutrient balance. The amounts of percolated total water-soluble organic carbon, hexose, Fe^{2+} and Mn^{2+} increased with increase in application level of rice straw (Kimura *et al.*, 1992). When 200 kg of fresh rice straw was returned to the field and 7.5 kg N / 670 m^2 applied, yield of rice increased while bulk density decreased from 1.165 g / cm^3 to 1.135 g / cm^3 (Li, 1994).

Application of pig manure, rice straw or urea increased soil porosity, the formation of large micro aggregates and organic matter and total N and C contents of the soil. Application of rice straw alone decreased the proportion of humic acids in the extracted humus (Sen *et al.*, 1994).

Drop in redox potential and Fe^{+2} suggested that the addition of straw hastened reduction of soil even under non-flooded conditions (Rath *et al.*, 1999)

Under continuously flooded conditions, the growth of rice was vigorous without straw addition and there was a strong response of rice growth to addition of P fertiliser. Straw addition enhanced P uptake by rice plants during loss of soil-water saturation, but its beneficial effects could not be attributed to direct addition of P, N or K to the soil (Seng *et al.* 1999).

Lal *et al.* (2000) reported that the incorporation of organic manures including rice straw significantly increased the populations of aerobic non-symbiotic nitrogen fixing, phosphate solubilising and sulphur oxidizing microorganisms. Incorporation of the wastes also significantly increased the pH and nutrient status of an acid soil.

Udayasoorian (1988) reported that continuous application of organic manure increased organic carbon content from 0.911 to 1.584 per cent. Among organic manures, FYM had a significant influence on organic carbon content (1.275 per cent) of surface soil followed by green leaf manure (*Gliricidia*), which gave 1.241 per cent.

Manuring with cattle dung increased the soil organic matter, phosphorus and potassium contents and pH. It also had a residual effect on soil organic matter content for two years, three years for phosphorus and one year for potassium and three years for pH. It was recommended that cattle dung be applied every alternate year (Hernandez *et al.*, 1989).

Farmyard manure application increased the N uptake by rice (Ohyama, 1989). Farmyard manure increased total porosity, gravimetric wetness, volumetric water content and available water capacity (Rose 1991). Availability of N, P and K in soil was increased with previous application of recommended NPK fertiliser + FYM (Selvi and Ramaswami, 1995).

In studies conducted in Bihar the application of farmyard manure was found to significantly bring down bulk density of both surface and subsurface soils in comparison with the control. Also higher porosity of the subsurface soil was recorded due to the application of FYM. Root length density and dry matter added through root was significantly higher in FYM treated plots (Singh *et al.*, 2000).

The levels of ammonium nitrogen in soils following application of FYM showed an increase throughout the growth period of the crop (Hideshima and Aikawa, 2001). Jeong *et al.* (1996) observed that N content of rice plants was higher and silicic acid content was lower in plant given with chicken manure.

Singh *et al.* (1996) found that the apparent N recovery by rice decreased from 45-28per cent on urea application but it remained the same for poultry manure. Also organic matter increased in the plots that were manured. A residual effect of poultry manure applied to rice to supply 120 or 180 kg N/ha was observed in wheat to the tune of 40kg N/ha.

O'Halloran's *et al.* (1997) discussed the possibility of using green and animal manure as a possible cheaper alternative to liming to correct soil acidity. The results showed that soil pH increased significantly from 4.92 in control plot to 5.32, six months after application of chicken manure. KCl extractable aluminium decreased significantly from 0.38 – 0.2 mol/kg along with decrease in aluminium saturation by 7.71per cent and significant increase in available phosphorus from 34.14 mg/kg in control treatment to 178.04 mg/kg.

2.8 Nutrient dynamics

2.8.1 Nitrogen

Nitrogen is the most important plant nutrient, being involved in the formation of proteins and also the chlorophyll content. A positive correlation between leaf N content and chlorophyll was observed by Mitsui and Ishii (1938). Increased yield with application of N was possible upto 180 kg/ha (Singh and Om, 1993 and Monapara *et a.*, 1993).

Jacob (1994) and Musthafa and Potty (1996) found that response of rice to N is limited below 70 kg/ha in laterite soils. Reduced NUE was attributed to increase in exchangeable Al and decrease in exchangeable cations (Patiram and Singh, 1993).

Nitrogen applied is taken up by plants or lost from soil/plant system by various mechanisms. Nitrogen can be lost by ammonia volatalization, denitrification, leaching, surface runoff, erosion and immobilization. (Simpson and Freney, 1974). Fertilized rice obtains 50-80per cent of its N requirement from the soil (Koyama, 1971 and Broadbent, 1978).

Mitsui (1954) estimated that in Japan rice recovers only 30-40 per cent of applied N. Yoshida and Padre (1975) reported that with straw addition, the total plant recovery of added ammonium sulphate increased by 21 per cent due to initial immobilization and slow mineralization.

Yoshida and Padre (1977) observed that most of the volatalization losses occurred in the first nine days after N application. Knowles (1982) concluded that factors controlling denitrification include oxygen, organic carbon, N oxides, pH, temperature and metabolic inhibitors

Takamura *et a.*, (1977) reported 16.6 per cent loss of N due to runoff and 4.7 per cent due to leaching, in Japan. Padmaja and Koshy (1978) found that approximately 70 per cent of total applied N was lost when the field was drained on same day of N fertilization.

Immobilization is regulated by the amount and type of carbonaceous material in soil (Broadbent and Nakashima, 1965). Koyama (1975) reported that a fairly large portion of fertilizer, about 30 per cent of basal N applied is immobilized even when no plant residue or compost are added. Smirnov (1977) reported 30 to 40 per cent immobilization of added N in the soil organic matter from pot and field experiment with cereals.

2.8.2 Phosphorus

It is one of the three most important elements along with N and K. Phosphorus is associated with metabolic processes such as synthesis and breakdown of carbohydrates, fats and proteins (Anonymous, 1961). Majumdar(1973) found that recovery of applied P was only 2 per cent. Mosi *et al* (1973) concluded that low land rice was not as likely to respond to addition of phosphatic fertilizers as upland rice.

The availability of P is controlled by soil pH, soluble Fe, Al and Mn, available Ca and Ca minerals, amount and decomposition of organic matter and the activity of microbes and the availability in acid soils is influenced by the soluble Fe, Mn, and Al which results in formation of insoluble hydroxy precipitates (Brady, 1996).

Release of soil P in flooded soil may be attributed to reduction of ferric phosphate to the more soluble ferrous phosphate by organic anions (Shapiro, 1958). However, the beneficial effects of flooding on phosphate availability depend on intensity of reduction and the anion content of soil (Davide, 1960).

When organic residues low in P, but high in other nutrients are added to soil, rapid microbial activity takes place and available H_2PO_4 in soil solution temporarily disappears due to absorption of inorganic P ions and subsequent conversion to organic tissue, thus, immobilising it (Brady,1996). Alam and Azmi (1989), observed an increase in content of N, P, K, Cu, Mn, and Fe with P application and decreased Zn uptake.

2.8.3 Potassium

Potassium fixation in the soil occurs due to nature of colloids, wetting and drying of soil and also due to presence of excess lime. The major mechanism by which K is lost from the soil is by erosion (Brady, 1996).The requirement of K by plant is high. Mikkelsen and Patrick (1968) indicated that 75 per cent of total amount of potassium is absorbed prior to the booting stage and no absorption takes place from grain forming to grain filling.

Dixit and Sharma (1993) observed a significant reduction in concentration of Al, Fe and acidity of soil by addition of K. Mitra *et al.* (1990) evaluated effects of higher levels of K on rice in iron toxic laterite soil and reported that Fe toxicity symptoms decreased with increased K application.

MATERIALS AND METHODS

3. Materials and Methods

A field experiment was carried out during the Kharif season of the year 2000 to assess the efficacy of various green leaves and organic manures in relation to nutrient accretion, rice growth and yield. In addition to the field experiment, an incubation study also was carried out at the College of Horticulture to study the nitrogen mineralization pattern and changes in carbon nitrogen relations in soil. The details of materials used and methods followed for the conduct of the experiments are presented in the following sections.

3.1 Experiment 1. Field Experiment

3.1.1 Location

The experiment was laid out at the Agricultural Research Station, Mannuthy, Thrissur District, under the Kerala Agricultural University, which is located at 12^0 32' N latitude and 74^0 20' E longitude. The site selected for the experiment is located at an altitude of 22.5 m above MSL.

3.1.2 Soil

The soil of the experimental field was sandy clay loam in texture. The physical and chemical properties of soil based on analysis carried out on composite samples collected from 0 – 30 cm before commencement of the experiments are *presented in Table.3.1.*

3.1.3 Climate

The area enjoys tropical humid climate. The relevant meteorological data pertaining to the experiment site during the period of investigation are presented in Fig 3.1 and Appendix I.

Table 3. 1 : Physico chemical characteristics of the experimental field

Particular	***Value***	***Procedure adopted***
Mechanical Composition		
Coarse sand (%)	27.1	Robinson's International pipette method, Piper (1950)
Fine sand (%)	23.9	
Silt (%)	22.8	
Clay (%)	26.2	
Texture	Sandy clay loam	
Physical constants of the soil		
Field capacity (0.3)	21.82	Pressure plate apparatus, Richards (1954)
Permanent wilting point (15 bars)	9.34	
Bulk density g / cm^3	1.34	Core sampler method, Black (1965)
Particle density g / cm^3	2.16	Pycnometer method, Black (1965)
Chemical Composition		
Organic carbon %	0.66	Modified Walkely-Black method , Jackson (1973)
Available nitrogen (kg / ha)	258.4	Alkaline permanganate method, Subbiah and Asija (1956)
Available phosphorus (kg / ha)	11.5	Ascorbic acid blue colour method, Watanabe and Olsen (1965)
Available potassium (kg / ha)	94.8	Neutral normal ammonium acetate extractant – flame photometry, Jackson (1973)
Soil reaction (pH)	5.5	1: 2.5 , soil : water suspension using pH meter, Jackson (1973)

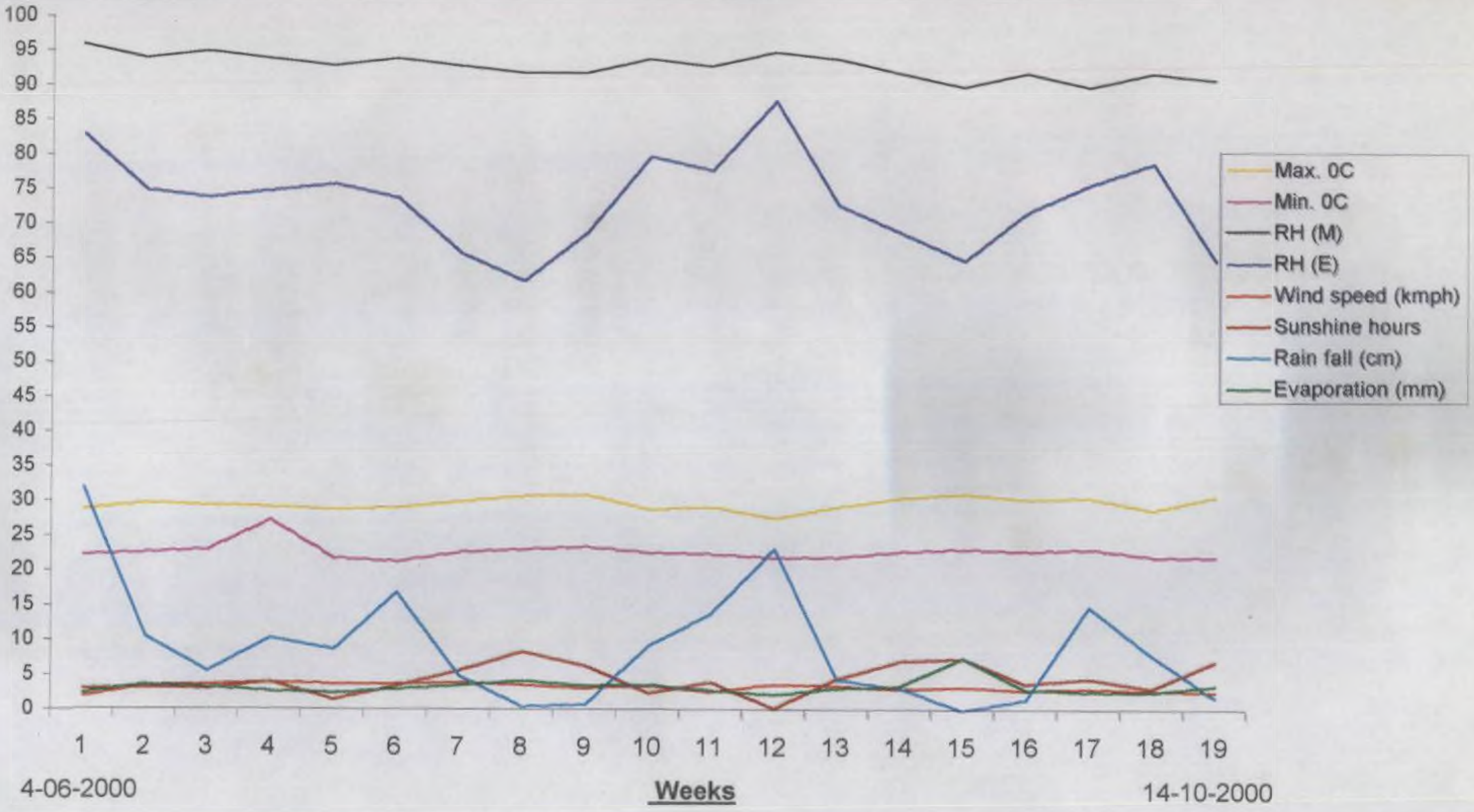


Fig. 3.1 Weekly weather data during the crop period

3.2 Cropping history

The experimental site was a double - cropped paddy wetland in which a semi dry crop (May – September) and wet crop (September – December) are regularly cultivated. The land is usually left fallow during summer season.

3.3 Variety

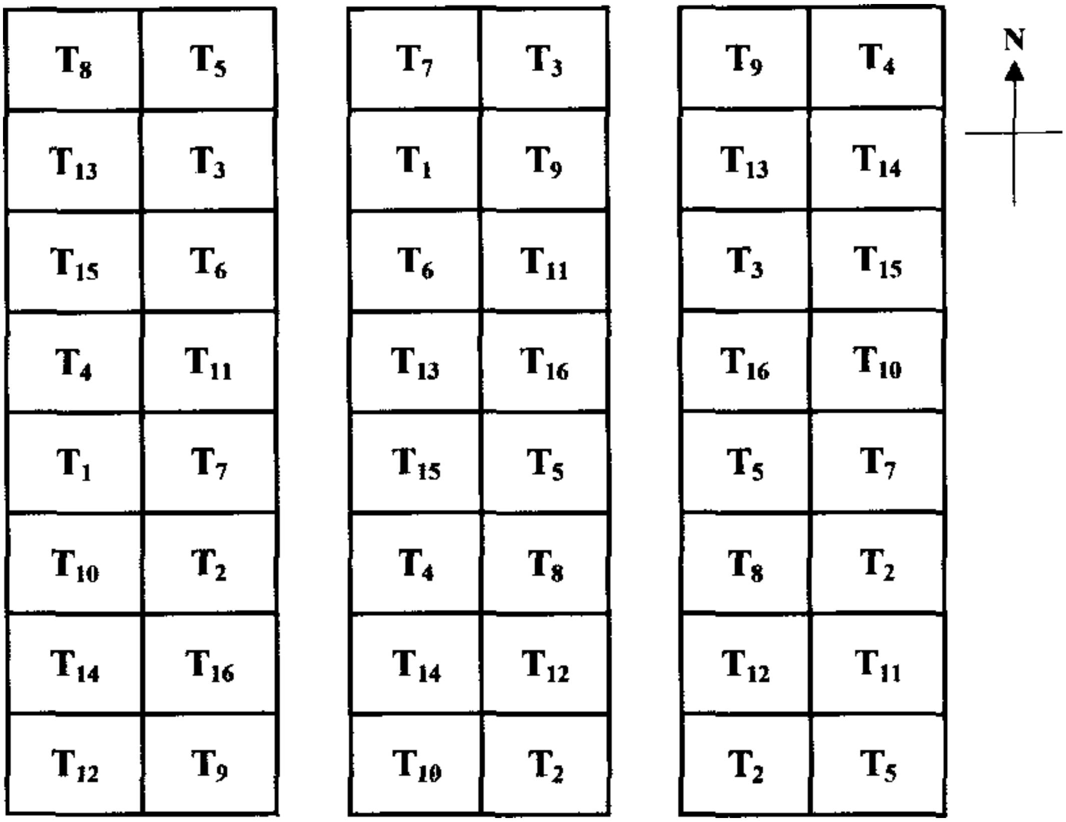
The rice variety used in the experiment was Matta Triveni (PTB – 45), which is of 100 – 105 days duration. It is a high yielding variety with red bold grains and is highly suited for conditions in Kerala (KAU, 1996).

3.4 Design and treatments

The experiment was laid out in a randomized block design with three replications and 16 treatments in each replication. The plot size allocated in each individual treatments was 5 x 4 m^2. The layout plan is presented in Fig 3.2

The details of treatments followed during the experiments are given below.

T_1	Green leaf manuring with Neem (*Azadirachta indica*) + NFR*
T_2	Green leaf manuring with Pongamia (*Pongamia glabra*) + NFR
T_3	Green leaf manuring with Mango (*Mangifera indica*) + NFR
T_4	Green leaf manuring with Jack (*Artocarpus integrifolius*) + NFR
T_5	Green leaf manuring with Acacia (*Acacia auriculiformis*) +NFR
T_6	Green leaf manuring with Gliricidia (*Gliricidia maculata*) + NFR
T_7	Green leaf manuring with Dhaincha (*Sesbania aculeata*) +NFR
T_8	Green leaf manuring with Terminalia (*Terminalia paniculata*) +NFR
T_9	Green leaf manuring with Macaranga (*Macaranga peltata*) + NFR
T_{10}	Incorporation of rice straw + NFR
T_{11}	Incorporation of Cow dung + NFR



T_8	T_5	T_7	T_3	T_9	T_4
T_{13}	T_3	T_1	T_9	T_{13}	T_{14}
T_{15}	T_6	T_6	T_{11}	T_3	T_{15}
T_4	T_{11}	T_{13}	T_{16}	T_{16}	T_{10}
T_1	T_7	T_{15}	T_5	T_5	T_7
T_{10}	T_2	T_4	T_8	T_8	T_2
T_{14}	T_{16}	T_{14}	T_{12}	T_{12}	T_{11}
T_{12}	T_9	T_{10}	T_2	T_2	T_5

Fig. 3.2: Layout of field experiment

T_1 – Neem leaf + NFR
T_2 – Pongamia leaf + NFR
T_3 – Mango leaf + NFR
T_4 – Jack leaf + NFR
T_5 – Acacia leaf + NFR
T_6 – Gliricidia leaf + NFR
T_7 – Sesbania leaf + NFR
T_8 – Terminalia leaf + NFR
T_9 – Macaranga leaf + NFR
T_{10} – Straw + NFR
T_{11} – Cowdung + NFR
T_{12} – Poultry manure + NFR
T_{13} – No organics (Normal fertilizer recommendation)
T_{14} – Fertilizer equivalent of organic source
T_{15} – 50 % of fertilizer equivalent of organic source
T_{16} – Absolute control

T_{12}	Incorporation of poultry manure + NFR
T_{13}	No Organics (Normal fertilizer recommendation only)
T_{14}	Fertilizer equivalent of organic source.
T_{15}	50 per cent of the Fertilizer equivalent of organic source
T_{16}	Absolute control

* Normal fertilizer recommendation for short duration HYVs

Fertilizer equivalent of organic source (T_{14}) was calculated based on the N, P and K content of pongamia leaf taking into account the relatively higher contents of particularly N and K. All the organic sources were applied at 5 t/ha on dry weight basis. Rice straw (T_{10}), cow dung (T_{11}) and poultry manure (T_{12}) were sun dried to constant weight and applied. Green leaf manure treatments were applied taking into consideration the corresponding driage and fresh weight required, driage and major nutrients accreted are given in Table 3.2 Absolute control (T_{16}) treatment received neither organic nor inorganic fertilizers.

3.5 Crop establishment

The soil was ploughed and puddled twice and individual plots were then established. Seedlings raised by wet nursery method using seeds from agricultural research Station, Mannuthy were used for the study. Twenty-three days old seedlings of uniform growth were transplanted at 15 x 10 cm spacing on 6th July, 2000 at the rate of two to three seedlings per hill.

The normal fertilizer recommendation for high yielding short duration varieties *viz.,* 70:35:35 kg N, P and K per hectare was followed. Fertilizer materials used were Urea (46per cent N), Rajphos (20per cent P) and Muriate of potash (60per cent K). Phosphorus was applied as a single dose at the time of final levelling of the plots. On the third day after transplanting (DAT) water was drained out and basal dose of fertilizer (half N and half K) was applied. The remaining half N and K was top dressed at 40 DAT.

Table 3.2: Fresh weight incorporated, driage and nutrients accreted from organics

Treatments	Fresh weight (t / ha)	Driage (%)	Nutrients accreted at 5 t/ ha		
			N (kg / ha)	P (kg / ha)	K (kg / ha)
Neem leaf	15.00	33.33	121	7.5	87.5
Pongamia leaf	14.38	34.78	154	8	90
Mango leaf	16.38	30.51	73	7	66.5
Jack leaf	14.87	33.61	98	6.5	95.5
Acacia leaf	14.06	35.55	50.5	5	82
Gliricidia leaf	17.50	28.57	145	8.5	110.5
Sesbania leaf	17.98	27.81	165	22.5	68.5
Terminalia leaf	15.66	31.93	85	20	81
Macaranga leaf	18.61	26.87	99	10.5	125
Straw	5.00	-	33	4	91.5
Cowdung	5.00	-	27.5	15.5	21
Poultry manure	5.00	-	105.5	35.5	40.5

Gap filling of missing or dead hills was done on the tenth day after transplanting. Water level was maintained at five to six cm of standing water in the field. Hand weeding of the plots was done at 20 DAT.

Harvesting was done at 105 days after transplanting. Two rows towards the periphery of each individual plot was harvested and removed first. An area of 1 x 4 m^2 next to border plants at one side of the plot was kept as destructive sampling area. The individual plots were then harvested and threshed separately.

3.6 Details of data collection

3.6.1 Soil Sampling

Initially soil samples were taken with the help of a spade and a representative sub-sample was drawn from this. In the later stages of the crop, a soil auger was used to take samples from the field.

3.6.2 Plant sampling

In each plot, 3 stakes were driven and the four hills around each stake were maintained for data collection with respect to plant height and tiller number.

For laboratory studies, six hills were collected randomly from the destructive sampling area of each plot at 35 DAT, 70 DAT and at harvest. These samples were dried to constant weight, powdered and used for further chemical analysis.

3.6.3 *Growth characters*

a) Plant height: Plant height was measured from bottom of the tillers to the tip of the longest leaf at 25, 45, 70 DAT and at harvest.

b) Number of tillers: The number of tillers were counted at 25, 45, 70 DAT and at harvest and expressed as number of tillers per hill.

c) Root and plant dry matter: The dry weight of the roots and shoots at different intervals were taken and used to estimate total dry matter production (t ha^{-1}).

d) Cell sap pH and Chlorophyll content: The cell sap pH of the plants were recorded at 30 DAT and 60 DAT and chlorophyll content (µg/g) was estimated in terms of chlorophyll *a,* chlorophyll *b* and total chlorophyll at 35 and 45 DAT. For both these analysis, fresh leaf samples were drawn from the field as per standard sampling procedure as and when required. Chlorophyll content of fresh leaf sample was determined at 35, and 45 DAT using acetone extraction method. (Yoshida *et al.,* 1972). The cell sap was analysed for pH by using a pH meter. A 1: 2.5-leaf sample: water suspension was utilized (Jackson, 1973).

3.7 Yield attributes:

a) Number of productive tillers per hill: The number of productive tillers of twelve hills were counted from each individual plot at harvest and expressed as average number of tillers per hill.

b) Number of spikelets per panicle: The total number of spikelets per panicle was obtained by counting the number of spikelets in each panicle of the twelve observation hills and average was worked out.

c) Length of the panicle: Measured in cm from the base to the tip of the panicle and was recorded as average length of the panicle.

d) Percentage of chaff: From the total number of grains per panicle, the number of chaffy grains were recorded and expressed on percentage basis.

e) Test weight: Thousand filled grains were collected randomly from samples taken from each plot and weight was recorded in grams.

f) Yield of grain and straw: All hills in the net plot area were harvested and threshed and dried to constant weight and the grain and straw yields were calculated and expressed on dry weight basis.

3.8 Laboratory studies

3.8.1 Soil analysis

3.8.1.1 Physical properties

The soil samples were analysed for pH and Eh using portable pH and Eh meters before the experiment, 40 DAT, 70 DAT and at harvest. The bulk density of the soil was determined by using a core sampler during the above stages. It was used to remove the soil samples, which were then weighed and kept for moisture determination from which bulk density was determined by dividing weight of soil by the volume occupied by it and expressed as g/cm^3.

3.8.1.2 Chemical analysis

Organic Carbon

Organic carbon in the soil samples was determined using modified Walkely – Black method (Jackson 1973).

Available Nitrogen

One gram of the sieved sample was used to determine available nitrogen by the method of Subbiah and Asija (1956).

Available Phosphorus and Potassium

Available phosphorus in soil was extracted by Bray No.1 Extractant and the phosphorus content was then determined by ascorbic acid blue colour method (Watanabe and Olsen, 1965) using a Spectonic 20 spectrophotmeter. Available potassium was extracted by neutral normal ammonium acetate and read in flame photometer (Jackson, 1973).

3.8.2 Plant analysis

Samples were dried to constant weight in a hot air oven at 70°C and then powdered and composite samples were used for analysis.

Kjeldahl digestion and distillation method (Jackson 1973) was used to determine the total N content in plant samples. For determination of P and K, a known quantity of the sample was digested in a mixture of nitric acid and perchloric acid in 9:4 proportions. The P content was determined colorimetrically by vanado-molybdate phosphoric yellow colour method and K was determined using a flame photometer (Jackson 1973).

Secondary nutrients such as Ca and Mg, micronutrients like Fe, Zn, Mn, Cu, and Na. The di-acid extract used for analysis of P and K was used for the estimation of these elements, which were determined using atomic absorption spectrophotometer (AAS) calibrated with suitable standards and read at recommended wavelengths.

3.8.3 Analysis of organics

Samples of all the green manures, green leaf manures, crop residue and animal wastes used in the experiment were taken and analysed for macro and micronutrients, organic carbon, lignin content and crude fibre. The composition of the organic sources used are presented in Table 3.3 and Table3.4

Kjeldahl digestion and distillation method (Jackson 1973) was used to determine the total N content in plant samples. For determination of P and K, a known quantity of the sample was digested in a mixture of nitric acid and perchloric acid in 9:4 proportions. The P content was determined colorimetrically by vanado molybdo phosphoric yellow colour method and K was determined using a flame photometer (Jackson 1973).

Table 3.3 : Concentrations of major, secondary and micro nutrients in organics

Treatments	N %	P %	K %	Ca (mg /g)	Mg (mg /g)	Cu µg /g	Zn (µg /g)	Fe (mg /g)
Neem leaf	2.41	0.15	1.75	26.68	4.24	13.54	43.96	0.31
Pongamia leaf	3.08	0.16	1.80	16.84	3.55	9.67	31.52	0.19
Mango leaf	1.46	0.14	1.33	20.34	3.08	7.74	23.09	0.69
Jack leaf	1.96	0.13	1.91	18.01	3.11	7.84	20.42	0.24
Acacia leaf	1.01	0.10	1.64	16.01	2.31	5.80	17.76	0.13
Gliricidia leaf	2.90	0.17	2.21	12.34	5.86	9.67	18.20	0.16
Sesbania leaf	3.30	0.45	1.37	34.02	2.02	9.07	28.86	0.29
Terminalia leaf	1.70	0.40	1.62	26.31	4.13	10.03	19.21	0.29
Macaranga leaf	1.98	0.21	2.50	10.01	2.47	11.60	20.42	0.30
Straw	0.66	0.08	1.83	3.36	1.36	8.67	32.33	0.48
Cowdung	0.55	0.31	0.42	28.00	5.01	4.4	36.0	0.14
Poultry manure	2.11	0.71	0.81	9.10	1.93	2.8	14.5	0.10

Table 3.4 : Organic carbon, lignin and fibre contents of source materials

Treatments	Organic Carbon (%)	Lignin (%)	Fibre % (NDF)	C/N ratio	Lignin / N ratio
Neem leaf	44.6	10.95	26.9	18.51	4.54
Pongamia leaf	49.1	10.06	22.2	15.94	3.27
Mango leaf	37.8	18.46	34.4	25.89	12.64
Jack leaf	38.9	17.88	32.8	19.84	9.12
Acacia leaf	40.8	19.24	39.6	40.39	19.05
Gliricidia leaf	40.7	8.16	22.3	14.03	2.81
Sesbania leaf	48.6	8.94	22.4	14.72	2.70
Terminalia leaf	41.2	14.64	24.8	24.23	8.61
Macaranga leaf	41.5	13.61	30.9	20.96	6.87
Straw	36.7	18.73	40.4	55.60	28.38
Cowdung	22.3	5.61	13.6	14.39	3.62
Poultry Manure	33.8	2.04	8.4	16.02	0.97

Secondary nutrients such as Ca and Mg, micronutrients such as, Fe, Zn, Mn, Cu, and Na, were determined using atomic absorption spectrophotometer (AAS) following the same methods used for plant sample analysis.

Lignin content was estimated by spectrophotometric method using acetyl bromide (Hatfield, 2001) and crude fibre was estimated following the method described by Maynard (1970). Organic carbon content of the organic sources was estimated using the method suggested by el Wakeel and Riley (1956). The C: N and lignin: N ratios were also worked out and are presented in Table 3.4

3.9 Experiment 2. Incubation study

An incubation study using the same treatments as in the field experiment was conducted to understand the degradation and decomposition of the various organic and inorganic sources and establish the mineralization patterns of major nutrients, especially nitrogen at 5 t/ha on dry weight basis. The incubation was carried out at saturated moisture status. The study was conducted for duration of 100 days.

The physico-chemical characters of the soil used are given in Table 3. 1. Hundred grams of the soil was placed in glass conical flasks and corresponding amount of organic and inorganic fertilizer as in Experiment 1 were applied to the soil and maintained at saturated moisture status. Thirty six replications were kept for each treatment and three replications were drawn at five day intervals up to 40 days and later at 15 days intervals and analysed for organic carbon by modified Walkley - Black method (Jackson, 1973), extractable NH_4^+ and $N0_3^-$ (Bremner, 1965), available phosphorus by ascorbic acid blue colour method (Watanabe and Olsen, 1965) and available potassium by extracting with neutral normal ammonium acetate and read on flame photometer (Jackson, 1973). The pH of the soil was determined using a portable pH meter.

3.10 Statistical analysis

The statistical analyses were done using the MSTAT-C package developed by Harvard University.

RESULTS

4. Results

4.1 Soil characteristics

4.1.1 Soil pH, Eh and Bulk Density

Soil pH, Eh and bulk density were determined to evaluate the effect of organic amendments on degree of acidity, state of oxidation or reduction and density of the soil. Mobility of the nutrients is highly dependent on the pH and Eh of the soils. The results are summarized in Table 4.1.

At 40 DAT pH values, varied between 5.1 and 5.7, in FE treated and pongamia leaf treated plots, respectively. Macaranga leaf treated plots recorded highest pH of 5.6 whereas, the lowest value of 5.1 was observed for the plots treated with jack and sesbania leaves, at 70 DAT. At harvest stage, highest pH of 5.7 was recorded in the control plot, whereas, the lowest pH of 5.1 was observed in the plot treated with sesbania leaves.

Soil Eh is indicative of the stage of oxidation or reduction of the soil at a particular point of time. Variations were observed in the soil Eh values ranging from 82 mv to 123 mv at 40 DAT. Plots treated with cowdung showed lowest values of Eh whereas, control plot maintained highest values as compared to other plots. The Eh values further dropped to 29 mv and 66 mv, respectively, at harvest.

At 40 DAT, the bulk density was highest in poultry manure treated plots (1.35 g/cm$^{3)}$ while the least value of 1.32 g/cm^3 was recorded for plots treated with pongamia, gliricidia and cowdung. At 70 DAT, the maximum value was obtained from control plots (1.35 g/cm^3) while the least value of 1.31 g/cm^3 was obtained from plots treated with cowdung, sesbania and gliricidia leaves. At harvest, the highest value was obtained in control plots (1.35 g/cm^3) while the lowest value was recorded in plots treated with cowdung and pongamia leaves (1.30 g/cm^3).

Table 4.1 : Effect of treatments on soil pH, Eh (mv) and bulk density

Treatments	pH			Eh (mv)		Bulk density (g / cm^3)		
	40 DAT	70 DAT	Harvest	40 DAT	Harvest	40 DAT	70 DAT	Harvest
Neem leaf	5.5^{b}	5.4^{bc}	5.6^{ab}	110^{de}	46^{i}	1.33^{a}	1.33^{a}	1.31^{a}
Pongamia leaf	5.1^{d}	5.2^{de}	5.5^{bc}	117^{bc}	54^{de}	1.32^{a}	1.32^{a}	1.30^{a}
Mango leaf	5.3^{c}	5.3^{cd}	5.3^{de}	112^{d}	49^{h}	1.34^{a}	1.34^{a}	1.33^{a}
Jack leaf	5.2^{cd}	5.1^{e}	5.4^{cd}	115^{c}	55^{d}	1.33^{a}	1.33^{a}	1.32^{a}
Acacia leaf	5.5^{b}	5.5^{ab}	5.3^{de}	115^{c}	52^{ef}	1.34^{a}	1.33^{a}	1.33^{a}
Gliricidia leaf	5.6^{ab}	5.2^{de}	5.6^{ab}	110^{de}	51^{fg}	1.32^{a}	1.31^{a}	1.31^{a}
Sesbania leaf	5.3^{c}	5.1^{e}	5.1^{f}	108^{ef}	49^{gh}	1.33^{a}	1.31^{a}	1.31^{a}
Terminalia leaf	5.6^{ab}	5.5^{ab}	5.3^{de}	119^{b}	49^{gh}	1.34^{a}	1.32^{a}	1.32^{a}
Macaranga leaf	5.5^{b}	5.6^{a}	5.2^{ef}	102^{g}	51^{fg}	1.34^{a}	1.32^{a}	1.31^{a}
Straw	5.2^{cd}	5.3^{cd}	5.3^{de}	111^{d}	53^{def}	1.34^{a}	1.33^{a}	1.33^{a}
Cowdung	5.2^{cd}	5.3^{cd}	5.4^{cd}	82^{i}	29^{k}	1.32^{a}	1.31^{a}	1.30^{a}
Poultry manure	5.3^{c}	5.4^{bc}	5.3^{de}	91^{h}	34^{j}	1.35^{a}	1.34^{a}	1.34^{a}
No Organics	5.3^{c}	5.3^{cd}	5.4^{cd}	119^{b}	53^{ef}	1.34^{a}	1.33^{a}	1.33^{a}
Fertilizer equivalent (FE)	5.7^{a}	5.2^{de}	5.6^{ab}	106^{f}	60^{b}	1.34^{a}	1.34^{a}	1.33^{a}
50 % FE	5.5^{b}	5.4^{bc}	5.2^{ef}	102^{g}	57^{c}	1.34^{a}	1.33^{a}	1.33^{a}
Control	5.6^{ab}	5.5^{ab}	5.7^{a}	123^{a}	66^{a}	1.34^{a}	1.35^{a}	1.35^{a}
Before the experiment	5.5			51		1.34		

4.1.2 Organic carbon content in soils

Concentrations of organic carbon in soil at different stages of the study are presented in Table 4.2. No significant difference in the soil organic carbon content was observed at 35 DAT, 70 DAT and harvest. However, in all the treatments where organics and inorganics were added there was an increasing trend in organic carbon content but in the absolute control plots it was reduced or maintained with time. Among the different organics, cowdung showed a notable increasing trend in organic carbon content.

4.1.3 Available N content of soil

The values of available N content in the soils at different stages of the crop are given in Table 4.3. The highest value of available N was obtained from FE treated plots (288.1 kg/ha), whereas, the least was recorded from straw incorporated plot (238.1 kg/ha), at 35 DAT. At 70 DAT the highest value was obtained for FE with 260.4 kg / ha with the minimum value of 230.6 kg / ha reported from control plot. At harvest too, the highest concentration of available N was recorded from FE treated plots (245.9 kg/ha) whereas, the least concentration was observed from control plot 211.9 kg / ha.

The difference in available N contents at different stages was worked out and between 35 DAT and 70 DAT, the maximum difference was noticed in sesbania treatment (30.4 kg/ ha), with cow dung (29.5 kg/ ha), gliricidia (29.2 kg/ ha) and 50 per cent FE (29.1 kg / ha) being on par. The least difference was observed in straw treatment (1 kg/ ha) with mango, jack and acacia also being comparatively less.

4.1.4 Available P content of soil

The details of the observations made are presented in Table 4.4. At 35 DAT, the highest content of available P was recorded in poultry manure incorporated plots (15.82 kg/ha) while the least content was recorded from control plot (11.17 kg/ha).

Table 4.2 : Effect of treatments on organic carbon content (%)

Treatments	35 DAT	70 DAT	Harvest
Neem leaf	0.67 [a]	0.69 [a]	0.70 [a]
Pongamia leaf	0.68 [a]	0.68 [a]	0.70 [a]
Mango leaf	0.66 [a]	0.67 [a]	0.67 [a]
Jack leaf	0.67 [a]	0.67 [a]	0.68 [a]
Acacia leaf	0.66 [a]	0.68 [a]	0.69 [a]
Gliricidia leaf	0.68 [a]	0.69 [a]	0.69 [a]
Sesbania leaf	0.67 [a]	0.68 [a]	0.68 [a]
Terminalia leaf	0.66 [a]	0.67 [a]	0.67 [a]
Macaranga leaf	0.67 [a]	0.68 [a]	0.68 [a]
Straw	0.66 [a]	0.67 [a]	0.67 [a]
Cowdung	0.69 [a]	0.71 [a]	0.72 [a]
Poultry manure	0.66 [a]	0.68 [a]	0.68 [a]
No Organics	0.66 [a]	0.67 [a]	0.67 [a]
Fertilizer equivalent(FE)	0.67 [a]	0.67 [a]	0.68 [a]
50 % FE	0.66 [a]	0.66 [a]	0.67 [a]
Control	0.65 [a]	0.66 [a]	0.66 [a]

* initial value of organic carbon was 0.66 %

Table 4.3 : Effect of treatments on available N content (kg / ha) of soil

Treatments	35 DAT	70 DAT	Harvest	Differences in available N content at		
				35 – 70 DAT	70 DAT-Harvest	35 DAT - Harvest
Neem leaf	261.6 ^{e}	249.0 ^{bcde}	229.4 ^{fgh}	12.6 ^{g}	19.6 ^{a}	32.2 ^{ef}
Pongamia leaf	272.5 ^{c}	253.2 ^{b}	239.5 ^{b}	19.3 ^{e}	13.7 ^{g}	33.0 ^{ef}
Mango leaf	253.9 ^{g}	248.9 ^{bcde}	232.3 ^{de}	5.0 ^{i}	16.6 ^{d}	21.6 ^{h}
Jack leaf	258.2 ^{f}	252.5 ^{bc}	234.8 ^{c}	5.7 ^{hi}	17.7 ^{bc}	23.4 ^{h}
Acacia leaf	248.1 ^{h}	241.2 ^{fgh}	231.3 ^{def}	6.9 ^{h}	9.9 ^{h}	16.8 ^{i}
Gliricidia leaf	279.3 ^{b}	250.1 ^{bcd}	230.9 ^{def}	29.2 ^{ab}	19.2 ^{a}	48.4 ^{a}
Sesbania leaf	273.2 ^{c}	242.8 ^{efgh}	227.6 ^{ghi}	30.4 ^{a}	15.2 ^{ef}	45.6 ^{b}
Terminalia leaf	256.4 ^{fg}	243.9 ^{defg}	229.3 ^{fgh}	12.5 ^{g}	14.6 ^{fg}	27.1 ^{g}
Macaranga leaf	259.0 ^{ef}	241.6 ^{fgh}	227.5 ^{hi}	17.4 ^{f}	14.1 ^{g}	31.5 ^{f}
Straw	238.1 ^{j}	237.1 ^{h}	220.3 ^{j}	1.0 ^{j}	16.8 ^{cd}	17.8 ^{i}
Cowdung	271.7 ^{c}	242.2 ^{fgh}	226.3 ^{i}	29.5 ^{a}	15.9 ^{de}	45.4 ^{b}
Poultry manure	273.7 ^{c}	246. 8 ^{cdef}	232.8 ^{cd}	26.9 ^{c}	14.0 ^{g}	40.9 ^{c}
No Organics	265.3 ^{d}	240.7 ^{fgh}	230.4 ^{ef}	24.6 ^{d}	10.3 ^{h}	34.9 ^{e}
Fertilizer equivalent (FE)	288.1 ^{a}	260.4 ^{a}	245.9 ^{a}	27.7 ^{bc}	14.5 ^{fg}	42.2 ^{c}
50 % FE	267.4 ^{d}	238.3 ^{gh}	229.8 ^{fg}	29.1 ^{ab}	8.5 ^{i}	37.6 ^{d}
Control	243.7 ^{I}	230.6 ^{i}	211.9 ^{k}	13.1 ^{g}	18.7 ^{ab}	31.8 ^{f}

Table 4.4 : Effect of treatments on available P content (kg / ha) in soil

Treatments	35 DAT	70 DAT	Harvest	Differences in available P content at		
				35 DAT -70 DAT	70 DAT - Harvest	35 DAT - harvest
Neem leaf	12.86 ^{de}	12.05 ^{de}	11.33 ^{fgh}	0.81 ^{d}	0.72 ^{c}	1.53 ^{f}
Pongamia leaf	12.92 ^{de}	12.36 ^{c}	11.48 ^{def}	0.56 ^{e}	0.88 ^{b}	1.44 ^{g}
Mango leaf	12.08 ^{efg}	12.15 ^{cde}	11.43 ^{efg}	- 0.07 ^{g}	0.72 ^{c}	0.65 ^{l}
Jack leaf	12.15 ^{efg}	12.21 ^{cd}	11.65 ^{cd}	- 0.06 ^{g}	0.56 ^{d}	0.50 ^{m}
Acacia leaf	11.63 ^{fg}	12.07 ^{de}	11.26 ^{ghi}	- 0.44 ^{h}	0.81 ^{bc}	0.37 ^{n}
Gliricidia leaf	14.33 ^{bc}	12.58 ^{b}	11.83 ^{c}	1.75 ^{b}	0.75 ^{c}	1.00 ^{i}
Sesbania leaf	14.86 ^{ab}	12.69 ^{b}	12.09 ^{b}	2.17 ^{a}	0.60 ^{d}	2.77 ^{b}
Terminalia leaf	13.72 ^{cd}	12.22 ^{cd}	11.83 ^{c}	1.5 ^{c}	0.39 ^{e}	1.89 ^{d}
Macaranga leaf	12.38 ^{ef}	11.93 ^{ef}	11.59 ^{de}	0.45 ^{ef}	0.34 ^{ef}	0.79 ^{k}
Straw	11.58 ^{fg}	11.73 ^{fg}	11.21 ^{hi}	- 0.15 ^{g}	0.52 ^{d}	0.37 ^{n}
Cowdung	13.03 ^{de}	12.65 ^{b}	12.39 ^{a}	0.38 ^{f}	0.26 ^{f}	0.64 ^{l}
Poultry manure	15.82 ^{a}	13.53 ^{a}	12.45 ^{a}	2.29 ^{a}	1.08 ^{a}	3.37 ^{a}
No Organics	14.98 ^{ab}	13.37 ^{a}	12.30 ^{a}	1.61 ^{bc}	1.07 ^{a}	2.68 ^{c}
Fertilizer equivalent (FE)	13.01 ^{de}	12.13 ^{cde}	11.36 ^{fgh}	0.88 ^{d}	0.77 ^{c}	1.65 ^{e}
50 % FE	12.35 ^{ef}	11.60 ^{g}	11.08 ^{i}	0.75 ^{d}	0.52 ^{d}	1.27 ^{h}
Control	11.17 ^{g}	10.79 ^{h}	10.26 ^{j}	0.38 ^{f}	0.53 ^{d}	0.91 ^{j}

The poultry manure treated plots recorded the highest concentration of available P of 13.53 kg/ha and 12.45 kg/ha whereas; the least concentration of available P at stages of 75 DAT and harvest respectively was recorded from control plot (10.79 kg/ha and 10.26 kg/ha).

The difference in levels of available P at different stages was worked out. Between 35 and 70 DAT it was observed that values ranged from 2.29 kg / ha in poultry manure to – 0.44 kg / ha in acacia. Mango, jack and straw treatments also gave negative values which, suggest a higher level of P in soil at 70 DAT than at 35 DAT. Between 70 DAT and harvest, however, no negative values were recorded. The maximum difference was observed in poultry manure (1.08 kg / ha) with no organics (1.07 kg / ha), being on par. The least difference was observed in cow dung with 0.26 kg / ha.

4.1.5 Available K content of soil

Concentrations of available K in soil at different stages of crop growth are presented in Table 4.5. The highest amount was observed in plot received with FE treatment (117.7 kg/ha), while least amount was noticed in control plot (93.81 kg/ha) at 35 DAT. At 70 DAT also the highest concentration of K was observed for the plot treated with FE (109.27 kg / ha), while the least was noticed in case of control plot (91.3 kg / ha). Highest value was observed for macaranga leaf treated plot (96.01kg/ha), while least value was recorded for control plot (89.76 kg/ha) at harvest stage.

The difference in levels of available K at the various stages was calculated. Between 35 DAT and 70 DAT, the maximum difference was in case of pongamia treatment (18.27 kg / ha), whereas a difference of – 3.85 kg / ha was observed in case of straw, indicating higher available K content in the soil at 70 DAT. Between 70 DAT and harvest, maximum difference was in case of FE treatment (14.2 kg / ha) with 50 per cent FE (12.25 kg / ha) and straw (9.94 kg / ha) being on par. The least difference was observed in control plot (1.54 kg / ha).

Table 4.5 : Effect of treatments on available K content (kg / ha) of soil

Treatments	35 DAT	70 DAT	Harvest	Differences in available K content at		
				35 DAT – 70 DAT	70 DAT - Harvest	35 DAT - Harvest
Neem leaf	111.86^{d}	98.21^{g}	92.19^{fgh}	13.65^{bc}	6.02^{c}	19.67^{ab}
Pongamia leaf	115.15^{b}	96.88^{h}	92.33^{fgh}	18.27^{a}	4.55^{c}	22.82^{a}
Mango leaf	100.87^{g}	95.55^{i}	91.35^{fgh}	5.32^{gh}	4.2^{cd}	9.52^{fg}
Jack leaf	99.82^{g}	95.62^{i}	91.49^{h}	4.20^{hi}	4.13^{cd}	8.33^{fgh}
Acacia leaf	96.81^{h}	94.78^{i}	90.37^{i}	2.03^{i}	4.41^{cd}	6.44^{ghi}
Gliricidia leaf	114.52^{bc}	103.46^{c}	94.71^{bc}	11.06^{d}	8.75^{b}	19.81^{ab}
Sesbania leaf	106.61^{ef}	98.63^{fg}	93.59^{de}	7.98^{ef}	5.04^{c}	13.02^{de}
Terminalia leaf	108.01^{e}	98.21^{g}	92.75^{ef}	9.8^{de}	5.46^{c}	15.26^{cd}
Macaranga leaf	106.9^{ef}	99.48^{ef}	96.01^{a}	7.42^{fg}	3.47^{cd}	10.89^{ef}
Straw	98.56^{gh}	102.41^{d}	92.47^{fg}	-3.85^{j}	9.94^{ab}	6.09^{hi}
Cowdung	113.89^{bcd}	98.64^{fg}	94.62^{bc}	15.25^{b}	4.02^{cd}	19.27^{b}
Poultry manure	112.14^{cd}	100.24^{e}	94.01^{cd}	11.90^{cd}	6.23^{c}	18.13^{bc}
No Organics	104.79^{f}	96.74^{h}	91.7^{gh}	8.05^{ef}	5.04^{c}	13.09^{de}
Fertilizer equivalent (FE)	117.7^{a}	109.27^{a}	95.07^{b}	8.43^{ef}	14.2^{abz}	22.63^{a}
50 % FE	108.01^{e}	104.51^{b}	92.26^{fgh}	3.50^{hi}	12.25^{ab}	15.75^{cd}
Control	93.81^{I}	91.3^{j}	89.76^{i}	2.51^{i}	1.54^{d}	4.05^{i}

4.2 Plant characters

4.2.1 Physiological characters

4.2.1.1 Chlorophyll content

Chlorophyll concentrations recorded during various stages of growth of plants and the ratios of chlorophyll *a* to chlorophyll *b* are presented in Table 4.6. At 35 DAT chlorophyll *a* content of all the treatments were on par with pongamia leaf treatment (2.45 μg/g) whereas, plots treated with jack leaf showed highest amounts of chlorophyll *b* (1.04 μg/g). Plots amended with acacia and sesbania leaf showed least amount of chlorophyll *b*. with both being on par.

In case of total chlorophyll, plots treated with pongamia leaf (3.33 μg/g) showed the highest concentration, whereas, control plots and plots amended with poultry manure and acacia leaves were on par with sesbania treated plots (3.07 μg/g).

At 45 DAT plots receiving 50 per cent FE treatment showed highest amount of chlorophyll *a* (2.49 μg/g) whereas, gliricidia leaf treatment gave lowest amounts of chlorophyll *a* (2.20 μg/g). In case of chlorophyll *b*, all treatments were on par. Total chlorophyll content was highest in case of 50 per cent FE (3.35 μg/g) and least in control (3.11 μg/g).

4.2.1.2 Cell Sap pH

The variations in cell sap pH are presented in Table 4.7. The analysis done at 30 DAT showed no significant difference among the treatments with respect to the cell sap pH as all were on par with the value ranging between 6.63 and 6.83.

In observations carried out at 60 DAT, plants receiving mango leaf treatment showed highest cell sap pH of 6.67 while plot treated with straw and jack leaf along with control showed values as low as 6.47.

Table 4.6 : Effect of treatments on chlorophyll content (µg/g) of rice plants at different stages of growth

Treatments	**35 DAT**			**45DAT**			**Chl *a* : Chl *b***	
	Chl.*a*	Chl.*b*	Total	Chl.*a*	Chl.*b*	Total	**35 DAT**	**45DAT**
Neem leaf	2.33 ^{a}	0.90 ^{ab}	3.12 ^{ab}	2.36 ^{abc}	0.90 ^{a}	3.15 ^{cd}	2.59	2.62
Pongamia leaf	2.45 ^{a}	1.02 ^{a}	3.33 ^{a}	2.36 ^{abc}	1.03 ^{a}	3.29 ^{abc}	2.40	2.29
Mango leaf	2.35 ^{a}	0.97 ^{ab}	3.21 ^{ab}	2.33 ^{abcd}	1.02 ^{a}	3.23 ^{abcd}	2.42	2.28
Jack leaf	2.37 ^{a}	1.04 ^{a}	3.30 ^{ab}	2.42 ^{abc}	1.01 ^{a}	3.33 ^{ab}	2.28	2.40
Acacia leaf	2.40 ^{a}	0.80 ^{b}	3.10 ^{b}	2.38 ^{abc}	0.86 ^{a}	3.15 ^{bcd}	3.00	2.77
Gliricidia leaf	2.34 ^{a}	0.94 ^{ab}	3.18 ^{ab}	2.20 ^{d}	1.02 ^{a}	3.22 ^{abcd}	2.49	2.16
Sesbania leaf	2.37 ^{a}	0.82 ^{b}	3.07 ^{b}	2.41 ^{abc}	0.91 ^{a}	3.21 ^{abcd}	2.89	2.65
Terminalia leaf	2.35 ^{a}	0.90 ^{ab}	3.14 ^{ab}	2.38 ^{abc}	0.88 ^{a}	3.15 ^{bcd}	2.61	2.70
Macaranga leaf	2.35 ^{a}	0.94 ^{ab}	3.19 ^{ab}	2.43 ^{abc}	0.89 ^{a}	3.23 ^{abcd}	2.50	2.73
Straw	2.41 ^{a}	0.94 ^{ab}	3.24 ^{ab}	2.42 ^{abc}	0.91 ^{a}	3.28 ^{abc}	2.56	2.66
Cowdung	2.38 ^{a}	0.87 ^{ab}	3.14 ^{ab}	2.40 ^{abc}	0.93 ^{a}	3.21 ^{abcd}	2.74	2.58
Poultry manure	2.34 ^{a}	0.87 ^{ab}	3.10 b	2.29 ^{cd}	0.96 ^{a}	3.14 ^{cd}	2.69	2.38
No Organics	2.35 ^{a}	0.92 ^{ab}	3.17 ^{ab}	2.47 ^{ab}	0.94 ^{a}	3.30 ^{abc}	2.55	2.63
FE	2.38 ^{a}	0.90 ^{ab}	3.18 ^{ab}	2.44 ^{abc}	0.91 ^{a}	3.24 ^{abcd}	2.64	2.68
50 % FE	2.44 ^{a}	0.86 ^{ab}	3.19 ^{ab}	2.49 ^{a}	0.95 ^{a}	3.35 ^{a}	2.84	2.62
Control	2.37 ^{a}	0.84 ^{ab}	3.10 ^{ab}	2.31 ^{bcd}	0.88 ^{a}	3.11 ^{d}	2.82	2.63

Table 4.7 : Effect of treatments on cell sap pH of rice plant.

Treatments	30 DAT	60 DAT
Neem leaf	6.63 ^{a}	6.57 ^{ab}
Pongamia leaf	6.73 ^{a}	6.57 ^{ab}
Mango leaf	6.73 ^{a}	6.67 ^{a}
Jack leaf	6.70 ^{a}	6.47 ^{b}
Acacia leaf	6.63 ^{a}	6.53 ^{ab}
Gliricidia leaf	6.63 ^{a}	6.53 ^{ab}
Sesbania leaf	6.67 ^{a}	6.63 ^{a}
Terminalia leaf	6.70 ^{a}	6.57 ^{ab}
Macaranga leaf	6.73 ^{a}	6.53 ^{ab}
Straw	6.67 ^{a}	6.47 ^{b}
Cowdung	6.67 ^{a}	6.63 ^{a}
Poultry manure	6.63 ^{a}	6.63 ^{a}
No Organics	6.83 ^{a}	6.63 ^{a}
Fertilizer equivalent (FE)	6.83 ^{a}	6.57 ^{ab}
50 % FE	6.80 ^{a}	6.57 ^{ab}
Control	6.67 ^{a}	6.47 ^{b}

4. 3 Crop growth characters

Crop growth characteristics such as height of tillers, number of tillers, weight of roots, plant dry matter and total plant weight were determined at different intervals and are presented in Tables 4.8 and 4.9.

4.3.1 Height of plants

Application of different treatments showed significant influence on height of tillers at different stages of growth of the crop. At 25 DAT height of tillers was maximum (47 cm) in plots which received poultry manure treatment.

Plots treated with neem leaf were next best followed by plots treated with acacia and terminalia leaves. Plots treated with mango leaf, straw, no organics and fertilizer equivalent of organic sources (FE), were on par but the height of tillers was less than that of terminalia leaf treated plots. Cowdung and 50 per cent FE were still lesser and on par whereas, the tiller height was least (34.03 cm) in control plot.

At 45 DAT height of tillers in plots amended with poultry manure was still highest (63.27 cm) with jack, macaranga and pongamia leaf amendments being on par. Gliricidia, sesbania and terminalia leaf treated plots were next best treatments while height of tillers was least in control plot (47.76 cm).

At 70 DAT, poultry manure was still the best treatment recording 87.0cm tiller height with jack, pongamia, neem, macaranga and FE treatments being on par. All other treatments except mango leaf, cowdung and control plots were on par and were the next best. Mango leaf treatment was marginally better than the cowdung treatment while control plots recorded the least tiller height of 69.23 cm.

Table 4.8 : Effect of treatments on plant height (cm) and tiller number

Treatments	Height of tillers (cm)			Number of tillers		
	25 DAT	**45 DAT**	**70 DAT**	**25 DAT**	**45 DAT**	**70 DAT**
Neem leaf	43.70 ^{abc}	53.03 ^{cde}	81.00 ^{ab}	6.30 ^{bcde}	7.80 ^{bcd}	5.66 ^{bc}
Pongamia leaf	45.53 ^{ab}	58.93 ^{abc}	81.80 ^{ab}	7.63 ^{abc}	7.93 ^{abc}	6.26 ^{bc}
Mango leaf	39.23 ^{de}	54.66 ^{cd}	72.86 ^{cde}	6.10 ^{cde}	7.06 ^{cd}	5.50 ^{bc}
Jack leaf	44.93 ^{abc}	61.73 ^{ab}	86.96 ^{a}	7.03 ^{abcde}	8.83 ^{ab}	6.46 ^{bc}
Acacia leaf	42.20 ^{bcd}	54.70 ^{cd}	74.96 ^{bcde}	6.86 ^{abcd}	7.50 ^{bcd}	6.36 ^{bc}
Gliricidia leaf	44.40 ^{abc}	56.16 ^{bcd}	78.56 ^{bc}	7.16 ^{abcd}	8.00 ^{abc}	6.33 ^{bc}
Sesbania leaf	44.63 ^{abc}	57.20 ^{bc}	76.26 ^{bcde}	7.73 ^{ab}	8.10 ^{abc}	6.36 ^{bc}
Terminalia leaf	40.90 ^{cde}	56.36 ^{bcd}	78.00 ^{bcd}	6.63 ^{abcde}	7.20 ^{cd}	5.90 ^{bc}
Macaranga leaf	44.00 ^{abc}	57.53 ^{abc}	79.56 ^{abc}	7.30 ^{abc}	7.50 ^{bcd}	6.66 ^{bc}
Straw	38.36 ^{de}	53.03 ^{cde}	74.66 ^{bcde}	5.50 ^{e}	7.13 ^{cd}	6.26 ^{bc}
Cowdung	37.73 ^{ef}	50.66 ^{de}	70.56 ^{de}	5.56 ^{de}	6.26 ^{de}	5.80 ^{bc}
Poultry manure	47.00 ^{a}	63.26 ^{a}	87.00 ^{a}	8.23 ^{a}	8.80 ^{ab}	6.83 ^{abc}
No Organics	38.20 ^{de}	52.76 ^{cde}	73.97 ^{bcde}	6.20 ^{bcde}	7.00 ^{cd}	5.43 ^{c}
Fertilizer equivalent (FE)	38.86 ^{de}	54.50 ^{cd}	79.53 ^{abc}	6.70 ^{abcde}	9.36 ^{a}	8.26 ^{a}
50 % FE	37.50 ^{ef}	53.06 ^{cde}	76.43 ^{bcde}	6.03 ^{cde}	7.16 ^{cd}	7.13 ^{ab}
Control	34.03 ^{f}	47.76 ^{e}	69.23 ^{e}	6.10 ^{cde}	5.30 ^{e}	5.53 ^{bc}

Table 4.9 : Effect of treatments on weight of roots, plant dry matter and total plant weight at 35 DAT

Treatments	35 DAT		
	Plant dry matter (t/ha)	Root (t/ha)	Total dry matter (t/ha)
Neem leaf	3.60^{b}	0.51^{def}	4.11^{bc}
Pongamia leaf	3.49^{b}	0.57^{d}	4.06^{bc}
Mango leaf	3.19^{c}	0.53^{de}	3.72^{de}
Jack leaf	2.98^{de}	0.43^{gh}	3.41^{fgh}
Acacia leaf	3.11^{cd}	0.49^{efg}	3.61^{ef}
Gliricidia leaf	3.45^{b}	0.82^{a}	4.27^{ab}
Sesbania leaf	3.81^{a}	0.65^{c}	4.46^{a}
Terminalia leaf	2.81^{ef}	0.54^{de}	3.35^{gh}
Macaranga leaf	3.47^{b}	0.66^{c}	4.13^{bc}
Straw	2.62^{g}	0.38^{h}	2.99^{i}
Cowdung	2.82^{ef}	0.45^{fgh}	3.27^{h}
Poultry manure	3.19^{c}	0.75^{b}	3.94^{cd}
No Organics	2.70^{fg}	0.51^{def}	3.21^{hi}
Fertilizer equivalent (FE)	3.18^{c}	0.48^{efg}	3.66^{e}
50 % FE	3.00^{d}	0.52^{def}	3.52^{efg}
Control	2.22^{h}	0.45^{fgh}	2.67^{j}

4.3.2 Number of tillers

At 25 DAT poultry manure amended plots recorded maximum number of 8.23 tillers per hill while mango leaf and 50 per cent FE treated plots fared poorly with 6.10 and 6.03 tillers per hill respectively. Straw amended plot had least number of tillers (5.50). At 45 DAT FE treated plot recorded highest number of tillers (9.36) with poultry manure, sesbania, gliricidia, jack and pongamia leaf treatments being on par with. Control plot registered the lowest number of tillers (5.30). At 70 DAT, FE treatment gave highest number of tillers (8.26) while 50 per cent FE and poultry manure treatments were on par with it.

4.3.3 Weight of Roots

Destructive sampling of plants at 35 DAT were done to estimate the weight of roots, weight of plant dry matter and total plant weight. The results are presented in Table 4.9

At 35 DAT, the maximum dry weight of the roots was obtained in gliricidia treated plots (0.82 t/ha), while the least value was recorded in plots receiving straw treatment (0.38 t/ha).

4.3.4 Plant dry matter

At 35 DAT, maximum plant dry matter was observed in case of sesbania leaf treatment(3.81 t/ha) whereas, the least value was recorded for control plot (2.22 t/ha).

4.3.5 Total dry matter production

At 35 DAT the highest value was observed for sesbania treated plot (4.46 t/ha) and the least value (2.67 t/ha) was recorded in control plot.

Table 4.9 : Effect of treatments on weight of roots, plant dry matter and total plant weight at 35 DAT

Treatments	**35 DAT**		
	Plant dry matter (t/ha)	Root (t/ha)	Total dry matter (t/ha)
Neem leaf	3.60 ^{b}	0.51 ^{def}	4.11 ^{bc}
Pongamia leaf	3.49 ^{b}	0.57 ^{d}	4.06 ^{bc}
Mango leaf	3.19 ^{c}	0.53 ^{de}	3.72 ^{de}
Jack leaf	2.98 ^{de}	0.43 ^{gh}	3.41 ^{fgh}
Acacia leaf	3.11 ^{cd}	0.49 ^{efg}	3.61 ^{ef}
Gliricidia leaf	3.45 ^{b}	0.82 ^{a}	4.27 ^{ab}
Sesbania leaf	3.81 ^{a}	0.65 ^{c}	4.46 ^{a}
Terminalia leaf	2.81 ^{ef}	0.54 ^{de}	3.35 ^{gh}
Macaranga leaf	3.47 ^{b}	0.66 ^{c}	4.13 ^{bc}
Straw	2.62 ^{g}	0.38 ^{h}	2.99 ^{i}
Cowdung	2.82 ^{ef}	0.45 ^{fgh}	3.27 ^{h}
Poultry manure	3.19 ^{c}	0.75 ^{b}	3.94 ^{cd}
No Organics	2.70 ^{fg}	0.51 ^{def}	3.21 ^{hi}
Fertilizer equivalent (FE)	3.18 ^{c}	0.48 ^{efg}	3.66 ^{e}
50 % FE	3.00 ^{d}	0.52 ^{def}	3.52 ^{efg}
Control	2.22 ^{h}	0.45 ^{fgh}	2.67 ^{j}

4.4 Elemental composition of rice plant

4.4.1 Nitrogen

Nitrogen (N) content at 35 DAT and 70 DAT of rice plants are presented in Table 4.10.

At 35 DAT, N concentrations varied between 2.58 per cent (control plot) and 3.63 per cent in plants from the plots received FE treatment. Plants in the plot treated with no organics showed N concentration of 3.58 per cent followed by plots treated with 50 per cent FE (3.50 per cent), gliricidia leaf (3.50 per cent) and sesbania leaf (3.45 per cent). Plants in the control plot had least concentration of N during the above period (2.58 per cent) followed by plots treated with straw (2.69 per cent) and macaranga leaves (2.85 per cent).

Rice plants analysed at 70 DAT showed total nitrogen concentrations between 1.09 and 1.67 per cent of which plants treated with pongamia leaves recorded highest concentration (1.67 per cent) followed by plants treated with jack leaves (1.59 per cent). Lowest concentration of N was observed in plants collected from control plots followed by 50 per cent FE (1.25 per cent) and FE (1.36 per cent). Plants treated with poultry manure (1.37 per cent), cowdung (1.41 per cent) and straw (1.43 per cent) showed intermediate concentrations of N.

4.4.2 Phosphorus

Observations at similar intervals as in the case of nitrogen estimations have been carried out for the determination of phosphorus concentrations and uptake in plants and the results are given in Table 4.10

At 35 DAT, no remarkable variations in the concentrations of P have been noticed, it varied between 0.30 and 0.40 per cent. Plots treated with poultry manure recorded 0.40 per cent followed by plants treated with no organics 0.37 per cent. Plants treated with sesbania leaves showed a concentration of 0.36 per cent. Control plots recorded the least value with 0.30 per cent.

Table 4.10 : Effect of treatments on N, P and K content (%) of rice plant at 35 and 70 DAT

Treatments	N		P		K	
	35 DAT	70 DAT	35 DAT	70 DAT	35 DAT	70 DAT
Neem leaf	3.08^{e}	1.51^{cd}	0.32^{bc}	0.28^{ab}	3.26^{b}	2.70^{def}
Pongamia leaf	3.13^{e}	1.67^{a}	0.33^{bc}	0.27^{ab}	3.31^{b}	2.61^{efg}
Mango leaf	2.95^{f}	1.46^{de}	0.31^{bc}	0.28^{ab}	2.91^{fg}	2.87^{bcd}
Jack leaf	3.28^{d}	1.59^{b}	0.32^{bc}	0.28^{ab}	2.95^{f}	2.91^{abc}
Acacia leaf	2.94^{f}	1.49^{cd}	0.31^{bc}	0.27^{ab}	2.98^{f}	2.99^{ab}
Gliricidia leaf	3.50^{bc}	1.49^{cd}	0.34^{bc}	0.28^{ab}	3.45^{a}	2.77^{cde}
Sesbania leaf	3.45^{c}	1.49^{cd}	0.36^{abc}	0.30^{ab}	3.27^{b}	2.65^{ef}
Terminalia leaf	2.93^{f}	1.46^{de}	0.33^{bc}	0.29^{ab}	3.06^{e}	2.93^{abc}
Macaranga leaf	2.85^{f}	1.46^{de}	0.31^{bc}	0.27^{ab}	3.13^{de}	3.07^{a}
Straw	2.69^{g}	1.43^{e}	0.30^{c}	0.26^{ab}	2.92^{fg}	2.97^{ab}
Cowdung	2.88^{f}	1.41^{ef}	0.33^{bc}	0.29^{ab}	2.86^{gh}	2.43^{gh}
Poultry manure	3.06^{e}	1.37^{f}	0.40^{a}	0.32^{a}	2.98^{f}	2.57^{fg}
No Organics	3.58^{ab}	1.37^{f}	0.37^{ab}	0.29^{ab}	3.16^{cd}	2.42^{gh}
Fertilizer equivalent (FE)	3.63^{a}	1.36^{f}	0.31^{bc}	0.27^{ab}	3.41^{a}	2.66^{ef}
50 % FE	3.50^{bc}	1.25^{g}	0.30^{c}	0.26^{ab}	3.23^{bc}	2.51^{fg}
Control	2.58^{h}	1.09^{h}	0.30^{c}	0.24^{b}	2.82^{h}	2.26^{h}

Similarly, P concentration in plants at 70 DAT also was observed to be in a very narrow range. It varied between 0.24 per cent and 0.32 per cent. Plots treated with poultry manure recorded 0.32 per cent followed by 0.30 per cent in plots which received treatment with sesbania leaves. The least value was yet again from control plots at 0.24 per cent.

4.4.3 Potassium

The results are summarized in Table 4.10. Potassium content of the plant and soil is of importance in the electron transfer systems and also on the quality of the grains. It also has an important role in maintaining the health of the plants.

The results showed that the concentration of K at 35 DAT ranged between 2.82 per cent and 3.45 per cent. Highest concentration of K was observed in plants from plots treated with gliricidia (3.45 per cent) whereas, the lowest concentration (2.82 per cent) was recorded in control plots with macaranga.

At 70 DAT, the range of K in plant samples was between 2.26 per cent and 3.07 per cent of which the highest concentration of 3.07 per cent was observed in plants from mango leaf plots. Plants collected from control plots showed K concentration of 2.26 per cent, which was the lowest value, recorded.

4.4.4 Secondary and micronutrient contents of the rice plant

Analysis have been carried out for the determination of secondary nutrients such as calcium (Ca), magnesium (Mg), micronutrients like iron (Fe), sodium (Na), copper (Cu) and zinc (Zn) and the details are presented in Tables 4.11 and 4.12.

Secondary nutrients have important roles to play in the health of plants and also an important factor in facilitating or limiting the uptake of other nutrients. Micronutrients are generally not deficient in soils of Kerala but their deficiencies can limit crop productivity as they play important roles in various enzyme systems.

At 35 DAT plant samples were taken and analysed for secondary and micronutrients. The results showed that at 35 DAT Ca content was highest in plants receiving macaranga treatment (2.34 mg/g) with all other samples except neem being on par. Neem treated plots had least concentration of Ca (1.23 mg/g). In case of Mg also, macaranga showed the highest value of 1.44 mg/ g with neem and sesbania treated plots giving concentrations of 1.02 and 0.97 mg/g respectively.

Sodium (Na) concentrations ranged between 0.86 mg/g in neem treated plots and 2.92 mg/g in control plots, while concentrations of Fe showed variations between 3.30 and 4.73 mg/g for plants treated with no organics and straw respectively.

In the case of Cu, poultry manure gave highest concentration of 27.45 µg/g whereas, the least value was obtained acacia treated plots (14.12 µg/g). Highest amount of Zn was obtained in plot treated with poultry manure (54.17 µg/g) while the least concentration was obtained in FE treated plots (32.33µg/g).

Concentrations of various elements analysed in the plants at 70 DAT has been summarized and presented in Table 4.12. At 70 DAT, Ca content was highest in plots treated with jack (2.58 mg/g) and least in case of straw treatments (1.2 mg/g). Mg content was highest in case of terminalia treatment (1.6 per cent mg/g) and least was observed in straw treatment (1.1 mg/g). In the case of Na, all treatments were on par with 50 per cent FE giving highest amount (2.25 mg/g). In the case of Fe also, all treatments were on par with the highest being in straw treatment with 3.76 mg/g.

Cu values were all on par. The highest value was obtained for acacia (27.45 µg/g) and poultry manure and control treatments gave least value of 14.90 µg/g. Concentrations of zinc varied between 35.69 µg/g (control) and 47.96 µg/g (mango).

Table 4.11 : Effect of treatments on content of secondary and micronutrients of rice plant at 35 DAT

Treatments	Ca (mg/g)	Mg (mg/g)	Fe (mg/g)	Na (mg/g)	Cu (µg/g)	Zn (µg/g)
Neem leaf	1.23^{b}	1.01^{cd}	0.348^{a}	1.56^{de}	21.96^{abc}	35.21^{bc}
Pongamia leaf	2.26^{a}	1.25^{abcd}	0.385^{a}	1.38^{abcde}	18.93^{bc}	36.47^{bc}
Mango leaf	1.91^{ab}	1.07^{bcd}	0.390^{a}	1.32^{bcde}	21.96^{abc}	39.12^{bc}
Jack leaf	1.66^{ab}	1.25^{abcd}	0.403^{a}	1.26^{bcde}	23.53^{ab}	41.26^{bc}
Acacia leaf	2.22^{a}	1.19^{abcd}	0.367^{a}	1.45^{abcde}	14.11^{c}	34.57^{bc}
Gliricidia leaf	1.87^{ab}	1.22^{abcd}	0.399^{a}	1.38^{abcde}	24.31^{ab}	41.75^{bc}
Sesbania leaf	1.79^{ab}	0.97^{d}	0.441^{a}	1.41^{abcde}	16.47^{bc}	33.30^{c}
Terminalia leaf	1.75^{ab}	1.14^{abcd}	0.366^{a}	1.64^{abcd}	19.60^{abc}	35.69^{bc}
Macaranga leaf	2.34^{a}	1.44^{a}	0.366^{a}	1.50^{abcde}	18.07^{bc}	34.86^{bc}
Straw	1.59^{ab}	1.07^{bcd}	0.473^{a}	1.36^{abcde}	27.45^{a}	40.47^{bc}
Cowdung	2.30^{a}	1.20^{abcd}	0.376^{a}	1.75^{ab}	18.82^{bc}	36.96^{bc}
Poultry manure	1.87^{ab}	1.36^{ab}	0.352^{a}	1.68^{abc}	27.45^{a}	54.17^{a}
No Organics	2.30^{a}	1.33^{abc}	0.330^{a}	1.12^{e}	20.39^{abc}	43.97^{b}
Fertilizer equivalent (FE)	1.90^{ab}	1.13^{abcd}	0.343^{a}	1.21^{cde}	17.25^{bc}	32.33^{c}
50 % FE	1.45^{ab}	1.23^{abcd}	0.342^{a}	1.59^{abcde}	21.15^{abc}	52.83^{a}
Control	2.01^{ab}	1.18^{abcd}	0.385^{a}	1.84^{a}	18.82^{bc}	36.96^{bc}

Table 4.12 : Effect of treatments on contents of secondary and micronutrients of rice plant at 70 DAT

Treatments	Ca (mg/g)	Mg (mg/g)	Fe (mg/g)	Na (mg/g)	Cu (µg/g)	Zn (µg/g)
Neem leaf	2.22 ^{ab}	1.35 ^{ab}	0.306 ^{a}	1.55 ^{a}	19.60 ^{a}	44.45 ^{ab}
Pongamia leaf	1.63 ^{bcd}	1.25 ^{ab}	0.260 ^{a}	1.11 ^{a}	20.39 ^{a}	41.58 ^{ab}
Mango leaf	1.87 ^{abcd}	1.26 ^{ab}	0.288 ^{a}	1.25 ^{a}	17.25 ^{a}	47.96 ^{a}
Jack leaf	2.58 ^{a}	1.40 ^{ab}	0.260 ^{a}	0.85 ^{a}	19.60 ^{a}	40.47 ^{ab}
Acacia leaf	1.67 ^{bcd}	1.18 ^{ab}	0.264 ^{a}	1.05 ^{a}	27.45 ^{a}	43.18 ^{ab}
Gliricidia leaf	1.67 ^{bcd}	1.31 ^{ab}	0.269 ^{a}	1.58 ^{a}	21.17 ^{a}	42.70 ^{ab}
Sesbania leaf	1.99 ^{abcd}	1.11 ^{b}	0.339 ^{a}	1.21 ^{a}	15.68 ^{a}	44.45 ^{ab}
Terminalia leaf	1.63 ^{bcd}	1.55 ^{a}	0.227 ^{a}	1.15 ^{a}	17.25 ^{a}	43.50 ^{ab}
Macaranga leaf	2.07 ^{abc}	1.24 ^{ab}	0.218 ^{a}	0.85 ^{a}	17.25 ^{a}	41.74 ^{ab}
Straw	1.19 ^{d}	1.05 ^{b}	0.375 ^{a}	0.72 ^{a}	18.04 ^{a}	42.54 ^{ab}
Cowdung	1.47 ^{bcd}	1.26 ^{ab}	0.246 ^{a}	1.21 ^{a}	21.17 ^{a}	40.15 ^{ab}
Poultry manure	1.47 ^{bcd}	1.39 ^{ab}	0.236 ^{a}	1.16 ^{a}	14.90 ^{a}	47.80 ^{a}
No Organics	1.31 ^{cd}	1.22 ^{ab}	0.310 ^{a}	1.38 ^{a}	15.68 ^{a}	43.66 ^{ab}
Fertilizer equivalent (FE)	1.31 ^{cd}	1.21 ^{ab}	0.353 ^{a}	1.21 ^{a}	15.68 ^{a}	41.90 ^{ab}
50 % FE	1.55 ^{bcd}	1.24 ^{ab}	0.324 ^{a}	2.24 ^{a}	15.69 ^{a}	36.64 ^{ab}
Control	1.35 ^{cd}	1.13 ^{b}	0.213 ^{a}	1.26 ^{a}	14.90 ^{a}	35.69 ^{b}

4.5 Major, secondary and micronutrients in straw and grains

The details of the analysis of grain and straw for major, secondary and micronutrients are presented in Tables 4.13 and 4.14.

The concentration of N in straw was highest in case of cowdung treatment (0.88 per cent) and least in case of control plot (0.71 per cent). In case of P content, the highest value was recorded in poultry manure treated plot (0.29 per cent) while the least value of 0.23 per cent was recorded in plots treated with neem leaves, pongamia leaves, FE, 50 per cent FE and also in control plots. Potassium (K) content was highest in straw treated plots (2.68 per cent) and least in cowdung treated plots (2.16 per cent).

The contents of secondary micronutrients in straw were also estimated. Highest amount of Ca (8.39mg/g) was observed in case of poultry manure treatment and least concentraion was obtained in case of control plot (3.19 mg/g).

In case of Mg, the highest value was obtained in case of no organic treatment (1.77 mg/g) and the least was noticed in case of straw incorporation (0.89 mg/g) while for Fe and Na, the highest values were obtained for poultry manure treatment in both cases with 1.58 mg/g and 1.47 mg/g respectively while the least values were recorded in case of FE (0.79 mg/g) and no organic treatments (0.70 mg/g) respectively. Concentrations of Cu was highest in case of gliricidia treatment (15.68 μg/g) and least in case of no organics treatment (6.93μg/g) while in case of Zn it was highest in mango leaf treated plot (65.32μg/g) and least in poultry manure amended plot (41.26μg/g).

In case of grain, the highest concentration of N was observed in FE treated plot (1.3 per cent) while the least was reported from control plot (1.03 per cent). Phosphorus content was highest in grain from NO treated plot (0.19 per cent) and least in FE and control plot (0.11 per cent) while in case of K the highest concentration was recorded in grain from macaranga treated plot (0.34 per cent) and the least in control plot (0.27 per cent).

Table 4.13 : Effect of treatments on N, P and K content of grain and straw

Treatments	Grain N %	Grain P %	Grain K %	Straw N %	Straw P %	Straw K %
Neem leaf	1.26^{ab}	0.12^{b}	0.29^{ab}	0.87^{a}	0.23^{a}	2.21^{ghi}
Pongamia leaf	1.13^{e}	0.12^{b}	0.32^{ab}	0.89^{a}	0.23^{a}	2.26^{fgh}
Mango leaf	1.07^{f}	0.13^{ab}	0.31^{ab}	0.79^{cd}	0.25^{a}	2.34^{e}
Jack leaf	1.19^{cd}	0.12^{b}	0.32^{ab}	0.86^{ab}	0.24^{a}	2.51^{cd}
Acacia leaf	1.13^{e}	0.13^{ab}	0.32^{ab}	0.86^{ab}	0.25^{a}	2.53^{c}
Gliricidia leaf	1.26^{ab}	0.15^{ab}	0.33^{ab}	0.85^{abc}	0.24^{a}	2.33^{ef}
Sesbania leaf	1.29^{a}	0.15^{ab}	0.30^{ab}	0.87^{a}	0.24^{a}	2.28^{efg}
Terminalia leaf	1.17^{de}	0.15^{ab}	0.32^{ab}	0.80^{bcd}	0.25^{a}	2.45^{d}
Macaranga leaf	1.20^{cd}	0.13^{ab}	0.34^{a}	0.83^{abc}	0.25^{a}	2.61^{b}
Straw	1.06^{f}	0.11^{b}	0.33^{ab}	0.77^{d}	0.25^{a}	2.68^{a}
Cowdung	1.16^{de}	0.12^{b}	0.28^{ab}	0.88^{a}	0.26^{a}	2.16^{i}
Poultry manure	1.21^{bcd}	0.17^{ab}	0.29^{ab}	0.84^{abc}	0.29^{a}	2.21^{ghi}
No Organics	1.23^{bc}	0.19^{a}	0.30^{ab}	0.83^{abc}	0.27^{a}	2.17^{i}
Fertilizer equivalent (FE)	1.30^{a}	0.11^{b}	0.31^{ab}	0.84^{abc}	0.23^{a}	2.28^{efg}
50 % FE	1.26^{ab}	0.12^{b}	0.29^{ab}	0.79^{cd}	0.23^{a}	2.21^{ghi}
Control	1.03^{f}	0.11^{b}	0.27^{b}	0.71^{e}	0.23^{a}	2.19^{hi}

Table 4.14 : Effect of treatments on contents of secondary and micronutrients in plant at harvest

Treatments	Ca (mg/g)	Mg (mg/g)	Fe (mg/g)	Na (mg/g)	Cu (µg/g)	Zn (µg/g)
Neem leaf	1.84^{abc}	0.97^{bc}	0.92^{b}	0.81^{ab}	10.20^{b}	41.90^{b}
Pongamia leaf	1.72^{abc}	1.08^{abc}	1.15^{ab}	1.18^{ab}	10.98^{ab}	43.18^{b}
Mango leaf	1.03^{cd}	1.12^{abc}	1.16^{ab}	0.87^{ab}	10.98^{ab}	65.32^{a}
Jack leaf	2.08^{abc}	1.59^{abc}	0.92^{b}	0.81^{ab}	9.41^{b}	45.73^{b}
Acacia leaf	1.14^{bc}	1.09^{abc}	0.88^{b}	1.09^{ab}	11.76^{ab}	42.86^{b}
Gliricidia leaf	2.16^{abc}	1.17^{abc}	0.93^{b}	0.86^{ab}	15.68^{a}	49.87^{b}
Sesbania leaf	1.99^{abc}	0.92^{bc}	1.02^{b}	0.79^{b}	10.19^{b}	52.27^{ab}
Terminalia leaf	1.00^{cd}	1.44^{abc}	1.25^{ab}	1.12^{ab}	8.62^{b}	42.38^{b}
Macaranga leaf	1.72^{abc}	1.47^{abc}	1.11^{ab}	0.81^{ab}	11.76^{ab}	43.65^{b}
Straw	1.45^{bc}	0.89^{c}	1.29^{ab}	0.75^{b}	11.77^{ab}	53.37^{ab}
Cowdung	1.36^{bc}	1.38^{abc}	1.25^{ab}	0.78^{b}	10.98^{ab}	53.37^{ab}
Poultry manure	1.39^{bc}	1.34^{abc}	1.58^{a}	1.47^{a}	11.21^{ab}	41.26^{b}
No Organics	1.06^{cd}	1.77^{a}	1.23^{ab}	0.70^{b}	6.93^{b}	55.82^{ab}
Fertilizer equivalent (FE)	2.28^{a}	1.64^{ab}	0.79^{b}	0.91^{ab}	10.20^{b}	49.39^{b}
50 % FE	1.67^{ab}	1.74^{a}	1.20^{ab}	0.85^{ab}	10.98^{ab}	45.09^{b}
Control	0.98^{d}	0.93^{bc}	1.20^{ab}	1.09^{ab}	8.62^{b}	48.59^{b}

4 .6 Yield and Yield attributes

The yield attributes such as spikelets per panicle, length of panicles, 1000 seed weight, chaff percentage, grain and straw yield, total dry matter production, grain straw ratio and harvest index are given in Tables 4.15 and 4.16.

The length of panicle was maximum for plants subjected to poultry manure treatment (18.36 cm) which was on par with no organic treatment (18.15 cm) and least was noted in control plot (14.96 cm).

The number of spikelets per panicle was highest for plants treated with poultry manure with 81.31 and least was recorded in control with 53.65. The 1000 seed weight was maximum in sesbania (27.80 g) and least in cowdung treated plots (25.76 g).

The chaff percentage was highest in sesbania treated plots (24.13 per cent). The number of productive tillers was maximum in FE plot (7.50) and the least number was observed in control plot (5.06).

The quantity of straw obtained was highest in case of plot receiving FE (5.20 t/ha) whereas, it was least in the control plots (2.91 t/ha) on dry weight basis.

The grain yield was highest in plots treated with FE (4.37 t/ha) while pongamia (4.25 t/ ha), gliricidia (4.27 t/ ha) and poultry manure (4.91 t/ ha) were on par. The least green yield was observed in control (2.49 t /ha).

Table 4.15 : Effect of treatments on yield attributes

Treatments	No. of productive tillers	Length of panicle(cm)	Spikelets / panicle	1000 seed wt.(g)	Chaff %
Neem leaf	5.33 ^{bc}	16.97 ^{bcd}	72.67 ^{abcd}	26.75 ^{ab}	20.90 ^{a}
Pongamia leaf	5.66 ^{bc}	17.57 ^{abc}	74.58 ^{ab}	27.05 ^{ab}	19.13 ^{a}
Mango leaf	5.13 ^{c}	16.65 ^{cd}	63.84 ^{cd}	26.94 ^{ab}	20.23 ^{a}
Jack leaf	6.06 ^{bc}	17.71 ^{ab}	75.58 ^{ab}	26.70 ^{ab}	18.93 ^{a}
Acacia leaf	5.80 ^{bc}	15.57 ^{ef}	60.97 ^{de}	27.18 ^{ab}	19.23 ^{a}
Gliricidia leaf	6.10 ^{bc}	17.61 ^{abc}	67.77 ^{bcd}	27.69 ^{a}	19.06 ^{a}
Sesbania leaf	6.03 ^{bc}	16.89 ^{bcd}	69.14 ^{bcd}	27.80 ^{a}	24.13 ^{a}
Terminalia leaf	5.73 ^{bc}	16.81 ^{bcd}	73.02 ^{abcd}	26.79 ^{ab}	22.80 ^{a}
Macaranga leaf	6.03 ^{bc}	17.74 ^{ab}	76.36 ^{ab}	26.63 ^{ab}	20.53 ^{a}
Straw	5.66 ^{bc}	16.21 ^{de}	61.62 ^{de}	26.47 ^{ab}	19.07 ^{a}
Cowdung	5.43 ^{bc}	16.84 ^{bcd}	66.58 ^{bcd}	26.76 ^{ab}	18.60 ^{a}
Poultry manure	5.63 ^{bc}	18.36 ^{a}	81.31 ^{a}	26.60 ^{ab}	21.67 ^{a}
No Organics	5.10 ^{c}	18.15 ^{a}	70.03 ^{abcd}	26.24 ^{ab}	18.70 ^{a}
Fertilizer equivalent (FE)	7.50 ^{a}	17.37 ^{abc}	74.89 ^{abc}	27.71 ^{a}	21.97 ^{a}
50 % FE	6.56 ^{ab}	16.74 ^{bcd}	66.49 ^{bcd}	26.22 ^{ab}	21.53 ^{a}
Control	5.06 ^{c}	14.96 ^{f}	53.65 ^{e}	26.34 ^{ab}	20.87 ^{a}

Table 4.16 : Effect of treatments on yield

Treatments	Grain yield (t/ha) dry wt.	Straw yield (t/ha) dry wt.	Total dry matter (t/ha)	Grain / Straw Ratio	Harvest Index (HI)
Neem leaf	4.02 ^{bc}	4.51 ^{cde}	8.53 ^{c}	0.89 ^{ab}	0.47 ^{a}
Pongamia leaf	4.25 ^{a}	4.68 ^{bcd}	8.93 ^{b}	0.91 ^{ab}	0.48 ^{a}
Mango leaf	3.77 ^{d}	4.14 ^{fgh}	7.91 ^{e}	0.91 ^{ab}	0.48 ^{a}
Jack leaf	3.87 ^{cd}	4.35 ^{efg}	8.22 ^{d}	0.89 ^{ab}	0.47 ^{a}
Acacia leaf	3.41 ^{e}	3.66 ^{i}	7.07 ^{f}	0.93 ^{a}	0.48 ^{a}
Gliricidia leaf	4.27 ^{a}	4.79 ^{bc}	9.06 ^{b}	0.89 ^{ab}	0.47 ^{a}
Sesbania leaf	4.18 ^{ab}	4.87 ^{b}	9.05 ^{b}	0.86 ^{ab}	0.46 ^{a}
Terminalia leaf	3.85 ^{cd}	4.41 ^{def}	8.26 ^{d}	0.87 ^{ab}	0.47 ^{a}
Macaranga leaf	3.84 ^{cd}	4.33 ^{efgh}	8.17 ^{d}	0.89 ^{ab}	0.47 ^{a}
Straw	3.11 ^{f}	3.52 ^{i}	6.63 ^{g}	0.88 ^{ab}	0.47 ^{a}
Cowdung	3.93 ^{cd}	4.41 ^{def}	8.34 ^{cd}	0.89 ^{ab}	0.47 ^{a}
Poultry manure	4.19 ^{ab}	4.71 ^{bcd}	8.90 ^{b}	0.89 ^{ab}	0.47 ^{a}
No Organics	3.73 ^{d}	4.07 ^{gh}	7.80 ^{e}	0.91 ^{ab}	0.48 ^{a}
Fertilizer equivalent (FE)	4.37 ^{a}	5.20 ^{a}	9.57 ^{a}	0.84 ^{ab}	0.46 ^{a}
50 % FE	3.75 ^{d}	4.03 ^{h}	7.78 ^{e}	0.93 ^{a}	0.48 ^{a}
Control	2.49 ^{g}	2.91 ^{j}	5.40 ^{h}	0.86 ^{ab}	0.46 ^{a}

4.7 Uptake of nutrients

The observations made for uptake of nutrients at 35 DAT and at harvest by the plant are presented in Table 4.17.

At 35 DAT, the highest N, P and K uptake was for sesbania with 131.51 kg / ha, 13.72 kg / ha and 124.65 kg / ha, respectively. The lowest N, P and K uptake at 35 DAT was in control plots with 57.3 kg / ha, 6.66 kg / ha and 62.3 kg / ha, respectively.

At harvest, the highest uptake of N by grain was in pongamia treatment (59.33 kg / ha), while the least was in case of control treatment (25.67 kg / ha). N uptake by straw was highest in FE treated plots (43.73 kg / ha) and lowest in control treatment (20.71 kg / ha).

In case of P uptake by grain, the highest value was obtained for poultry manure treatment (7.12 kg / ha), while the least was in control (2.74 kg / ha). The P content of straw was highest in poultry manure (13.65 kg / ha) and lowest in control (6.71 kg / ha).

In case of K uptake by grain, highest was observed in gliricidia treatment (14.11 kg / ha), while the least was for control (6.73 kg / ha). The uptake of K by straw was highest in FE treated plots (118.69 kg / ha) and least in control (63.88 kg / ha).

Table 4.17: Effect of treatments on uptake of nutrients

Treatments	Uptake of nutrients at 35 DAT (kg/ha)			Grain N Uptake kg / ha	Straw N Uptake kg / ha	Grain P Uptake kg / ha	Straw P Uptake kg / ha	Grain K Uptake kg / ha	Straw K Uptake kg / ha
	N	P	K						
Neem leaf	110.91 ^{bc}	11.52 ^{b}	117.39 ^{b}	50.65 ^{d}	39.26 ^{c}	4.82 ^{de}	10.38 ^{g}	11.66 ^{efg}	99.73 ^{i}
Pongamia leaf	109.53 ^{bc}	11.52 ^{b}	115.62 ^{bc}	59.33 ^{a}	41.65 ^{b}	6.30 ^{bc}	10.76 ^{ef}	16.8 ^{a}	105.77 ^{d}
Mango leaf	94.16 ^{ef}	9.89 ^{de}	92.89 ^{cd}	40.34 ^{g}	32.73 ^{hi}	4.90 ^{de}	10.36 ^{g}	11.69 ^{efg}	96.95 ^{ef}
Jack leaf	97.84 ^{de}	9.54 ^{ef}	87.99 ^{d}	46.06 ^{f}	37.41 ^{de}	5.03 ^{de}	10.44 ^{g}	12.00 ^{defg}	109.19 ^{d}
Acacia leaf	91.49 ^{ef}	9.66 ^{ef}	92.74 ^{cd}	38.53 ^{h}	31.48 ^{i}	4.43 ^{e}	9.15 ^{h}	10.91 ^{gh}	92.60 ^{gh}
Gliricidia leaf	120.85 ^{ab}	11.74 ^{ab}	119.13 ^{ab}	53.89 ^{c}	40.67 ^{bc}	6.41 ^{bc}	11.48 ^{c}	14.11 ^{b}	111.49 ^{bc}
Sesbania leaf	131.51 ^{a}	13.72 ^{a}	124.65 ^{a}	53.99 ^{c}	42.37 ^{ab}	6.28 ^{bc}	11.68 ^{c}	12.55 ^{cde}	110.04 ^{bc}
Terminalia leaf	82.42 ^{f}	9.28 ^{fg}	86.07 ^{de}	45.10^{f}	35.28 ^{fg}	5.78 ^{cd}	10.58 ^{fg}	12.34 ^{cde}	108.05 ^{cd}
Macaranga leaf	98.92 ^{de}	10.76 ^{cd}	108.64 ^{c}	46.09 ^{f}	35.95 ^{ef}	4.99 ^{de}	10.82 ^{de}	13.06 ^{bcd}	113.04 ^{b}
Straw	70.56 ^{fg}	7.87 ^{g}	76.59 ^{fg}	32.97 ^{i}	27.13 ^{j}	3.42 ^{f}	8.81 ^{i}	10.26 ^{h}	94.44 ^{fg}
Cowdung	81.24 ^{f}	9.31 ^{fg}	80.68 ^{ef}	45.62 ^{f}	38.90 ^{cd}	4.72 ^{de}	11.49 ^{c}	11.01 ^{gh}	95.49 ^{fg}
Poultry manure	97.71 ^{de}	12.72 ^{ab}	95.15 ^{cd}	50.69 ^{d}	39.53 ^{c}	7.12 ^{ab}	13.65 ^{a}	12.15 ^{defg}	104.02 ^{d}
No Organics	96.77 ^{de}	10.00 ^{cd}	85.41 ^{e}	45.94 ^{f}	33.82 ^{gh}	7.09 ^{a}	11.00 ^{d}	11.21 ^{fgh}	88.43 ^{i}
FE	115.51 ^{b}	9.86 ^{de}	108.51 ^{c}	56.81 ^{b}	43.73 ^{a}	4.81 ^{de}	11.97 ^{b}	13.55 ^{bc}	118.69 ^{a}
50 % FE	105.51 ^{bc}	9.01 ^{g}	96.99 ^{cd}	47.30 ^{e}	31.89 ^{i}	4.50 ^{e}	9.29 ^{h}	10.88 ^{gh}	89.22 ^{hi}
Control	57.30 ^{g}	6.66 ^{h}	62.63 ^{h}	25.67 ^{j}	20.71 ^{k}	2.74 ^{f}	6.71 ^{j}	6.73 ^{i}	63.88 ^{j}

4 .8 Experiment 2. Incubation study

The field experiment was replicated as an incubation study to observe the variations if any in organic carbon content to understand the pattern of N, P and K mineralization from various organic and inorganic sources. The experiment was carried out for a period of 100 days. Samples were analysed at an interval of 5 days till 40 days and thereafter at 15 days intervals.

4.8.1 Organic carbon content of soil

Observations for organic carbon content of the soil were made along with that for total nitrogen, phosphorus and potassium. The values are presented in Table 4.18. The organic carbon contents did not differ significantly among treatments or show any major increase, with values ranging from minimum of 0.66 per cent initially to a highest value of 0.75 per cent at the end of 100 days. All the values were on par.

4.8.2 Mineralization of nitrogen

Organic and inorganic sources showed varied mineralization patterns. The NH_4^+ and NO_3^- fractions were determined using the method suggested by Bremner, (1965). The results of NH_4^+ - N and NO_3 –N are summarized in Tables 4.19 and 4.20. Total N concentrations are presented in Table 4.21. The results indicate that most immediate mineralization occurred in case of inorganic sources i.e. within 5 days after incubation (DAI), while among the plant materials, gliricidia and sesbania were the quickest to release N in to the soil by 15 days after incubation. Pongamia and neem treatments attained maximum mineralization status at 20 DAI. Cowdung, however, was the quickest amongst organic manures to mineralize, attaining a peak by about 10 DAI.

Terminalia treatment showed maximum release at 35 DAI, while in case of macaranga it was 40 DAI. Mango and jack leaf treatments recorded maximum mineralization at 55 DAI, while straw and macaranga took 70 days for their mineralization to reach its peak. Mineralization of NO_3 –N also showed a more or less similar pattern as that of NH_4-N.

Table 4.18 : Organic carbon content (%) during incubation study

Treatments	DAYS AFTER INCUBATION												
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**55**	**70**	**85**	**100**	**Mean**
Neem leaf	0.67^{a}	0.67^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.71^{a}	0.72^{a}	0.73^{a}	0.72^{a}	0.70
Pongamia leaf	0.68^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.70^{a}	0.70^{a}	0.70^{a}	0.70^{a}	0.71^{a}	0.72^{a}	0.72^{a}	0.70
Mango leaf	0.67^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.70^{a}	0.71^{a}	0.71^{a}	0.71^{a}	0.69
Jack leaf	0.67^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.71^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.70
Acacia leaf	0.67^{a}	0.67^{a}	0.67^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.71^{a}	0.71^{a}	0.71^{a}	0.69
Gliricidia leaf	0.66^{a}	0.67^{a}	0.67^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.71^{a}	0.73^{a}	0.73^{a}	0.73^{a}	0.69
Sesbania leaf	0.68^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.71^{a}	0.73^{a}	0.74^{a}	0.74^{a}	0.70
Terminalia leaf	0.68^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.70^{a}	0.71^{a}	0.71^{a}	0.71^{a}	0.69
Macaranga leaf	0.67^{a}	0.67^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.69^{a}	0.71^{a}	0.71^{a}	0.71^{a}	0.72^{a}	0.69
Straw	0.67^{a}	0.67^{a}	0.67^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.70^{a}	0.71^{a}	0.70^{a}	0.69
Cowdung	0.67^{a}	0.67^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.72^{a}	0.73^{a}	0.73^{a}	0.74^{a}	0.75^{a}	0.75^{a}	0.75^{a}	0.72
Poultry manure	0.68^{a}	0.68^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.70^{a}	0.70^{a}	0.70^{a}	0.71^{a}	0.71^{a}	0.73^{a}	0.73^{a}	0.70
No Organics	0.69^{a}	0.70^{a}	0.70^{a}	0.71^{a}	0.71^{a}	0.71^{a}	0.71^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.71
Fertilizer equivalent	0.70^{a}	0.70^{a}	0.70^{a}	0.71^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.73^{a}	0.73^{a}	0.73^{a}	0.73^{a}	0.72
50 % FE	0.68^{a}	0.69^{a}	0.69^{a}	0.70^{a}	0.70^{a}	0.70^{a}	0.71^{a}	0.71^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.72^{a}	0.71
Control	0.66^{a}	0.66^{a}	0.67^{a}	0.66^{a}	0.67^{a}	0.66^{a}	0.66^{a}	0.67^{a}	0.68^{a}	0.68^{a}	0.68^{a}	0.67^{a}	0.67

Table 4.19 : Concentrations of NH_4 (ppm) during incubation study

Treatments	DAYS AFTER INCUBATION											
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**55**	**70**	**85**	**100**	**Mean**
Neem leaf	9.8^{efg}	11.2^{e}	13.3^{d}	15.4^{e}	19.5^{ab}	16.4^{abcd}	14.7^{d}	13.5^{ef}	12.6^{ef}	12.6^{d}	11.9^{e}	10.5^{bcde}	13.5
Pongamia leaf	11.2^{de}	14.0^{d}	17.5^{c}	21.6^{ab}	18.9^{abc}	14.7^{bcde}	14.0^{e}	13.8^{de}	13.3^{d}	13.0^{cd}	12.6^{d}	11.9^{bc}	14.7
Mango leaf	9.6^{efg}	10.5^{ef}	11.2^{de}	11.9^{f}	12.0^{ef}	12.6^{e}	15.4^{c}	16.8^{a}	17.7^{a}	16.1^{abc}	13.3^{c}	10.5^{bcde}	13.2
Jack leaf	9.2^{efg}	10.1^{efg}	10.9^{de}	11.6^{f}	12.5^{ef}	14.0^{de}	14.6^{d}	15.3^{c}	18.1^{a}	15.0^{bcd}	12.6^{d}	11.2^{bcd}	12.9
Acacia leaf	8.4^{fg}	9.8^{efg}	10.5^{de}	11.2^{f}	11.7^{f}	14.1^{cde}	14.4^{de}	15.0^{c}	16.1^{b}	18.9^{a}	18.2^{a}	16.6^{a}	13.7
Gliricidia leaf	10.5^{ef}	15.4^{d}	20.3^{b}	18.2^{cd}	16.8^{bcd}	14.7^{bcde}	14.2^{de}	13.8^{de}	13.3^{d}	12.6^{d}	12.0^{e}	11.9^{bc}	14.5
Sesbania leaf	10.3^{ef}	19.6^{bc}	25.2^{a}	23.1^{a}	22.1^{a}	19.0^{a}	15.7^{bc}	14.2^{d}	13.4^{d}	13.5^{bcd}	12.6^{d}	11.2^{bcd}	16.7
Terminalia leaf	9.1^{efg}	9.8^{efg}	11.2^{de}	11.9^{f}	12.1^{ef}	13.6^{de}	16.8^{a}	16.1^{b}	14.1^{c}	12.6^{d}	11.9^{e}	9.2^{cde}	12.4
Macaranga leaf	9.8^{efg}	10.5^{ef}	10.9^{de}	11.7^{f}	12.3^{ef}	12.6^{e}	13.3^{f}	17.2^{a}	16.1^{b}	14.0^{bcd}	11.9^{e}	9.3^{bcde}	12.5
Straw	7.7^{g}	7.6^{g}	7.6^{f}	7.5^{g}	8.1^{g}	8.3^{f}	9.7^{g}	11.6^{h}	14.4^{c}	16.8^{ab}	14.0^{b}	10.5^{bcde}	10.3
Cowdung	14.1^{c}	19.6^{bc}	16.1^{c}	15.4^{e}	14.7^{def}	13.3^{de}	13.0^{f}	12.9^{g}	12.2^{fg}	11.9^{d}	10.2^{g}	9.8^{bcde}	13.6
Poultry manure	13.3^{cd}	21.1^{b}	22.3^{b}	17.5^{de}	16.3^{bcd}	14.7^{bcde}	14.2^{de}	13.1^{fg}	12.8^{e}	12.2^{d}	11.9^{e}	9.8^{bcde}	14.9
No Organics	21.7^{b}	21.0^{b}	20.8^{b}	20.3^{bc}	18.2^{bcd}	17.5^{abc}	13.3^{f}	12.8^{g}	12.0^{g}	11.6^{d}	11.2^{f}	8.4^{de}	15.7
FE	28.2^{a}	24.5^{a}	21.7^{b}	21.0^{ab}	18.9^{abc}	17.6^{ab}	16.1^{b}	15.4^{c}	14.2^{c}	14.0^{bcd}	12.6^{d}	12.6^{b}	18.1
50 % FE	20.3^{b}	18.2^{c}	16.8^{c}	16.1^{de}	15.4^{cde}	14.3^{bcde}	14.0^{e}	13.8^{de}	13.3^{d}	11.9^{d}	11.4^{f}	11.2^{bcd}	14.8
Control	7.7^{g}	8.2^{fg}	8.4^{ef}	7.9^{g}	8.0^{g}	7.9^{f}	8.1^{h}	7.6^{i}	8.1^{h}	7.6^{e}	7.3^{h}	7.3^{e}	7.8

Table. 4.20 : Concentrations of NO_3 (ppm) during incubation study

Treatments	DAYS AFTER INCUBATION											
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**55**	**70**	**85**	**100**	**Mean**
Neem leaf	5.6^{cde}	7.7^{cd}	8.4^{e}	8.6^{e}	9.1^{bc}	8.4^{c}	7.8^{c}	7.2^{ef}	7.0^{d}	6.6^{abcd}	6.3^{abcd}	5.6^{d}	7.4
Pongamia leaf	6.3^{cde}	8.5^{c}	9.3^{de}	10.1^{bc}	9.8^{b}	9.1^{b}	8.3^{b}	7.7^{de}	7.2^{cd}	7.0^{abcd}	6.8^{ab}	6.4^{b}	8.0
Mango leaf	4.9^{de}	5.6^{e}	5.7^{gh}	6.1^{gh}	6.6^{efg}	7.3^{de}	7.7^{cd}	8.1^{bcd}	8.4^{b}	6.2^{bcd}	5.7^{bcd}	4.9^{e}	6.4
Jack leaf	4.3^{de}	4.9^{ef}	5.6^{gh}	5.8^{ghi}	6.3^{efg}	7.0^{e}	7.3^{de}	8.4^{bc}	9.1^{a}	8.2^{ab}	7.7^{a}	6.1^{bcd}	6.7
Acacia leaf	4.2^{de}	4.9^{ef}	5.1^{gh}	5.6^{hi}	5.9^{fg}	6.9^{e}	7.1^{ef}	7.7^{de}	8.2^{b}	8.8^{a}	7.9^{a}	6.3^{bc}	6.6
Gliricidia leaf	7.7^{bcde}	11.2^{ab}	10.5^{bc}	9.8^{cd}	8.7^{bcd}	7.7^{d}	7.2^{e}	6.3^{g}	5.6^{f}	5.6^{cde}	5.1^{cd}	4.7^{ef}	7.5
Sesbania leaf	7.4^{bcde}	10.5^{ab}	11.3^{ab}	10.7^{ab}	9.1^{bc}	8.9^{b}	8.4^{b}	7.9^{cd}	7.7^{c}	7.0^{abcd}	6.4^{abc}	6.1^{bcd}	8.5
Terminalia leaf	4.9^{de}	6.3^{de}	6.6^{f}	7.0^{f}	7.6^{cde}	8.3^{c}	8.5^{b}	7.0^{f}	6.5^{e}	5.1^{de}	4.9^{cd}	4.3^{f}	6.4
Macaranga leaf	4.5^{de}	5.6^{e}	5.9^{fg}	6.5^{fg}	7.3^{def}	7.7^{d}	8.1^{bc}	8.6^{ab}	7.5^{cd}	7.0^{abcd}	6.3^{abcd}	4.2^{f}	6.6
Straw	4.2^{de}	4.6^{ef}	4.9^{h}	5.1^{i}	5.6^{g}	6.3^{f}	6.6^{f}	7.1^{f}	7.3^{cd}	7.8^{abc}	6.4^{abc}	5.8^{cd}	6.0
Cowdung	8.4^{bcd}	10.9^{ab}	9.1^{de}	8.8^{e}	8.6^{bcd}	8.3^{c}	7.2 de	7.0^{f}	6.3^{e}	6.3^{abcd}	5.6^{bcd}	4.2^{f}	7.6
Poultry manure	8.4^{bcd}	10.6^{ab}	10.3^{c}	9.1^{de}	8.2^{cd}	7.7^{d}	7.0 ef	6.3^{g}	5.6^{f}	4.9^{de}	4.7^{d}	4.1^{f}	7.2
No Organics	11.6^{ab}	11.2^{ab}	9.8^{cd}	9.1^{de}	8.9^{bc}	8.4^{c}	8.4 b	8.2^{bcd}	7.7^{c}	6.4^{abcd}	5.8^{bcd}	5.6^{d}	8.4
FE	14.0^{a}	12.1^{a}	11.9^{a}	11.6^{a}	11.2^{a}	10.5^{a}	10.2 a	9.1^{a}	9.1^{a}	8.4^{ab}	7.8^{a}	7.7^{a}	10.3
50 % FE	11.2^{ab}	9.6^{bc}	8.5^{e}	8.4^{e}	7.7^{cde}	7.7^{d}	7.0 ef	6.9^{f}	6.5^{e}	6.3^{abcd}	5.4^{bcd}	4.3^{f}	7.5
Control	3.5^{e}	3.3^{f}	3.3^{i}	3.2^{j}	3.8^{h}	3.6^{g}	3.5 g	3.4^{h}	3.9^{g}	3.4^{e}	3.2^{e}	3.1^{g}	3.4

Table. 4.21 : Concentrations of total N (ppm) during incubation study

Treatments	DAYS AFTER INCUBATION												
	5	10	15	20	25	30	35	40	55	70	85	100	Mean
Neem leaf	15.4 ^{def}	18.9 ^{f}	21.7 ^{e}	24.0 ^{b}	28.6 ^{abc}	24.8 ^{bc}	22.5 ^{bcd}	20.7 ^{defg}	19.6 ^{de}	19.2 ^{cde}	18.2 ^{bcd}	16.1 ^{cdef}	20.8
Pongamia leaf	17.5 ^{de}	22.5 ^{e}	26.8 ^{d}	31.7 ^{b}	28.7 ^{abc}	23.8 ^{bcd}	22.3 ^{bcd}	21.5 ^{cdefg}	20.5 ^{cde}	20.0 ^{cde}	19.4 ^{bc}	18.3 ^{bc}	22.8
Mango leaf	14.5 ^{efg}	16.1 ^{g}	16.9 ^{f}	18.0 ^{d}	18.6 ^{fgh}	19.9 ^{e}	23.1 ^{bcd}	24.9 ^{ab}	26.1 ^{ab}	22.3 ^{bcd}	19.0 ^{bc}	15.4 ^{def}	19.6
Jack leaf	13.5 ^{fg}	15.0 ^{g}	16.5 ^{f}	17.4 ^{d}	18.8 ^{fg}	21.0 ^{de}	21.9 ^{cd}	23.7 ^{abcd}	27.2 ^{a}	23.2 ^{bc}	20.3 ^{b}	17.3 ^{cd}	19.7
Acacia leaf	12.6 ^{fg}	14.7 ^{g}	15.6 ^{f}	16.8 ^{d}	17.6 ^{gh}	21.0 ^{e}	21.5 ^{cd}	22.7 ^{abcdef}	24.3 ^{abc}	27.7 ^{a}	26.1 ^{a}	22.9 ^{a}	20.3
Gliricidia leaf	18.2 ^{d}	26.6 ^{d}	30.8 ^{c}	28.0 ^{b}	25.5 ^{bcd}	22.4 ^{cde}	21.4 ^{cd}	20.1 ^{efg}	18.9 ^{e}	18.2 ^{de}	17.1 ^{cd}	16.6 ^{cde}	22.0
Sesbania leaf	17.7 ^{d}	30.1 ^{bc}	36.5 ^{a}	33.8 ^{a}	31.2 ^{a}	27.9 ^{a}	24.1 ^{abc}	22.1 ^{bcdef}	21.1 ^{cde}	20.5 ^{bcde}	19.0 ^{bc}	17.3 ^{cd}	25.2
Terminalia leaf	14.0 ^{fg}	16.1 ^{g}	17.8 ^{f}	18.9 ^{d}	19.7 ^{efg}	21.9 ^{cde}	25.3 ^{ab}	23.1 ^{abcde}	20.6 ^{cde}	17.7 ^{e}	16.8 ^{cd}	13.5 ^{f}	18.8
Macaranga leaf	14.3 ^{fg}	16.1 ^{g}	16.8 ^{f}	18.2 ^{d}	19.6 ^{efg}	20.3 ^{e}	21.4 ^{cd}	25.8 ^{a}	23.6 ^{abcde}	21.0 ^{bcde}	18.2 ^{bcd}	13.5 ^{f}	19.1
Straw	11.9 ^{g}	12.2 ^{h}	12.5 ^{g}	12.6 ^{e}	13.7 ^{hi}	14.6 ^{f}	16.3 ^{e}	18.7 ^{g}	21.7 ^{cde}	24.6 ^{ab}	20.4 ^{b}	16.3 ^{cdef}	16.3
Cowdung	22.5 ^{c}	30.5 ^{b}	25.2 ^{d}	24.2 ^{c}	23.3 ^{def}	21.6 ^{de}	20.2 ^{d}	19.9 ^{efg}	18.5 ^{e}	18.2 ^{de}	15.8 ^{d}	14.0 ^{ef}	21.2
Poultry manure	21.7 ^{c}	31.7 ^{b}	32.6 ^{bc}	26.6 ^{bc}	24.5 ^{cde}	22.4 ^{cde}	21.2 ^{cd}	19.4 ^{fg}	18.4 ^{e}	17.1 ^{e}	16.6 ^{cd}	13.9 ^{ef}	22.2
No Organics	33.3 ^{b}	32.2 ^{b}	30.6 ^{c}	29.4 ^{b}	27.1 ^{abcd}	25.9 ^{ab}	21.7 ^{cd}	21.0 ^{defg}	19.7 ^{de}	18.0 ^{de}	17.0 ^{cd}	14.0 ^{ef}	24.2
FE	42.2 ^{a}	36.6 ^{a}	33.6 ^{b}	32.6 ^{a}	30.1 ^{ab}	28.1 ^{a}	26.3 ^{a}	24.5 ^{abc}	23.3 ^{bcd}	22.4 ^{bcd}	20.4 ^{b}	20.3 ^{b}	28.4
50 % FE	31.5 ^{b}	27.8 ^{cd}	25.3 ^{d}	24.5 ^{c}	23.1 ^{def}	22.0 ^{cde}	21.0 ^{cd}	20.7 ^{defg}	19.8 ^{de}	18.2 ^{de}	16.8 ^{cd}	15.5 ^{cdef}	22.2
Control	11.2 ^{g}	11.5 ^{h}	11.7 ^{g}	11.1 ^{e}	11.8 ^{i}	11.5 ^{g}	11.6 ^{f}	11.0 ^{h}	12.0 ^{f}	11.0 ^{f}	10.5 ^{e}	10.4 ^{g}	11.3

4.8.3 Mineralization of Phosphorus

The incubation study also envisaged assessing the mineralization pattern of P from the added organic and inorganic sources. The results obtained are presented in Table 4.22. Addition of organic matter showed a slight initial increase in P content in soil in case of neem, mango, gliricidia, sesbania, terminalia, macaranga and cowdung treatments, whereas, the addition of synthetic fertilizers showed a significant increase. However, the amount of P released in soil decreased between 25 and 40 days for all treatments though the decrease was less pronounced in case of synthetic fertilizer treatments.

4.8.4 Mineralization of Potassium

The observation relating to mineralization K from various treatments are presented in Table 4.23. In case of K mineralization, addition of organic manures and synthetic fertilizers, showed an upward trend. However, the release from synthetic fertilisers was more rapid. The values tended to decrease slightly towards the final phase of incubation in case of some treatments.

Table 4.22 : Concentrations of P (ppm) during incubation study

Treatments	DAYS AFTER INCUBATION												
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**55**	**70**	**85**	**100**	**Mean**
Neem leaf	5.77 ^{efg}	5.64 ^{bcde}	5.08 ^{h}	4.31 ^{j}	4.28 ^{d}	3.90 ^{gh}	3.89 ^{g}	3.96 ^{g}	4.33 ^{f}	4.48 ^{gh}	5.37 ^{ef}	5.94 ^{f}	4.7
Pongamia leaf	5.73 ^{fgh}	5.41 ^{cde}	5.18 ^{g}	5.03 ^{de}	4.58 ^{d}	4.01 ^{g}	3.68 ^{h}	3.73 ^{h}	4.09 ^{g}	4.65 ^{g}	5.41 ^{def}	6.04 ^{e}	4.8
Mango leaf	5.78 ^{efg}	5.57 ^{bcde}	5.29 ^{f}	4.39 ^{ij}	4.26 ^{d}	3.01 ^{k}	3.66 ^{h}	3.70 ^{h}	4.26 ^{fg}	5.19 ^{ef}	5.71 ^{cd}	5.88 ^{fg}	4.7
Jack leaf	5.74 ^{efgh}	5.63 ^{bcde}	5.48 ^{d}	4.92 ^{def}	4.38 ^{d}	3.95 ^{gh}	3.59 ^{hi}	4.43 ^{f}	4.51 ^{ef}	4.98 ^{f}	5.51 ^{cdef}	5.79 ^{h}	4.9
Acacia leaf	5.71 ^{gh}	5.66 ^{ab}	5.37 ^{e}	4.65 ^{gh}	4.29 ^{d}	4.01 ^{g}	4.21 ^{f}	4.96 ^{e}	5.38 ^{d}	5.64 ^{cd}	5.71 ^{cd}	5.83 ^{gh}	5.1
Gliricidia leaf	5.77 ^{efg}	5.27 ^{bcd}	5.03 ^{h}	4.91 ^{def}	4.47 ^{d}	3.76 ^{h}	3.45 ^{ij}	3.28 ^{i}	4.36 ^{f}	5.21 ^{ef}	5.98 ^{bc}	6.17 ^{b}	4.8
Sesbania leaf	5.81 ^{e}	5.08 ^{e}	4.87 ^{i}	4.48 ^{hij}	3.71 ^{e}	3.21 ^{j}	3.41 ^{j}	3.99 ^{g}	4.76 ^{e}	5.93 ^{ab}	6.24 ^{b}	6.36 ^{d}	4.8
Terminalia leaf	5.76 ^{efgh}	5.23 ^{de}	4.91 ^{i}	4.56 ^{ghi}	3.89 ^{e}	3.45 ^{i}	3.31 ^{j}	3.36 ^{i}	4.39 ^{f}	5.01 ^{f}	5.26 ^{fg}	6.24 ^{c}	4.6
Macaranga leaf	5.78 ^{efg}	5.71 ^{bcd}	5.21 ^{g}	4.87 ^{ef}	4.53 ^{d}	4.22 ^{f}	3.69 ^{h}	3.45 ^{hi}	3.63 ^{h}	4.28 ^{h}	5.64 ^{cde}	5.89 ^{fg}	4.7
Straw	5.69 ^{h}	5.62 ^{bcde}	5.47 ^{d}	5.11 ^{cd}	4.98 ^{c}	4.71 ^{d}	4.38 ^{e}	4.45 ^{f}	4.63 ^{e}	5.01 ^{f}	5.54 ^{cdef}	5.71 ^{i}	5.1
Cowdung	5.79 ^{ef}	5.41 ^{cde}	5.32 ^{ef}	4.76 ^{fg}	4.32 ^{d}	4.51 ^{e}	4.93 ^{d}	5.10 ^{de}	5.48 ^{cd}	5.61 ^{cd}	5.75 ^{c}	5.93 ^{f}	5.2
Poultry manure	6.43 ^{b}	5.84 ^{bc}	5.49 ^{c}	4.87 ^{ef}	5.16 ^{bc}	5.38 ^{b}	5.61 ^{a}	5.73 ^{a}	5.89 ^{a}	6.04 ^{a}	6.79 ^{a}	7.03 ^{a}	5.9
No Organics	6.61 ^{a}	6.45 ^{a}	6.23 ^{a}	5.87 ^{a}	5.48 ^{ab}	5.32 ^{b}	5.41 ^{b}	5.43 ^{bc}	5.66 ^{bc}	5.78 ^{bc}	5.71 ^{cd}	5.91 ^{f}	5.8
FE	6.05 ^{c}	5.92 ^{abc}	5.83 ^{b}	5.42 ^{b}	5.31 ^{bc}	5.08 ^{c}	5.16 ^{c}	5.18 ^{cde}	5.36 ^{d}	5.29 ^{e}	5.67 ^{cde}	5.87 ^{fg}	5.5
50 % FE	5.91 ^{d}	5.85 ^{bc}	5.77 ^{b}	5.28 ^{bc}	5.20 ^{bc}	5.19 ^{bc}	5.14 ^{c}	5.29 ^{c}	5.38 ^{d}	5.41 ^{de}	5.52 ^{cdef}	5.79 ^{h}	5.5
Control	4.75 ^{i}	4.68 ^{f}	4.63 ^{ij}	4.61 ^{ghi}	4.64 ^{cd}	4.60 ^{g}	4.63 ^{ef}	4.67 ^{e}	4.69 ^{e}	4.71 ^{g}	4.70 ^{g}	4.71 ^{j}	4.7

Table 4.23 : Concentrations of K (ppm) during incubation study

Treatments	DAYS AFTER INCUBATION												
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**55**	**70**	**85**	**100**	**Mean**
Neem leaf	49.3 ^{bcde}	49.8 ^{e}	50.4 ^{cd}	50.7 ^{cdef}	51.7 ^{bcd}	53.3 ^{c}	54.2 ^{bc}	56.4 ^{ab}	56.1 ^{ab}	55.7 ^{b}	55.1 ^{abc}	54.8 ^{bcd}	53.1
Pongamia leaf	49.6 ^{bcd}	50.1 ^{de}	51.3 ^{bcd}	51.8 ^{cd}	52.6 ^{bc}	55.4 ^{b}	56.8 ^{a}	57.4 ^{a}	56.3 ^{a}	55.8 ^{b}	55.7 ^{ab}	56.3 ^{ab}	54.1
Mango leaf	48.3 ^{defg}	49.2 ^{e}	49.9 ^{cd}	50.4 ^{def}	51.6 ^{bcde}	52.8 ^{cd}	53.1 ^{bcde}	53.6 ^{bcde}	54.1 ^{bc}	54.2 ^{c}	53.8 ^{abcd}	52.6 ^{de}	52.0
Jack leaf	47.9 ^{efg}	48.2 ^{e}	48.6 ^{d}	49.3 ^{efg}	49.9 ^{def}	50.4 ^{fg}	50.6 ^{ef}	51.5 ^{defg}	53.8 ^{c}	55.4 ^{b}	55.6 ^{ab}	54.8 ^{ab}	51.3
Acacia leaf	47.6 ^{fg}	47.9 ^{e}	48.2 ^{d}	48.5 ^{fg}	49.1 ^{ef}	49.4 ^{g}	49.8 ^{f}	51.9 ^{cdefg}	53.8 ^{c}	54.5 ^{c}	54.2 ^{abcd}	53.3 ^{bcd}	50.7
Gliricidia leaf	50.4 ^{abc}	52.1 ^{cd}	55.6 ^{a}	57.6 ^{a}	57.4 ^{a}	56.9 ^{a}	56.7 ^{a}	56.4 ^{ab}	55.9 ^{ab}	55.6 ^{b}	55.4 ^{ab}	55.5 ^{abc}	55.5
Sesbania leaf	49.8 ^{abcd}	50.1 ^{de}	50.4 ^{cd}	51.7 ^{cd}	53.5 ^{b}	54.8 ^{b}	54.1 ^{bc}	53.6 ^{bcde}	52.9 ^{c}	52.7 ^{d}	51.6 ^{bcdef}	51.9 ^{ef}	52.3
Terminalia leaf	48.5 ^{defg}	48.7 ^{e}	49.2 ^{d}	49.9 ^{defg}	50.8 ^{cdef}	51.6 ^{def}	52.9 ^{bcde}	55.3 ^{abc}	56.2 ^{ab}	55.8 ^{b}	55.4 ^{ab}	55.7 ^{abc}	52.5
Macaranga leaf	48.7 ^{defg}	49.1 ^{e}	49.3 ^{d}	49.9 ^{defg}	50.6 ^{cdef}	50.9 ^{ef}	51.7 ^{cdef}	53.8 ^{bcde}	56.9 ^{a}	58.1 ^{a}	57.6 ^{a}	57.3 ^{a}	52.8
Straw	47.5 ^{fg}	47.9 ^{e}	48.3 ^{d}	48.5 ^{fg}	49.1 ^{ef}	50.3 ^{fg}	50.9 ^{def}	51.8 ^{defg}	53.6 ^{c}	53.9 ^{c}	54.2 ^{abcd}	54.8 ^{bcd}	50.9
Cowdung	48.2 ^{defg}	49.3 ^{e}	50.6 ^{ab}	51.4 ^{cde}	50.7 ^{cdef}	50.4 ^{fg}	49.9 ^{f}	49.8 ^{fg}	49.4 ^{de}	49.1 ^{f}	48.9 ^{ef}	49.0 ^{gh}	49.7
Poultry manure	49.1 ^{cdef}	49.9 ^{e}	50.3 ^{cd}	51.7 ^{cd}	51.9 ^{bcd}	52.0 ^{de}	51.8 ^{cdef}	51.6 ^{defg}	50.8 ^{d}	50.2 ^{e}	49.9 ^{def}	49.6 ^{fgh}	50.7
No Organics	50.8 ^{ab}	52.6 ^{c}	53.8 ^{abc}	52.9 ^{bc}	52.3 ^{bcd}	51.9 ^{de}	51.4 ^{def}	51.1 ^{efg}	50.8 ^{d}	50.6 ^{e}	50.8 ^{cdef}	50.9 ^{efg}	51.7
FE	51.3 ^{a}	56.9 ^{a}	57.6 ^{a}	56.8 ^{a}	56.5 ^{a}	55.7 ^{b}	55.2 ^{ab}	54.9 ^{abcd}	53.4 ^{c}	53.0 ^{d}	53.1 ^{bcde}	52.9 ^{cde}	58.8
50 % FE	50.5 ^{abc}	54.8 ^{b}	54.6 ^{ab}	54.1 ^{b}	53.9 ^{b}	53.4 ^{c}	53.3 ^{bcd}	53.1 ^{bcdef}	52.9 ^{c}	53.1 ^{d}	52.6 ^{bcde}	52.7 ^{de}	53.3
Control	47.4 ^{g}	49.1 ^{e}	48.3 ^{d}	48.1 ^{g}	48.3 ^{f}	49.1 ^{g}	49.3 ^{f}	48.7 ^{g}	47.5 ^{e}	47.2 ^{g}	47.7 ^{f}	47.8 ^{h}	48.2

DISCUSSION

5. Discussion

In recent years "sustainable agriculture" has become a topic, which has received great attention from environmentalists, agriculturists and consumers. Sustainable agriculture has been given a number of definitions but the core concepts *viz.* ecologically sound; economically viable and socially just and humane remain the same. However, farmers are looking for ways to reduce production costs but are also concerned with the rising consumer interest in chemical free organic produce and the adverse effect of many conventional farming systems on the environment.

This approach could be realized to a great extent by reducing the amount of fertilizer added and increasing the efficiency of the fertilizer applied by more efficient management of nutrient cycles and precise fertilizer application. Also practices like application of green manures, crop and animal residues, crop rotations with legumes and improvement of crop health that may result in better use of nutrients and split application of fertilizers would have a significant role in achieving this objective.

Long-term experiments have shown that neither organic source nor mineral fertilizers alone can achieve sustainability in crop production. Productivity can be definitely raised through an integrated use of both organic and inorganic sources of nutrients which would be perhaps due to the correction of deficiencies of secondary and micro nutrients in course of mineralization on one hand, and favourable physical and ecological conditions on the other. Another reason could be the improved microbial condition of the soil leading to increased availability of nutrients.

The present study too had specific objectives in, identifying potential green leaf manure source among locally available plant species, their comparability to already established plant and animal manures and also to different levels of inorganic fertilizers. The results obtained are discussed in this chapter.

5.1 Composition of source materials

Leaves and tender twigs of the trees and plants were used for green leaf manuring. The driage, C/N ratio, lignin/ N ratio, fibre content and the nutrient contents were estimated in all the organic sources.

The driage varied from 26.87 per cent in macaranga to 35.55 per cent in acacia signifying the moisture content of the leaves and the time of incorporation. Together with other characters such as C/N ratio, lignin/ N ratio, fibre content and lignin content, moisture content plays an important role in decomposition of organic materials and mineralization of elements.

The organic carbon content of the organics varied from a low value of 36.7 per cent in straw to a high of 49.1 per cent in pongamia. The C/N ratio of source materials varied between 14.03 in gliricidia and 55.6 in straw. Straw attained the highest C/N ratio not because of its high carbon content but due to its relatively low N content. On the other hand, though pongamia had very high carbon percentage (49.1 per cent), it had a comparatively lower C/N ratio due to the high N content. The lignin/N ratio varied from 0.97 in poultry manure to 39.6 in acacia leaf. Each of the above parameters has effected its own influence on the mineralization of nutrient elements both in field as well as soil incubation situations and this is discussed in detail later on in this chapter.

An overall assessment of the results obtained from this experiment and the research reviews suggest that narrower C/N ratio, narrower lignin/N ratio and higher fibre content dictate the pace of mineralization in organic sources.

5.2 Influence of treatments on soil physico-chemical properties

Variations in the soil composition at intervals during the treatments have been studied. Soil pH did not show remarkable variations. The minor reductions in soil pH could be attributed to the release of carbon dioxide and weak acids (Rogers and Giddens, 1957 and Agboola, 1974). This can be noticed especially in case of pongamia, sesbania, straw and cow dung treatments, wherein there is an appreciable decrease in pH in comparison to the initial value. The pH fluctuations caused by the addition of external inputs in the organic or inorganic form is evident from the maintenance of a more or less constant pH in control treatment.

However, Eh variations were remarkably significant and indicated stages with reducing conditions. This could be a direct effect of the decomposition and the use of available oxygen by microorganisms leading to further shift towards anaerobic condition and hence high Eh values are observed in all green leaf manure treatments compared to animal residues.

Bulk density showed minor decreases in spite of addition of large amounts of organic matter except in case of cow dung, which showed a notable decrease. This could be due to higher organic carbon content, more pore space and good soil aggregation (Mishra and Sharma, 1997). The favourable effect of bulky organics on the above characters was well documented by Prasad and Goswami (1991).

The organic carbon contents did not vary significantly and this could be due to the fact that organic matter addition for a significant length of time is required to bring about notable changes in organic carbon content as was reported by Odell *et al.* (1984) and Udayasoorian *et al.* (1988).

5.3 Availability of nutrients

Monitoring of available N, available P and available K during plant growth particularly at 35 DAT, 70 DAT and at harvest has brought to light the effectiveness of source materials especially in influencing crop growth and yield. (Tables 4.3, 4.4 and 4.5). The differences in the available N content of the soil at various stages under individual treatments may be either due to differential release pattern or differential uptake of N by the crop. These variations are more clear when the differences in available N content between the stages of observation for a particular source material is compared.

The absence of high values of available N especially at 35 DAT in acacia and straw amended treatments is comparable to the available N content in absolute control treatment and this could be attributed to the slow release of N from the applied material. The reduced values at 70 DAT compared to 35 DAT is due to the uptake of released N by the crop. Mango, jack, acacia and straw incorporated treatments showed minor differences in N content between 35 and 70 DAT and may be due to slow decomposition of the material applied.

The available P content was in the range 10.26 kg /ha to 15.82 kg / ha in the different treatments and at different periods. The available P content is generally less in laterite soils due to its fixation by dominant iron and manganese in soil. Poultry manure resulted in a higher available P content in soil possibly due to high content of P in bio available form in the organic manure. Significantly higher P content in organics except mango, jack, acacia and straw is either due to the bio-available P in the material or due to enhanced mineralization due to changed soil environment created by decomposition of material or by inorganic fertilizer P added to soil. The solubilizing effect of decomposing organic matter on the release of P was reported by Shrikhande, (1948) and Nagarajah *et al.* (1989). The above four treatments showed a negative difference between 35 and 70 DAT due to slow mineralization of P from organic sources. Joseph (1994) reported a two-step mineralization of P from green manures. An initial slow release from the easily decomposable leaf tissues and a later release from the harder plant tissues.

The observations expressed in case of N and P are valid in the case of K also with regard to the varied differences in K content between different organic treatments. However, the K released into soil incorporated with straw is noticeable as it was the only treatment which showed a negative difference between 35 and 70 DAT period, which indicated its slow nutrient release, with maximum release at 70 DAT.

5.4 Influence of treatments on plant growth and related characters

Almost all the treatments irrespective of inorganics or inorganics in combination with organics produced significantly better plants in terms of height as compared to absolute control treatment. However, such a phenomenon was not observed with number of tillers. Increase in height is a direct expression of plant growth and is highly related to the nutrients taken up by the plant, however, tiller production may be hindered by other physical constraints. Also, enhancement in plant height need not be complimentary to rice yield. At 70 DAT, the plant height was highest in poultry manure applied treatment closely followed by jack leaf amended and then by neem and pongamia leaf amended plots. The concentration of major, secondary and micronutrients in poultry manure is relatively well balanced with minimum quantity of iron and zinc, which might have resulted in a favourable soil environment for growth. Jack leaf also contained relatively less amount of zinc and iron. Bridgit (1999) observed that excess amount of zinc and iron in the rhizosphere limits rice growth in laterite soil.

Cell sap pH estimations made at 30 and 60 DAT clearly showed that the pH was above 6.2, which is considered optimum for maximum rice productivity as reported by Marykutty *et al.* (1999). Higher pH of leaf sap has also been reported to be due to non metabolic accumulation of heavy metals like Fe (Singh, 1970) and in this study the general yield level is low irrespective of the treatments probably due to inherent dominance of iron in the soil.

Chlorophyll contents *viz.* chlorophyll *a*, chlorophyll *b* and total chlorophyll are important parameters, which decide the photosynthetic efficiency and ultimately the yield of the crop. Chlorophyll *a* is the precursor of chlorophyll *b* and a decline in the level of chlorophyll *b* is indicative of instability and stress (Sindhu, 2002) and hence the ratio of chlorophyll *a* to *b* becomes relevant in giving physiological explanations for yield variations. In this study it was seen that the treatments with higher ratio of chlorophyll *a* : chlorophyll *b* produced less growth and yield.

5.5 Elemental composition of plants

The elemental composition of plants is indicative of the amount of available nutrients in the soil. The N content of plant at 35 DAT and leafy part at 70 DAT was significantly lower in absolute control plot than in all other treatments, which received N application either as inorganics or organics + inorganics in varied quantities.

In all treatments, the N contents were well above the critical limit, however, the utilisation within the plant might have been different. Thomas *et al.* (2001) has reported that it is not the effect of one element but the net effect of the essential elements present in adequate quantity and in balance with other nutrients, which decides the productivity. However, those organic treatments which are seen to have low decomposition rates such as acacia, macaranga and straw are found to have relatively less N content at 35 DAT but the low N contents were considerably increased by 70 DAT in comparison to other organic and inorganic treatments.

With regard to the P content, the control treatment showed the least P content, both at 35 DAT and 70 DAT. The maintenance of P at a higher level by poultry manure application was spectacular signifying the higher bio-available P content in the manure. Among the different green leaf manuring treatments, sesbania was found to maintain higher P content in rice specifically due to its higher P content.

Potassium unlike N and P apparently does not form an integral part of any plant component and its function is catalytic in nature. The rice plant has a high capacity of absorbing and exhausting K thus maintaining the concentration at constant levels (Su, 1976). However, just like N, the leaf concentration of K in rice plants was significantly less in absolute control treatment both at 35 and 70 DAT. All the other treatments have contributed sufficient quantity of K into soil solution either by mineralization or directly, however, the quantity absorbed by plants was more or less proportional to the availability in soil solution.

The levels of Ca, Mg, Fe, Zn, Na and Cu in the plants at all stages were within acceptable limits and the slight differences among the treatments could be attributed to the contents and subsequent release of micronutrients present in the source materials. A perusal of the data on leaf, secondary and micronutrients showed that all nutrients were above critical limits and none of them limited the yield due to their inadequacy. The Fe content in plants was much more than the requirement and reached toxicity levels, which can be considered as a main constraint in not achieving the potential productivity of rice. Bridgit (1999) also reported that the higher availability of Fe in soil and its excessive accumulation is suspected to be one of the reasons for low fertilizer response resulting in low rice yield in Kerala. Iron is also reported to be an inhibitor of K uptake by plants.

The crop uptake value of any nutrient is the resultant of the crop dry matter production and nutrient concentration. At 35 DAT, the N uptake was significantly lowest in absolute control plots. The higher N uptake to the extent of 131.5 kg was observed with sesbania green manuring followed by gliricidia, neem and pongamia. The fertilizer equivalent (FE) treatment also resulted in a similar N uptake. In this study, the above leguminous green leaf manure and neem emerges out as an alternate for the highest inorganic fertilizer N dose. Those organics with high C/N ratio, lignin/ N ratio and higher crude fibre content are not efficient to supply the plant with enough N as indicated by lower uptakes at 35 DAT. The uptakes of P and K also followed a similar trend.

5.6 Yield and yield attributes

A thorough perusal of data on grain and straw yield as influenced by various treatments showed that grain yield from pongamia and gliricidia green leaf manured plots were on par with the yield from fertilizer equivalent (FE), however, the straw yield was significantly higher in FE treatments. This indicates that the nutrient release into soil solution and corresponding uptake and utilisation within the plant from the above green leaf manure treatments were almost equal to inorganic fertilizer application. These were closely followed by sesbania and poultry manure treatments, which indicate the efficiency of these organic sources for higher productivity. Those organic sources with slow decomposition were not able to produce higher yield because synchronization between nutrient supply and plant nutrient demand could not be achieved. Myers *et al.* (1994) reported that for short duration cereals, this asynchrony is the major constraint in achieving sustainable yields following organic matter addition. However, these organic sources may prove better for long duration crops or annuals in multiple cropping systems. So the residual effect of these organic sources may prove beneficial to the succeeding crop rather than the one it is applied to.

Rice grain yield is a product of *viz.* number of productive tillers, spikelets per panicle, test weight of seeds and the fertility percentage. Each of these characters can be influenced by the variations in input sources consequently resulting in yield variations. In the FE treated plots, the higher yield was achieved mainly due to increase in productive tillers, whereas in gliricidia and pongamia treated plots it was possibly due to the reduced chaff percentage and enhanced test weight. The higher yield in poultry manure amended plots was mainly due to enhancement in the number of spikelets per panicle. There are critical stages for rice plant, for nutrient elements, which may correspond to the different plant physiological stages such as tillering, spikelet differentiation, grain filling, etc. It is logical to assume that the nutrients released from different materials have positively influenced the various critical physiological processes leading to variations in rice yield.

For short duration high yielding rice varieties, the favourable harvest index is 0.5 or more. The gradual decrease from this indicates the non-proportionate increase in the quantity of straw, which is undesirable and may even be responsible for reducing grain yield. Such a tendency can result in higher pest and disease incidence and enhance chaff percentage. Such a phenomenon can be observed in the case of FE treatment compared to the organics and, this could lead to the usage of more organics alone or in judicious combination with inorganics as against the use of inorganic fertilizers alone.

Experiment 2. Incubation study

The decomposition process, which is a pre- requisite for often, begins with soil macro fauna physically breaking down the particle-size of organic matter and predigesting organic materials. The rate of decomposition is governed by a number of factors, the important ones being C/N ratio, composition of organic matter, especially lignin concentration and lignin/N ratio, fibre content and concentration of polyphenols and tannins.

Materials with lower C/N ratio, lower concentration of lignin, fibre and polyphenols and higher nutrient content decompose faster. The availability of nutrients from other soil pools also enhances decomposition rates if nutrient concentrations are low in litter.

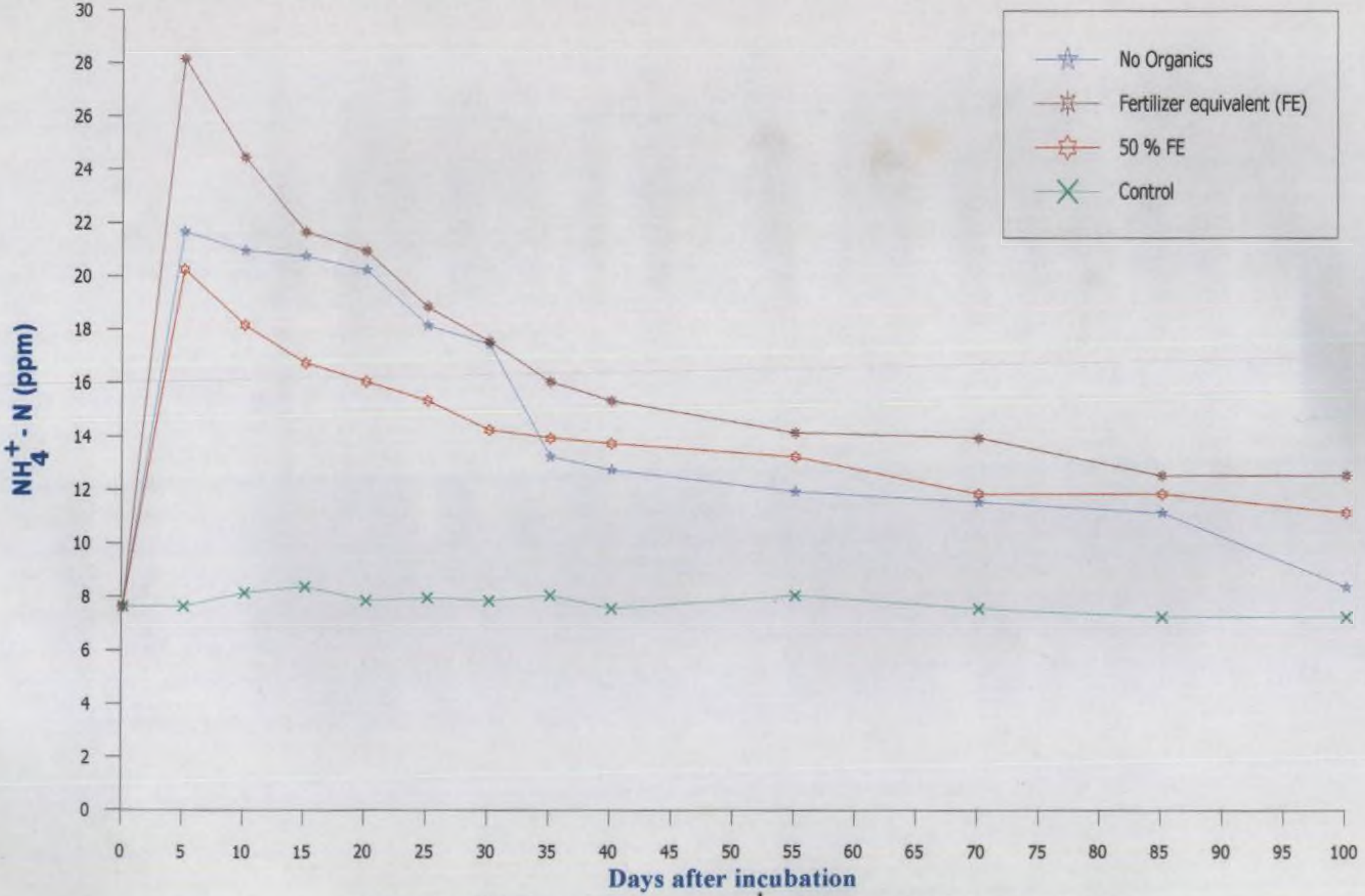


Fig 5.1 : Mineralization of NH_4^+ - N from inorganic sources

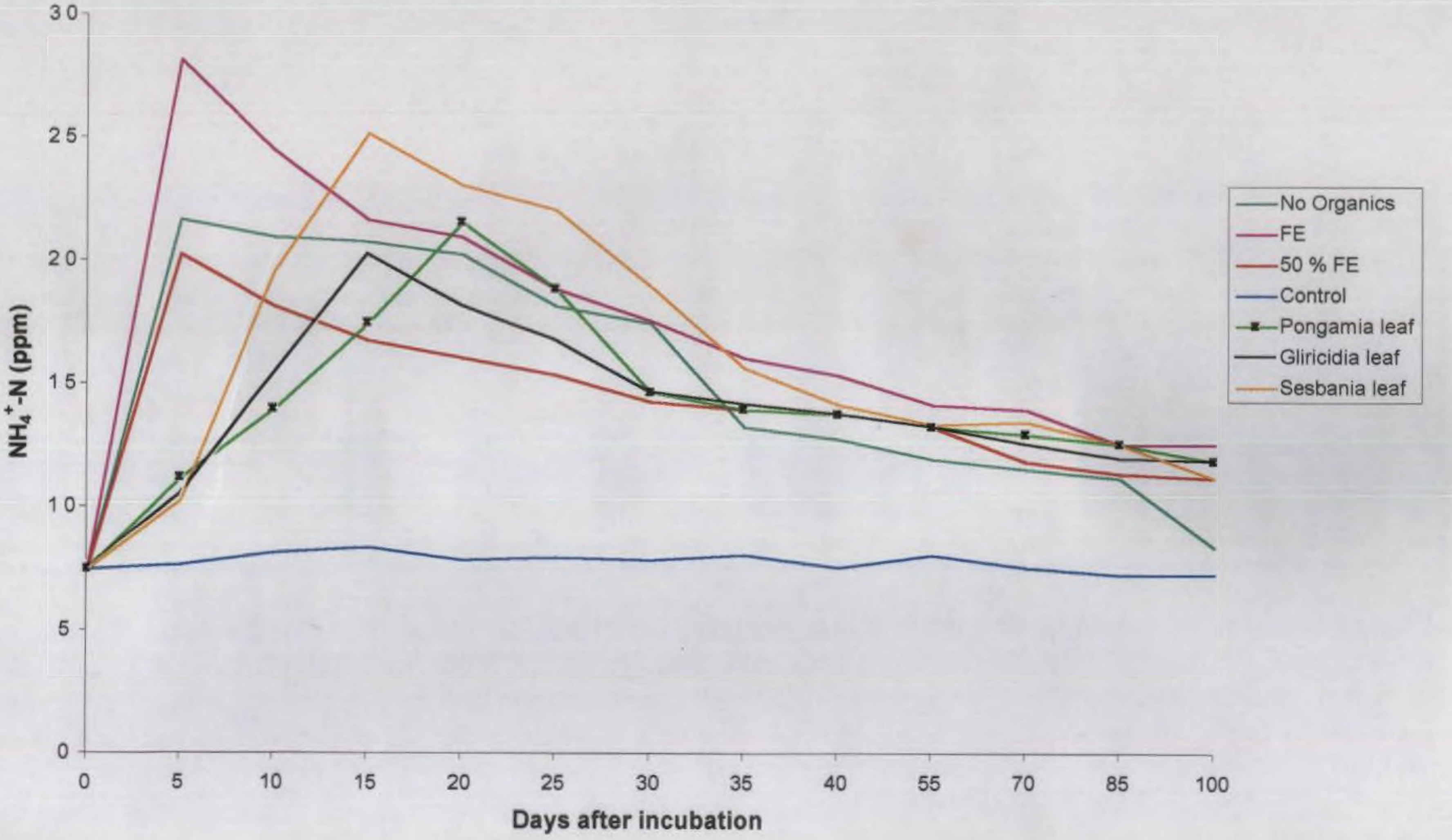


Fig.5.2 Mineralization of NH$_4^+$- N from inorganic and selected organic sources

The observations at various intervals for organic carbon contents of the soil showed no significant differences among the treatments and also the increase especially in cow dung treatment was only marginal. This is because of the difficulty in raising the organic carbon levels of the soil over a very short period. To improve the organic carbon status of the soil, organic matter addition in substantial quantities for an extended period is required.

The NH_4^+-N and NO_3^--N mineralization pattern and the relative changes in their levels in the soil show that inorganic fertilizers release nutrients into the soil before the organic treatments (Fig. 5.1 and 5.2) However, differences in the levels of NH_4^+-N and NO_3^--N in soil could be attributed to the differential quantities of N applied as inorganic fertilizers.

Among the organic materials, cow dung, poultry manure, gliricidia and sesbania showed peak N mineralization much earlier than the other treatments (Fig 5.3, 5.4 and 5.5). Poultry manure and cow dung are already partially decomposed. The narrower C/N and lignin/N ratio, lower fibre content, greater moisture content and consequent succulence of the green leaves might be responsible for early and large release of nutrients. In case of mango, jack, terminalia and macaranga, the comparatively higher C/N and lignin/N ratios have played a dominant part in slowing down the decomposition but the most intense effect of these factors on decomposition and mineralization can be observed in case of acacia and straw where there is a marked reduction in the rate of decomposition. The effect of these factors on mineralization can be better understood by a thorough inspection of Fig. 5.6 wherein the time taken to mineralize and, the peak levels of NH_4^+-N and NO_3^-- N together as total N mineralized is graphically represented. From the data, it would be safe to assume that the NO_3^- mineralization pattern followed a similar trend as NH_4^+ mineralization though the levels of NO_3^- in the soil were lesser owing to the partially anaerobic condition.

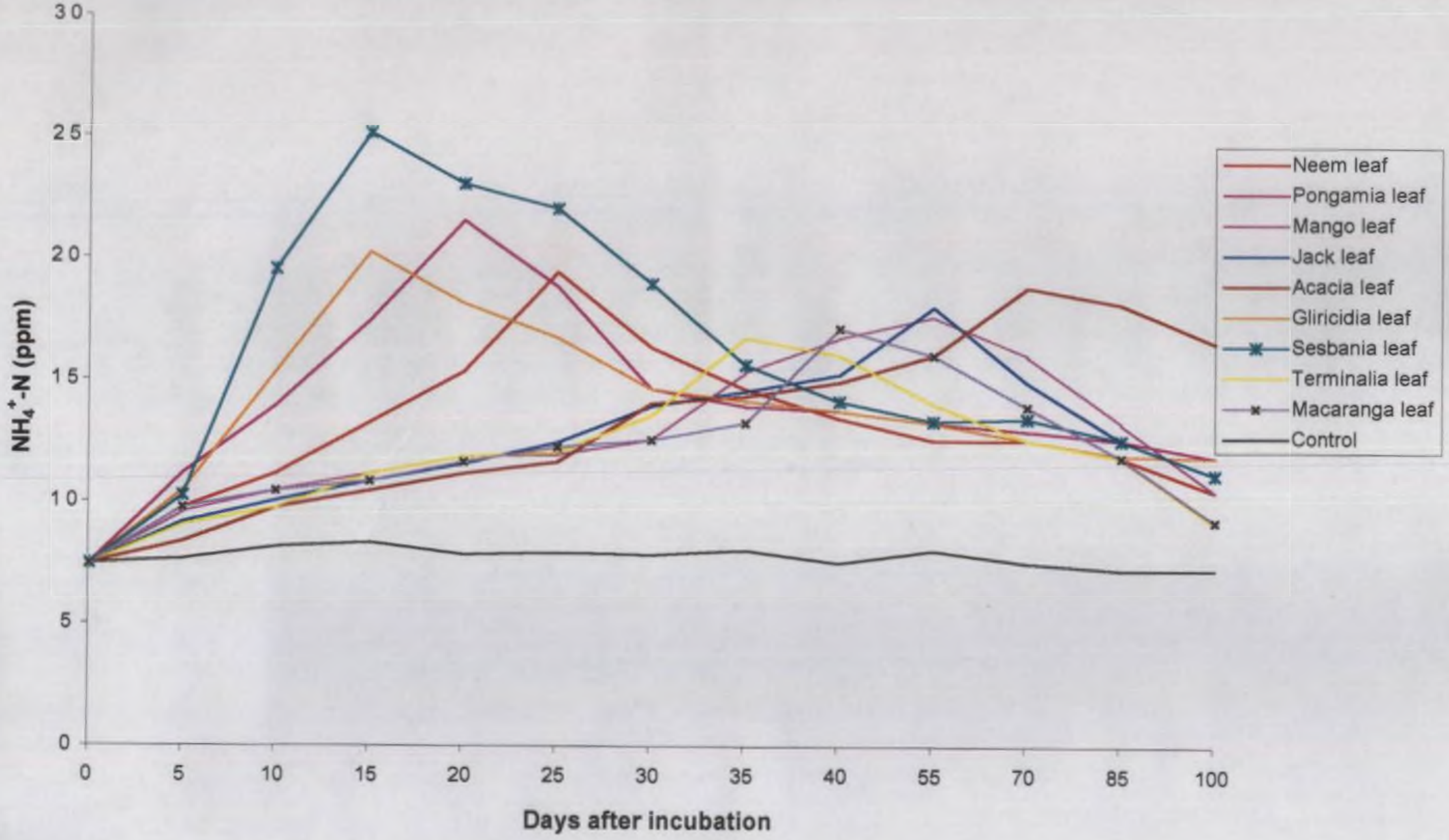


Fig.5.3 Mineralization of NH_4^+- N from green leaf sources

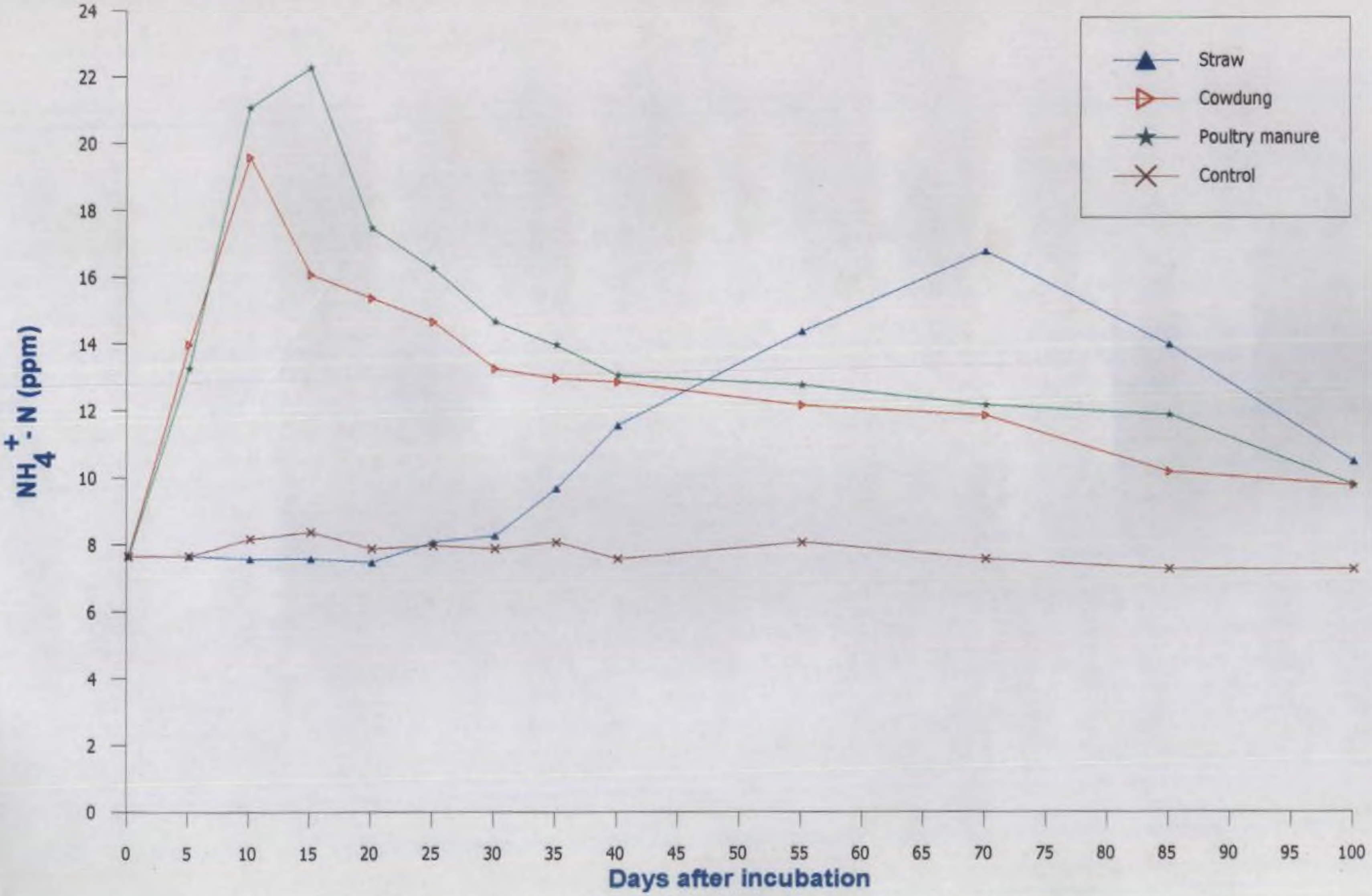


Fig 5.4 : Mineralization of NH_4^+ - N from plant and animal residues

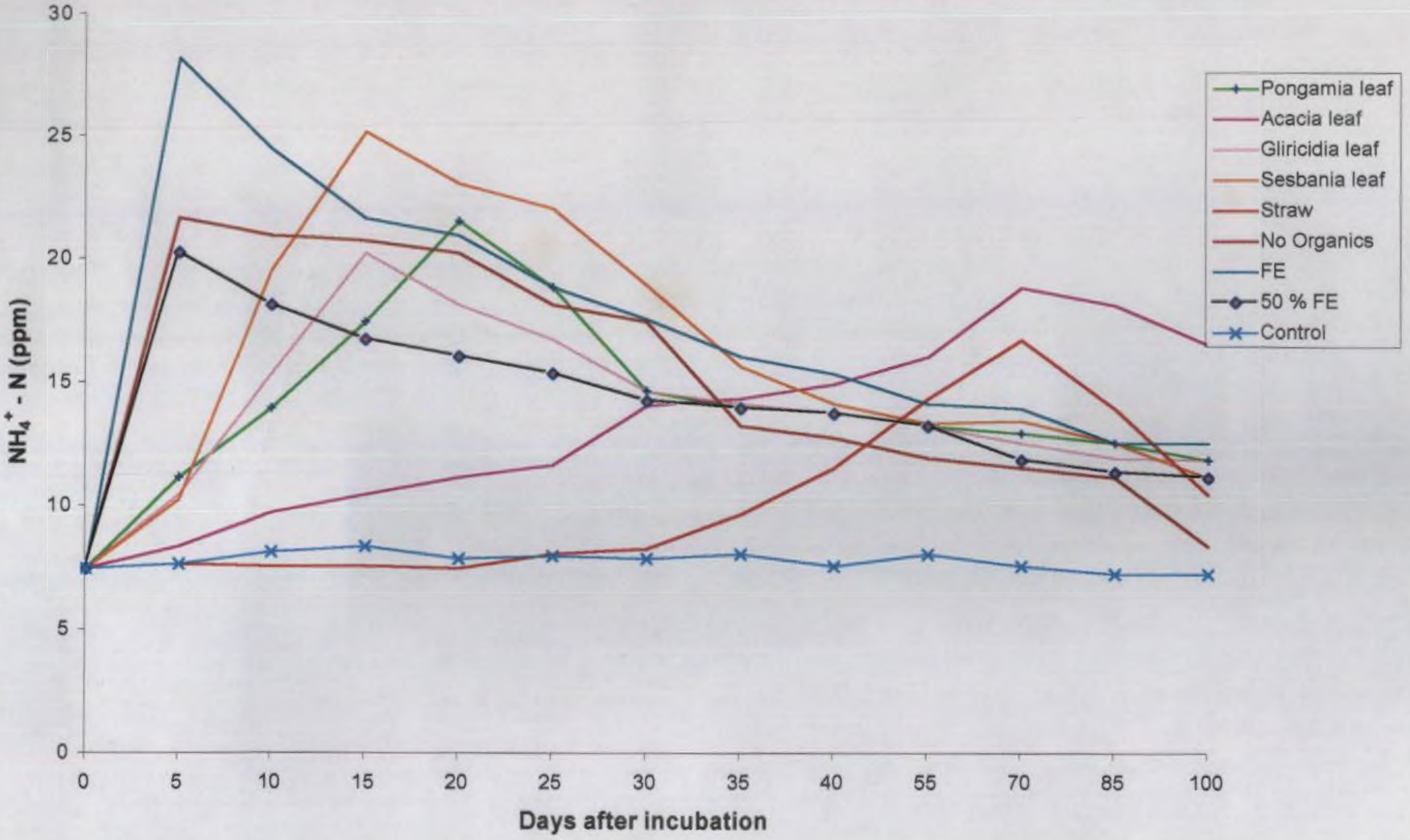


Fig.5.5 Mineralization of NH_4^+ - N from inorganic and some selected organic sources

It is seen from the data and also the figures that after reaching the peak of mineralization, in earlier or later stages of incubation depending on the various sources, there is a substantial decline in the NH_4^+ and NO_3^- content. It can also be seen that the percentage of decrease, increased with the quantity of NH_4^+ and NO_3^- mineralized. Since it was an incubation study and all the loss mechanisms except gaseous forms are prevented, the losses could only be due to either, volatilization and transformation to NO_3^- by nitrification in the case of NH_4^+ and denitrification in case of NO_3^-. It can be seen that in case of sesbania, the peak NH_4^+ production of 25.2 ppm was at 15 DAT, which declined to 11.2 ppm at 100 days. A decrease of more than 50 per cent in the NH_4^+ by either transformation to nitrate or volatilization is noticed. For the same treatment the peak NO_3^- levels were observed at 15 days (11.3 ppm), which declined to 6.1 ppm by 100 days indicating that almost, 50 per cent of nitrate is lost by way of denitrification. Thusthe total mineral N production, shows that more than 50 per cent N is lost in sesbania incorporated puddled soil over a period of 100 days in an uncropped situation. More or less same trend can be seen in case of all the inorganic and inorganic treatments (Fig 5.6).

Observations made for the P contents of the soil at similar intervals show that in case of P mineralization both organic and inorganic treatments had a pronounced influence as is evident from the fact that the levels of P in the control treatment did not vary much. It is worthy to note that in all the treatments except control, there was a marked difference in the levels of P in the soil corresponding to a period between 20 and 40 days after incubation. Beyond this period, however, the levels of P rose steadily and at 100 days, it was at a higher level than the initial, in all treatments.

The soil used for the study was lateritic in nature with a predominance of Fe and Mn and is noted for its P fixation ability. The mineralized P might have succumbed to fixation as phosphates of these dominant minerals and can be solubilised into the soil solution only under changed soil biochemical situation

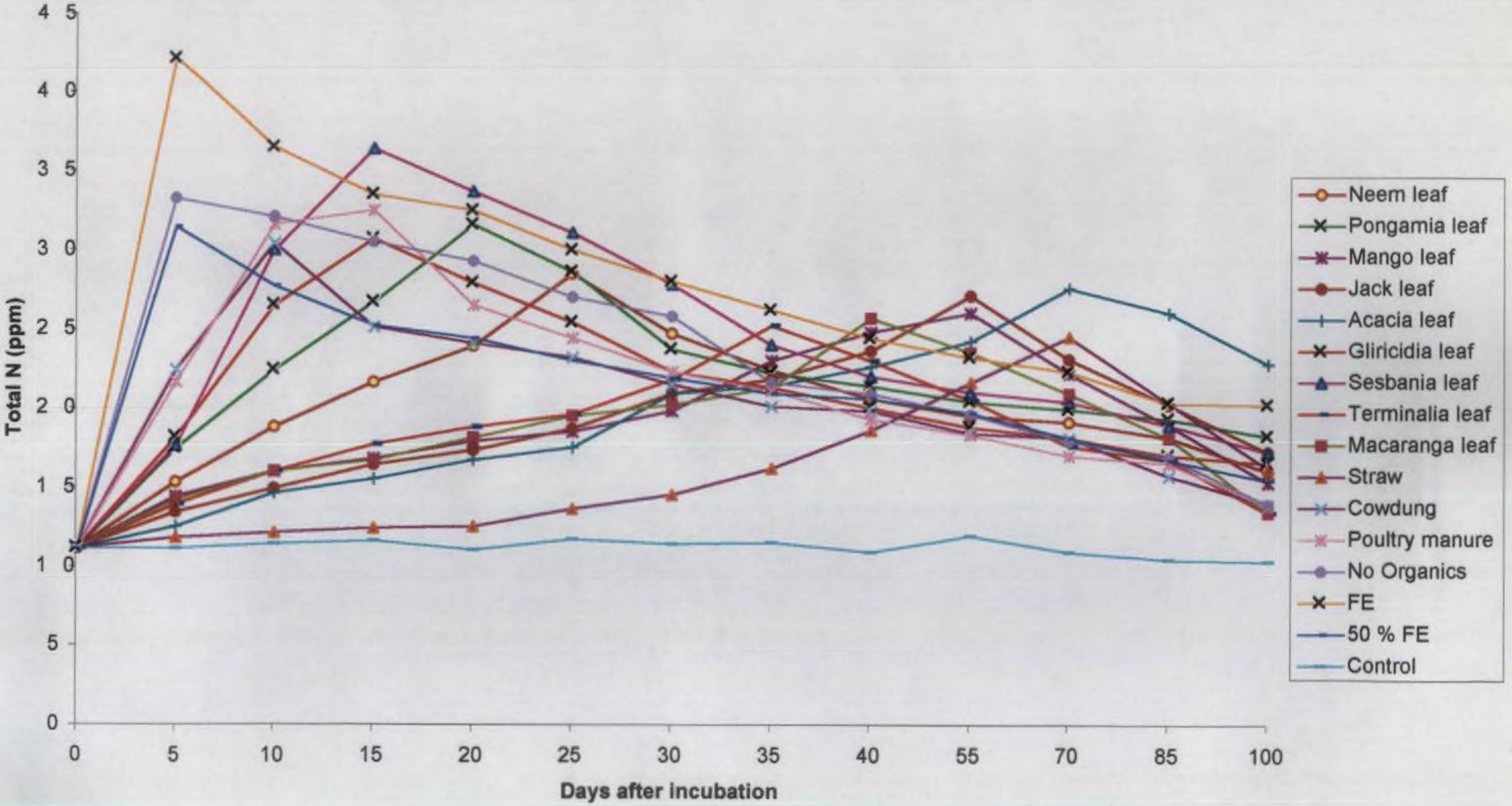


Fig. 5.6 Mineralization of Total N from source materials

created by death and decomposition of microorganisms or by the action of native phosphorus solubilizing bacteria, which may have become active in partially anaerobic situations. Similar observations were made by Joseph (1994) while studying the fate of labeled ^{32}P green leaf manure applied to lateritic soil and also by Vig *et al.* (1997).

In the case of K mineralization, as in N the rate of decomposition had a major role to play in the release of K into soil solution. The quantity of K present and ease with which the material decomposed had a direct bearing on the quantity of K released in the system. This is probably the reason why, higher levels of K are observed in soil treated with macaranga, gliricidia, pongamia and jack. However, the comparatively lesser content of K mineralized from straw even after 100 days could be attributed to inability of straw to decompose and mineralize completely over this period owing to the high C/N and lignin/N ratios and fibre content.

SUMMARY

6. Summary

A field experiment was carried out during the Kharif season of 2000 at the Agricultural Research Station, Mannuthy to assess the efficacy of various sources of green leaf and organic manures in relation to nutrient accretion, rice growth and yield. The interactive effect of decomposition products on nutrient mineralization, chemical properties of the soil and subsequent elemental composition of the plant were studied in relation to rice growth. The changes in carbon: nitrogen relations in the soil and the pattern of nitrogen mineralization were monitored through an incubation study conducted at the College of Horticulture, Vellanikkara. The important observations made and the conclusions drawn from them are presented in this chapter.

Experiment 1. Field experiment

The field experiment was laid out in randomized block design with three replications. The treatments consisted of twelve organic amendments of both plant and animal origin, coupled with the normal fertilizer recommendation for high yielding, short duration variety of rice, *viz.*70:35:35 kg/ha of N, P and K respectively, three synthetic fertilizer combinations and an absolute control. All organic treatments were incorporated at 5t/ha on dry weight basis. The short duration HYV, Matta Triveni was used in the experiment.

1) Among the organic materials used highest content of N was observed in sesbania (3.30%) while P content was highest in poultry manure (1.44%) and K content was maximum in macaranga (2.5%). Organic carbon content was highest in pongamia (49.1%) and lignin was maximum in acacia (19.24%). The C/N ratio was maximum in straw in spite of a comparatively low carbon content due to the lower level of N. The converse of this was noticed in case of pongamia where even though the carbon content was maximum, the C: N ratio was low owing to high N content

2) Soil pH and bulk density and organic carbon did not show any major variations during the course of the experiment but Eh values showed appreciable changes probably due to the shift from aerobic to partially anaerobic conditions and vice versa.

3) The content of available nitrogen in the soil was significantly influenced by the different treatments and throughout the experiment the highest values were reported from FE treated plot.

4) The content of available phosphorous in the soil was highest in poultry manure incorporated plots throughout the experiment, which could be directly linked, to the high percentage of P in the material.

5) The content of available potassium too was influenced by the treatments. The presence of high amounts of available K in FE and macaranga treated plots can be attributed to the higher levels of K received from the source materials.

6) Plant physiological characters like cell sap pH and chlorophyll content were only slightly influenced by the different treatments and there were no major variations among the values obtained. The ratio of chlorophyll *a* to chlorophyll *b* was highest at both stages of observation in acacia treatment suggesting stress on the plants and also this has affected the yield from the plants. Conversely the lowest ratio at 35 DAT was in case of jack treatment (2.28) and at 45 DAT, it was in gliricidia treatment (2.16) and the influence of this is reflected on the yield. Also cell sap pH was higher than optimum levels in all treatments and the repercussions could be observed in yield.

7). The height of tillers was maximum in plots treated with poultry manure with pongamia and jack being on par at all stages of the crop while number of tillers especially after 25 DAT was maximum in FE treated plots. However, poultry manure treatment was on par with this..

8) The elemental composition of the plants was significantly influenced by the treatments and the contents of nitrogen in plants were high in case of FE, pongamia and sesbania treatments. In case of phosphorus, the contents were high in poultry manure, gliricidia and pongamia treatments, while in case of potassium the major contributors were gliricidia, sesbania and macaranga.

9) Micronutrient contents too were studied and it was observed that all the nutrients were well above the critical limits at all stages and none of them limited the yield due to their inadequacy. The levels of Fe, however, were in excess and may have affected the productivity of rice in all treatments.

10) Among the yield attributes, the number of productive tillers was highest in FE treated plots, and the length of panicle was maximum in poultry manure treated plots. The number of spikelets per panicle was also highest in poultry manure. The test weight was highest in sesbania treatment but so was the chaff percentage.

11) The highest yield of grain (4.37 t/ha) and straw (5.20t/ha) were from FE treated plots but the grain straw ratio (0.84) was the lowest in this treatment. In FE treated plot, the higher yield was due to increase in number of productive tillers while in gliricidia and pongamia, it was a result of reduced chaff percentage and enhanced test weight. In poultry manure the increase in yield was due to enhanced number of spikelets per panicle.

12) The contents of major nutrients in grains and straw were analysed and highest content of nitrogen in straw was in case of cow dung treatment while in case of grain it was in FE treatment. Phosphorus content in straw was highest in poultry manure treatment and in grains it was maximum in plots receiving no organic treatments. Potassium content in straw was highest in straw incorporated plots while the content in grains was maximum for macaranga leaf treatment.

Experiment 2. Incubation study

The treatments in the field experiment were replicated as an incubation study to understand the pattern of nitrogen mineralization and to observe the variations in carbon nitrogen relations. A measured quantity of soil (100g) was placed in air tight glass bottles and corresponding quantity of organic manures so as to maintain a ratio of 5t/ha and the fertilizer treatments also in the same ratio were incorporated and incubated for a period of 100 days. The observations made are summarized.

1) The C/N ratio and lignin/N ratio along with the moisture content, fibre content and the amount of nutrients present determined the pace of decomposition and mineralization of nutrients in organics. This is clearly evident from the mineralization of straw, mango, jack and acacia.

2) The observations at different intervals did not show any major changes in the organic carbon values and even after 100 days, there was only a very marginal increase in the quantity of organic carbon in the soils.

3) The mineralization of nitrogen was studied as that from both, NH_4^+ and NO_3^- and it was observed that in both cases the synthetic fertilizers mineralized within the first 5 days, while in case of organic manures, cow dung, gliricidia and sesbania were the first to do so. Straw and acacia treatments were the slowest to mineralize achieving peak levels at 70 days after incubation. The general trend was attainment of a peak value and then a steep decline in the levels, which could be directly attributed to losses by way of denitrification and volatilization.

4) In case of phosphorus mineralization, it was noticed that mineralization in all treatments irrespective of it being organic or inorganic in nature, tended to decrease rapidly after incubation up to 40 days and then gradually increase to levels higher than the initial level. This was attributed to the initial P fixation by

the soil due to high Fe and Mn levels and also fixation as constituents of microbial cell, which is subsequently released by the action of weak acids produced as a result of death and decomposition of these organisms. Also the probable activity of phosphate solubilising bacteria especially considering the partially anaerobic condition is worthy of consideration

5) In case of potassium mineralization, a slow and gradual increase in the levels of K were observed which was noticed even after 70 days with a slight decrease being noticed towards the end in some treatments. The pattern could be solely associated with the decomposition and nutrient release pattern of the organics and inorganics.

Conclusion

The results obtained show that organic manures have the ability to substitute inorganic fertilizers to a great extent as is understood from the yield obtained. It was seen that almost all the organic sources except straw and Acacia produced higher grain yields than the normal fertilizer recommendation adopted for short duration HYV of rice. Also they were better than the 50% FE treatment with some treatments like pongamia, sesbania and gliricidia being only marginally inferior to the best treatment (FE), which involved substantially high amounts of nitrogen. Also with respect to the nutrient uptake by plants, receiving pongamia treatment was better than even FE treated though only marginally, whereas in case of phosphorus uptake poultry manure treatment was the best. Only in case of potassium did the fertilizer treatments fare better but only marginally as compared to macaranga, sesbania and macaranga.

Thus, it can be inferred that substitution of a major quantity of inorganic fertilizers is possible by the use of organic manures. However, considering the mineralization patterns, a better option would be combined use of inorganic and organic manures whereby the synthetic fertilizers meet only the initial nutrient requirement of the crop as they are readily available to the crop during the initial exponential growth phase. By adopting this method additional expenditure that may arise from the need of ploughing in of the manures, especially green manures before planting of the crop can be avoided by coupling manure addition and final ploughing of the field just prior to transplanting. The inorganic fertilizer provides the initial requirement while in the later stages that slow but consistent release from the organic sources would make nutrients available throughout the growth period. Also additional expenditure involved in top dressing of fertilizers can be done away with.

Future line of work

1) Explore the possibility of using a mixture of organic manures so as to enable steady supply of nutrients in available forms taking into consideration the rates of mineralization especially nitrogen. Also mixing manures such that an optimum supply of all nutrients is ensured by in where one source may make up for the lesser content of a certain nutrient/s in the other and vice versa.

REFERENCES

References

Abdul, H., Rai, R.K., Safeena, A.N. and Mukherjee, P.K. 1999. Available N status of the soil as influenced by phosphorus application and some kharif green manure crops grown in succession with some rabi crops. *Ann. agric. Res.* 20(4): 522-523

Agboola, A. A. 1974. Problems of improving soil fertility by the use of green manuring in tropical farming system. Organic materials as fertilizers. FAO, *Soils. Bull.* No. 17. Rome, p. 147-152

Ahmed, P., Medhi, D.N. and Dekamedhi, B. 1998. Influence of organic manures and urea on leaching loss in low land rice ecosystem. *J. agric. Sci. Soc. North East India* 11(1): 101-102

Alam, S.M and Azmi, A.R. 1989. Effect of P on growth and rice plant nutrient content. *Int. Rice Res. Newsl.* Manila. 14(1) : 20.

Anilakumar, K., Johnkutty, I. and Joseph, K. 1993. Long term effects of continuous fertilization by organic and inorganic sources on rice productivity. *Agric. Res. J. Kerala.* 31(2): 204-209

Anonymous. 1961. Eighth meeting on the IRC working party on rice soils, water and fertilizer practices. *Int. Rice. Comm. Newsl.* 11(2): 17 – 19

*Anzai, T., Kaneko, F. and Matsumoto, N. 1989. Effect of successive application of rice straw and rice straw compost on growth and yield of paddy rice. *Bull. Chiba Prefectural agric. Experiment Station* No. 30. pp 71-80

Bahl, G.S., Vig, A.C., Pal, Y. and Singh, A. 1998. Effect of green manures and cropping on P sorption in some soils of Punjab and Himachal Pradesh. *J. Indian Soc. Soil Sci.* 46(4): 574-579

Bal, A.S, Patil, R.A., Khanvilkar, S.A. and Jadhav, S.N. 1993. Effects of FYM and Glyricidia green manure in conjunction with fertilizer nitrogen applied in transplanted kharif rice. *J. Maharashtra agric. Univ.* 18(2): 235-237

Balasubramaniyan, P., Palaniappan, S.P. and Francis, H.J. 1993. Effect of organic and inorganic N fertilization and population of nutrient uptake and yield of low land rice. *Madras agric. J.* 80(2): 1-3

Behera, U.K. and Jha, K.P. 1997. On farm evaluation of promising rice varieties and their response to green manuring in the rainfed midland and low land ecosystem of Kalahandi, Orissa. *Crop Res.* 13(2): 267-276

Bin, J. 1983. Utilization of green manure for raising soil fertility in China. *Soil Sci.* 135(1): 65 – 69

Biswas, A.K. and Goswami, N.N. 1995. Kinetics of exchangeable and water-soluble ammonium – N in soil growing rice and amended with urea and *Sesbania aculeata. J. Indian Soc. Soil Sci.* 43(1): 20-24

Biswas, T.D., Roy, M.R. and Sahu, B.N. 1970. Effect of different sources of organic manures on the physical properties of the soil growing rice. *J. Indian Soc. Soil Sci.* 18(3): 233-242

Black, C. A. 1965. *Methods of Soil Analysis Part II.* ASA, Madison, p.420

Boparai, B.S., Singh, Y. 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 semi arid region of India. *Arid Soil Res. Rehabilitation* 6(2): 135-143

Brady, N.C. 1996. *The Nature and Properties of Soils.* Tenth edition. Prentice Hall of India. New Delhi, p. 621

Bremner, J. M. 1965. Chemical and Microbiological Properties. *Methods of Soil Analysis Part 2*. Second edition. (eds. Page, A.L Miller, R. H. and Keeney, D. R.). ASA , Madison, pp. 648 – 658

Bridgit, T. K. 1999. Nutritional balance analysis for productivity improvement of rice in iron rich lateritic alluvium. Ph. D Thesis, Kerala Agricultural Unversity Thrissur, p. 483

Broadbent, F.E. 1978. Nitrogen transformation in flooded soils. *Soils and Rice*, IRRI, Manila, pp. 543-559

Broadbent, F.E. and Nakashima, T. 1965. Plant recovery of immobilized nitrogen in green house experiments. *Soil Sci. Soc. Am.* 18: 55-60

Budhar, M.N., Palaniappan, S.P. and Rangaswamy, A. 1991. Effect of farm waste and green manures on low land rice. *Indian J. Agron.* 36(2): 251-252

Cassman, K.G., and Pingali, P.L. 1995. Extrapolating trends from long-term experiment to farmers fields: The case of irrigated rice systems in Asia. *Agricultural Sustainability in Economic, Environmental and Statistical Terms* (eds. Barnett, V., Payne, R. and Steiner, R.). Wiley, London. pp. 63 – 84

Chahal, D.S., Khehra, S.S. and Dhaliwal, G.S. 1998. Rice yield and iron availability as influenced by green manuring and ferrous sulfate application under different moisture regimes. *Ecological Agriculture and Sustainable Development Vol. I.* Proceedings of International Conference on Ecological Agriculture: Towards Sustainable Development, Chandigarh, (eds. Arora, R., Randhawa, N.S. and Dhawan, A.K.). p. 652-658

Chakraborty, A., Chakraborty, P.K., Banik, P. and Bagchi, D.K. 2001. Effect of integrated nutrient supply and management on yield of rice (*Oryza sativa*) and nitrogen and phosphorus recovery by it in acid lateritic soils. *Indian J. Agron.* 46(1): 75-80

Chandrakar, B.L., Tripathi, R.S. and Gahrewal, M.K. 1990. Relative efficiency of different organic materials and N fertilizer in wetland rice. Rice in wetland ecosystem: Proceedings of National Symposium on "Rice In Wetland

Ecosystem" Kottayam, December, 19-21 (eds. Nair, R.R., Nair, K.P.A. and Joseph, C.A.), p 58-60.

Chaphale, S.D. and Badole, W.P. 1999. Effect of green manuring and NPK combinations on soil health and yield of rice (*Oryza sativa*). *Indian J. Agron.* 44(3): 448-451

Chaphale, S.D., Chaphale, B.S., Yerne, A.Z. and Lanjewar, A.D. 2000. Effect of green manuring on soil properties and yield performance of rice (*Oryza sativa* L.). *J. Soil Crops.* 10(1): 136-140

Chen, L.Z. and Wang, J.Y. 1987. Effects of green manure on soil organic matter. *J. Soil Sci. 18(6): 270-273*

Dahama, A.K. 1996. *Organic Farming for Sustainable Agriculture.* Agro Botanical Publishers, India, p. 263

*Davide, J.G 1960. Phosphorus fixation in waterlogged soils. Ph.D. Dissertion. North Carolina State College, North Carolina.

Dixit, S.P. and Sharma, K.P. 1993. Effect of lime and potassium on soil acidity, forms of aluminium and iron and yield of crops in a sequence. *J. Indian Soc. Pl. Soil.* 51: 207 – 216

Dobermann, A. and Fairhurst, T.H. 2000. Nutrient Disorders and Nutrient Management, Rice. Third edition. IRRI, Manila, p. 230

Dobermann, A. and Fairhurst, T.H. 2002. Rice Straw Management. *Better Crops int.* 16: 7-9

Dwivedi, D.K. and Thakur, S.S. 1999. Effect of organics and inorganic fertility levels on productivity of rice (*Oryza sativa*) crop. *Indian.J.Agron* 45(3): 568-574

el Wakeel, S.K. and Riley, J.P. 1956. The determination of organic carbon in marine muds. *J. Du. Conseil.* 22(1): 180-183

Evans, D.O. and Rotar, P.P. 1987. *Sesbania in Agriculture.* West View Press, Boulder, Colorado, p.225

Fisher, G. and Heilig, G.K. 1998. Population momentum and the demand on land and water resources. *Land Resources: On the edge of the Malthusian precipice ?* (eds. Greenland, D.J., Gregory, P.J. and Nye, P.H) IRRI Manila. pp. 9-28

Fisher, K.S. 1998. Nutrient use efficiency in rice cropping systems. *Field Crop Res.* 56(1-2): 1 – 236

Gaur, A.C. 1982. Organic manures and biofertilizers. *Int. Rev. Soil Res. India.* 12th International Congress on Soil Science, February 8-16, 1982, New Delhi, p. 278-305

Gunapala, N. and Amarasiri, S.L. 1989. Green manuring of rice fields in central regions of Sri Lanka. *Trop. Agricst.* 145: 61-74

Gupta, A.P., Neue, H.U. and Singh, U.P. 1995. Increasing productivity through phosphatic fertilizer and poultry manure application in acid upland. *Ann. Biol.* 11(1-2): 151-157

Gurung, G.B. and Sherchan, D.P. 1996. Study on biomass production of Daincha (*Sesbania aculeata* Pers.) when relayed under maize and its green manuring effect on rice. Technical paper 170. Pakhribas Agricultural Centre, Nepal p. 14

Haroon, A.R.M., Krishnaswamy, R., Velu, V., Jawahar, D. and Ramaswami, P.P. 1992. Integrated nitrogen management for irrigated low land rice. *Int.Rice.Res.Newsl*, Manila, 17(2): 19-20

Hatfield, R. 2001. Extraction and isolation of lignin for utlization as a standard to determine lignin concentration by Acetyl Bromide Spectrophotmetric method . *J.agric. Food Chem.* 56: 201 – 203

Hegde, R. 1995. Nutrient content and decomposition of leaf litter of *Acacia mangium* (Wild) as affected by season and field conditions. M. Sc. (Forestry) thesis, Kerala Agricultural University, Thrissur, p.124

Hemalatha, M., Thirumurugan, V. and Balasubramanian, R. 1999. Influence of organic, biofertilizer and inorganic forms of nitrogen on rice quality. *Int.Rice.Res.Newsl* , Manila, 24(1): 33

Hemalatha, M., Thirumurugan, V. and Balasubramanian, R. 2000. Effect of organic sources of nitrogen on productivity, quality of rice (*Oryza sativa*) and soil fertility in single crop wet lands. *Indian J. Agron.* 45(3): 564-567

*Hernandez, C., Arteaga, O. and Munoz, P. 1989. Effect of application of cattle dung to a greyish brown soil. *Ciencia y Tecnica en la Agricultura, Suelos Agroquimica.* 12(1): 43-52

*Hideshima, Y. and Aikawa, Y. 2001. Effect of different applications of stable manure on growth, yield and quality in early paddy rice. Studies on utilization and approach of stable manure to early paddy rice in Uwaba, Saga prefecture. Report of the Kyushu Branch, The Crop Science Society of Japan 67. 44 : 1-14

Hiremath, S.M. and Patel, Z.G. 1996. Effects of incorporation of different green manure species with varying seeding date and rate on yield of summer rice. *J. Maharashtra agric. Univ.* 21(1): 36-39

Hossain, M. and Fisher, K.S. 1995. Rice research for food security and sustainable agricultural development in Asia: Achievements and Future Challenges. *Geo.J* 35(3): 286-298

Hundal, H.S., Dev, G. and Biswas, C.R. 1991. Effect of green manures on kinetics of dissolved and labile P release in anoxic soil. *J. Indian Soc. Soil Sci.* 39(2): 260-265

*Hussain, T., Zaki, Z.H. and Jilani, G. 1991. Comparison of various organic and inorganic fertilizer combinations for economical rice production. *Pakist. J. Soil Sci.* 6(1-2): 21-24

*Ikarashi, H., Ito, T. and Kambayashi, M. 1990. Rice cultivation with low levels of agricultural chemicals and a high level of organic manure. Report -Tohoku Branch, The Crop Science Society of Japan, 33: 11-12

Jackson, M. L. 1973. *Soil Chemical Analysis,* Prentice Hall of India (Pvt.) Ltd, New Delhi, p. 498

Jacob, B. 1994. Effect of incorporation of crop residues on productivity of succeeding rice crop. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 88

Jeong, E.K., Shin, Y.B., Oh, Y.B., Choi, I.H. and Shin, Y.S. 1996. Effects of organic matter application on rice growth and grain quality. *J. agric. Sci* 38(1): 17-26

Jha, J.N., Roy, B. and Singh, S.P. 1992. Effect of combined application of organic manures and inorganic fertilizers on rice and their residue on wheat. *J. Appl. Biol.* 2(1-2): 55-59

*Jin, H.J., Kim, J.G., Cho, Y.M., Kwag, J.H., Shin, J.S. and Lee, H.H. 1996. Growth, yields and quality of rice cultivated on paddy soils as after crop of fodder rye under heavy application of animal manures. *J. Korean Soc. Grassland Sci.* 16(4): 338-342

Joseph, K., Menon, P.K.G. and Anilakumar, K. 1991. Studies on the comparative efficiency of nutrient sources in low land rice. *Indian J. Agron.* 36(1): 122-123

Joseph, P. 1994 Utilization of phosphorus from green manure by rice. MSc. Thesis, Kerala Agricultural University Thrissur, p. 62

Kadke, J.R. 1965. Hastening decomposition of incorporated green manure. *Indian J. Agron.* 10: 443-446

KAU. 1996. *Package of Practices Recommendations.* Directorate of Extension, Kerala Agricultural University, Trichur, Kerala. p 267

*Khan, A.R., Ghorai, A.K. and Singh, S.R. 2000. Improvement of crop and soil sustainability through green manuring in a rainfed lowland rice ecosystem. *Agrochimica,* 44(1-2): 21-29

Kimura, M., Miura, Y., Watnabe, A., Murase, J. and Kuwatsuka, S. 1992. Effects of rice straw application and percolation rate on the leaching of methane and other soil components into the subsoil. Methane production and its fate in paddy fields. 1. *Soil Sci. Pl. Nutr.* 38(4): 665-672

Knowles, R. 1982. Denitrification. *Microbial Rev.* 46: 43-70

*Kobayashi, Y., Abe, S. and Matumoto, K. 1989. Growth and yield of paddy rice under natural cultivation. Report. 32. The Crop Science Society of Japan. pp. 12-13

Konboon, Y., Naklang, K., Surya-arunroj, D., Blair, G., Whitbread, A. and Lefroy, R. 1998. Managing the decomposition rate of crop residues and leaf litters to match nutrient demand and enhance the sustainability of lowland rice-croping systems. *Rainfed lowland Rice : Advances in Nutrient management research* (eds. Ladha, J. K., Wade, L.J., Dobermann, A., Reichardt, W., Kirk, G.J.D. and Piggin, C.). IRRI, Manila, p. 236

Koyama, T. 1971. The effect of soil fertility status of nitrogen and its liberation upon the nitrogen utilization by rice plants in Bankhen paddy soil. Soil-plant studied on tropical rice. *Soil Sci. Plant Nutr.* 17: 210-220

Koyama, T. 1975. Practice of determining potential nitrogen supplying capacities of paddy soil and rice yield. *J. Sci. Soil Manure* 46 (7): 260-289

*Kubota, M. 1992. Application of rice straw to wet and semi wet paddy fields with clay soil in Niigata. *J. Niigata agric. Experiment Stn.*39: 90

Kundu, D.K. and De Datta, S.K. 1988. Integrated nutrient management in irrigated rice. International Rice Research Conference, November 7-11, 1988, IRRI, Manila, pp.193 –208

Kundu, D.K., Ladha, J.K. 1995. Efficient management of soil and biologically fixed nitrogen in intensively cultivated rice fields. *Soil. Biol. Biochemistry*. 27: 431-439

Kundu, D.K., Rao, K.V. and Pillai, K.G. 1990. Mineralization pattern and agronomic efficiency of *Sesbania* and *Glyricidia* nitrogen in a wetland rice field. Rice in wetland ecosystem: . Proceedings of National Symposium on "Rice In Wetland Ecosystem" Kottayam, December, 19-21 (eds. Nair, R.R., Nair, K.P.A. and Joseph, C.A.), p. 54-57

Kwak, H.K., Lee, C.S. and Lim, S.K. 1990. Influence of soil amendments on phosphorus response and changes of available phosphate amount in paddy soil. Research Reports of the Rural Development Administration. *Soils .Fertilizers.* 32(3): 52-56

Lal, J.K., Mishra, B. and Sarkar, A.K. 2000. Effect of plant residues incorporation on specific microbial groups and availability of some plant nutrients in soil. *J. Indian Soc. Soil Sci.* 48(1): 67-71

Li, J.R. 1994. Studies on the effect of rice straw returned to soil on yield increase. *Soils. Fertilizers.*1: 16-19

Li, S.Y. 1991. Soil management problems in multiple cropped paddy fields in China. *Biol. Fertility Soils.* 12(3): 213-216

Liu, J.R. and Shen, R.P. 1992. The effects of fertilization on the properties and role of soil organic matter. Proceedings of International symposium on paddy soils, September 15-19, Nanjing, China, (ed. Li , J) p. 246-251

Luo, J. and Huang, Z.W. 1990. Effect of straw and $(NH_4)_2 SO_4$ application on rice. *Int.Rice.Res.Newsl*, Manila, 15(5): 17-18

Mahapatra, B.S. and Sharma, G.L. 1996. Contribution of *Sesbania* species to yield and nitrogen nutrition in low land rice (*Oryza sativa*). *Indian J. Agron.* 41(2): 226-229

Mahapatra, P., Panda, M.M., Chalam, A.B., Chakravati, S. P., and Mohanty, S.K. 1997. Effect of green manuring and N fertilization on the yield and nitrogen use efficiency of wetland rice. *J. Indian Soc. Soil Sci.* 45(1): 95-99

Majumdar, D.K. 1973. Uptake of nitrogen and phosphate as influenced by sowing time and fertilization and recoveries of nitrogen and phosphate from added fertilizers by rice(*Oryza sativa* L). *Indian Agricst.* 1 (1): 69-74

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*. *Trop. Agricst.* 69(1): 73-77

Marinikumar, K.M., Bagyaraj, D.J. and Mallesha, B.C. 1990. Effect of intercropping and organic soil amendments on native mycorrhizal fungi in an Oxisol. *Arid Soil Res. Rehabilitation.* 4(3): 193-197

Marykutty, K.C., Potty, N.N., Anila kumar, K. and Bridgit, T.K. 1999. Stress influence of nutrient ratios on rice productivity. Proceedings of the National Seminar on Plant Physiology, Jaipur, (ed. Singh, M.) p. 69-70

Maynard, A.J. 1970. *Methods in Food Analysis*. Academic Press, New York, pp. 176

Medhi, D.N., and De Datta, S.K. 1997. Phosphorus availability to irrigated low land rice as affected by sources, application level and green manure. *Nut.Cycling. Agroecosyst.* 46(3): 195-203

Mehla, D.S., Sagwal, K.K. and Dabas, D.S. 1997. Contribution of green manuring, farmyard manure and rice husk ash to yield and nutrition of paddy. *Ecological agriculture and sustainable development. Vol. 1* Proceedings of

International Conference an Ecological Agriculture: Towards Sustainable Development, November 15-17,Chandigarh, (eds. Arora, R., Randhawa, N.S. and Dhawan, A.K.). p 596-603

Mikkelsen, D.S and Patrick, W.H. 1968. Fertilizer use on rice. *Changing patterns of fertilizer use SSSA* (ed. L.B. Nelson). Madison, pp. 403 – 432

Mishra, V.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. *J. Indian Soc. Soil Sci.* 45(1): 84 - 88

Misra, R.D., Gupta, V.K. and Pandey, D.S. 1996. Managing crop residue in rice. *Int.Rice.Res.Newsl*, Manila, 21(2-3): 71-72

Mitra, G. N., Sahu, S.K. and Dev,G. 1990. Potassium chloride increases rice yield and reduces symptoms of iron toxicity. *Better Crops int.* 6(2): 14 – 15

Mitsui, S. 1954. Inorganic nutrition, fertilization and soil amelioration for lowland rice. Yokendo Ltd. Tokyo. p 107

Mitsui, S. and Ishii, Y. 1938. Effects of different application amounts of three major nutrients on the photosynthetic efficiency of rice seedlings. *J. Sci. Soil Manure Japan.* 12: 287 – 289

Mohopatra, A.K. and Jee, R.C. 1993. Response of low land rice (*Oryza sativa*) to green manuring levels and sources of phosphatic fertilizer in coastal Orissa. *Indian J. Agron.* 38(3): 374-377

Monapara, K.B., Kunjadia, B.B. and Mehta, P.M. 1993. Yield and nutrient uptake by rice as influenced by N management. *Gujarat agric. Univ. Res. J.* 18(2):49 – 55

Mosi, A.D., Venkataraman, A., Periasamy, M. and Natarajan, K. 1973. A preliminary study on the response to nitrogen, phosphorus and potassium of some high yielding varieties of rice in Tanjavur district . *Madras. agric. J.* 60(5): 302 – 307

Musthafa, K and Potty, N.N. 1996. Yield limiting influences in rice in soils of lateritic origin. Proceedings of Eighth Kerala Science Congress, Kochi. (ed Das, M.R.) p. 114 – 116

Myers ,R.T.K., Palm, C.A., Cuaves,E., Guntilleke, I.U.N. and Brossard, M (1994) The synchronization of nutrient mineralization and plant nutrient demand. The Biological Management of Tropical Soil Fertility (ed. Woomer,P.L and Swift, M.J.) Wiley London : 81-114

Nagarajah, S., Neue, H.U. and Alberto, M.C. 1989. Effect of Sesbania, Azolla and rice straw incorporation on the kinetics of NH_4, K, Fe, Mn, Zn and P in some flooded rice soils. *Pl. Soil* 116: 37-48

Narang, R.S., Chama, 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 J. Agron.* 35(1-2): 113-119

Odell, R.T., Melsted, S.W. and Walker., V.H. 1984. Changes in organic carbon and nitrogen of Morrow plots under different treatments 1904 - 1973. *Soil Sci. Am. J.* 137: 160-171

O' Hallorans, J..M., Munoz, M.A. and Marquez, P.E. 1997. Chicken manure as an amendment to correct soil acidity and fertility. *J. Agric. Univ. Puerto Rico.* 81 (1-2): 1-8

Ohyama, N. 1989. The use of manure to increase fertility. *Agric. Hort.* 64(1): 217-222

Padmaja, P. and Koshy, M..M. 1978. A note on the run – off losses of major plant nutrients in waterlogged rice soils. *Agric. Res. J. Kerala.* 16: 63 – 65

Patiram and Singh, K.A. 1993. Effect of continuous application of manure and nitrogenous fertilizers on some properties of acid inceptisol. *J. Indian Soc. Soil Sci.* 41(3): 430- 433

Paturde, J.T. and Patankar, M.N. 1998. Effect of green manuring with *Sesbania rostrata* and *S. aculeata* as well as levels of nitrogen on yield of transplanted paddy variety SKL-7. *Agric. Sci. Digest* 18(3): 213-216

*Pervin, S., Hoque, M.S., Jahiruddin, M. and Mian, M.H. 1995. The use of Sesbania as an alternative source of urea N for BR-11 rice. *Pakist. J. Scient. Ind. Res.* 38(2): 85-87

Pillai, K.G. and Kundu, D.K. 1990. Integrated nutrient management for sustainable rice farming in wetland ecosystem. Proceedings of National Symposium on "Rice In Wetland Ecosystem" Kottayam, December, 19-21 (eds. Nair, R.R., Nair, K.P.A. and Joseph, C.A.). p. 39-53

Piper, C,S. 1950. *Soil and Plant Analysis*. Hans Publishers, Bombay, p.368

*Ponnamperuma, F. N. 1984. Straw as a source of nutrient for wetland rice. Organic matter and rice. IRRI, Manila , pp.117- 136

Powar, S.L. and Mehta, V.B. 1997. Integrated nutrient management for rice in coastal saline soil of high rainfall area. *Ann. agric. Res.* 19(4): 538-540

Prasad, R and Goswami, N. N. 1991. Soil fertility restoration and management for sustainable agriculture in South Asia. *Adv. Soil. Sci.* 17 :37-77

Qi- Xiao, W. 1984. Utilization of organic materials in rice production in China. Organic matter and rice. International Rice Research Institute, Manila . pp. 45 – 56

Rajput, A.L. and Warsi, A.S. 1992. Effect of nitrogen and organic manure on rice (*Oryza sativa*) yield and residual effect on wheat (*Triticum aestivum*) crop. *Indian J. Agron.* 37(4): 716-720

Raju, N.S. 1952. Role of organic manures and inorganic fertilizers on soil fertility. *Madras agric. J.* 39: 130-147

Raman, K.R., Singh, M.P., Singh, R.O. and Singh, U.S.P. 1996. Long term effect of inorganic and organo inorganic nutrient supply system on yield trends in rice wheat cropping system. *J. Appl. Biol.* 6(1-2): 56-59

Rath, A.K., Mohanty, S.R., Mishra, S. and Kumaraswamy, S. 1999. Methane production in unamended and rice straw amended soil at different moisture levels. *Biol. Fertility Soils.* 28(2): 145-149

Reddy, V.C. and Shivaraj, B. 1999. Response of hybrid rice and varieties to NPK, FYM and poultry manure under Punaji cultivation. *Mysore J. agric. Sci.* 33(3): 133-138

*Richards, L.A. 1954. Diagnosis and Improvement of Saline and Alkali soils. *Agric. Handbook.* USDA, p. 60

Rogers, T.H. and Giddens, J.E. 1957. Green manuring and cover crops. *Yearbook of Agriculture*. USDA. pp.252-257

Rose, D.A. 1991. The effect of long continued organic manuring on some physical properties of soils. *Advances in soil organic matter research.* Proceedings of symposium, Colchester (ed. Wilson, W.S)., pp.197-205

*Sadana, U.S., Nayyar, V.K. and Takkar, P.N. 1990. Effect of green manuring, applied manganese and soil submergence on manganese equilibria in manganese deficient soil. Transactions of 14th International Congress of Soil Science, Kyoto, Japan, August, Vol II, 56-61

Salazar, F. S. , Pandey, S., Narro, L., Perez, J.C., Ceballos, H., Parentoni, S.N., and Bahia Filho, A.F.C. 1997. Diallel analysis of acid-soil tolerant and intolerant tropical maize populations. *Crop Sci.* 37: 1457-1462

Samad, A. A. and Sahadevan, P.C .1952. Manuring in rice in Malabar. *Madras agric. J.* 39: 1-3

Sanchez, P.A. and Uehara, G. 1980. Management consideration for acid soils with high phosphorus fixation capacity. *The Role of Phosphorus in Agriculture.* (ed. Khasawneh, F.E.). ASA, CSSA, Madison, pp. 471-514

Sanchez, P.A., Shepherd, K.D., Soule, M.J., Place, F.M., Buresh, R.J., and Izac, A.M.N. 1997. Soil fertility replenishment in Africa: An investment in natural resource capital. *Replenishing Soil Fertility in Africa.* (ed. Buresh, F. E.). ASA, CSSA, SSSA, Madison, pp. 1-46

Sarmah, A.C. 1997. Effect of green manures on phosphorus nutrition of rice. *J. agric. Sci. Soc. North East India* 10(2): 173-175

*Seki, M., Imaizumi, M., Imai, K., Kitamura, H., Kato, T. and Shiota, Y. 1989. Effects of successive applications of rice straw on changes of inorganic components in paddy soil. *Res. Bull. of the Aichi-ken agric. Res. Center.* 21: 62-68

Selvi, S. and Ramaswami, P.P. 1995. Residual effects of integrated nutrient management in rice-rice-pulse cropping sequence. *Madras agric. J.* 82(1): 24-26

Sen, D., Chen, E.F., Xu, X.C., Zhang, J.H. and Li, H.Z. 1994. Effect of organic manure application on physical properties and humus characteristics of paddy soil. *Pedosphere.* 4(2): 127-135

Seng, V., Bell, R.W., Willett, I.R. and Nesbitt, H.J. 1999. Phosphorus nutrition of rice in relation to flooding and temporary loss of soil-water saturation in two low land soils of Cambodia. *Pl. Soil.* 207(2): 121-132

Shapiro, R.E. 1958. Effect of flooding on availability of phosphorus and nitrogen. *Soil Sci.* 5(4): 190 – 197

Sharma, A.R. and Ghosh, A. 2000. Effect of green manuring with *Sesbania aculeata* and nitrogen fertilization on the performance of direct seeded flood prone low land rice. *Nut. Cycling .Agroecosyst.* 57(2): 141-153

Sharma, A.R. and Mittra, B.N. 1991. Effect of different rates of application of organic and nitrogen fertilizers in a rice based cropping system. *J. agric. Sci.* 117(3): 313-318

Sharma, S.N. and Prasad, R. 1999. Effects of Sesbania green manuring and mungbean residue incorporation on productivity and nitrogen uptake of a rice-wheat cropping system. *Bioresource Technol.* 67(2): 171-175

*Shiga, H., Miyamori, Y. and Kimura, K. 1990. Evaluation of soil nitrogen fertility in the paddy rice field with continuous application of rice straw. *Bull. of Hokkaido Prefectural agric. Experiment Station.* 60: 125-131

Shinde, S.N. 1995. Effects of green manuring on yield, yield attributes and nitrogen economy in low land rice. *J. Maharashtra agric. Univ.* 20(3) : 482-483

Shrikhande, J.G. 1948. Studies on the assimilation of phosphorus during decomposition of plant material. *Curr. Sci.* 17 (11): 364-365.

Simpson, J.R. and Freney, J.R. 1974. The fate of fertilizer nitrogen under different cropping systems. *Fertilizers and the environment.* Proceedings of Symposium, Sydney University, Australia (ed. Luce, D.R.), pp. 27 – 33

Sindhu, P.V. 2002. Effect of nutrient inter-relations on productivity of rice in lateritic soils. M.Sc. thesis, Kerala Agricultural Unversity Thrissur, India., p.193

Singh, A. 1962. Studies on the *Modus Operandi* of Green Manures in Tropical Climates: 1. A Critical Review of Literature. *Indian J.Agron.* 7: 59-75

Singh, A. L. 1970. Effect of sulpur in preventing the occurrence of chlorosis in peas, *Agron. J.* 62 : 708 – 711

Singh, A., Singh, R.D. and Awasthi, R.P. 1996. Organic and inorganic sources of fertilizers for sustained productivity in rice (*Oryza sativa*) – wheat (*Triticum aestivum*) sequence on humid hilly soils of Sikkim. *Indian J.Agron.* 41(2): 191-194

Singh, A.K., Amgain, L.P. and Sharma, S.K. 2000. Root characteristics, soil physical properties and yield of rice (*Oryza sativa*) as influenced by integrated nutrient management in rice-wheat (*Triticum aestivum*) system. *Indian J. Agron.* 45(2): 217-222

Singh, D and Om, H. 1993. Response of rice to graded levels of nitrogen. *Haryana J. Agron.* 9(2): 119 – 121

Smaling, E.M.A., Nandwa, S.M., and Jansse, B.H. 1997. Soil fertility in Africa is at stake. Replenishing Soil Fertility in Africa, (ed. Buresh, F.E.). ASA, CSSA, SSSA, Madison, pp. 47-79

*Smirnov,P.M. 1977. Soil nitrogen problems and results of ^{15}N studies . *Agrokhimiya* 19(1): 3 – 25

Su, S.R. 1976. Use of industrial wastes for recycling plant nutrients in Taiwan. *Soil. Fert. Taiwan.* pp 19-29

Subbiah, B.V., and Asija, G.L.A. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* 25: 259-260

Swaminathan, M.S. 1987. The Role of Green Manure Crops in Rice Farming Systems, Inaugural address at the International Symposium on Sustainable Agriculture 25 – 29, May, IRRI, Manila.

Swarup, A. 1991. Long term effect of green manuring (*Sesbania aculeata*) on soil properties and sustainability of rice and wheat on a sodic soil. *J. Indian Soc. Soil Sci.* 39(4): 777-780

*Takamura, Y., Tabuchi, T and Kobota, H. 1977. Behaviour and balance of applied nitrogen and phosphorus under rice field conditions. Proceedings of the International Seminar on Soil and Fertility Management in Intensive Agriculture (SEFMIA), Tokyo, (ed. Koji, I) p.342 – 349

Thakur, A.C., Ahmed, S. and Bora, D.D. 1999. Integrated nutrient management in rice-rice system. *Ann. agric. Res.* 20(1): 86-90

Thomas, D., Potty, N.N and John, P.S. (2001) Regulatory management for high productivity, nutrient use efficiency and sustainability. Proceedins.of the Thirteenth Kerala Science Congress (ed Das, M.R.) p. 305 - 307

Turkhede, A.B., Choudhari, B.T., Chore, C.N., Tayde, R.D. and Bobade, P.N. 1996. Effect of green manuring and fertilizer levels on yield of low land paddy (*Oryza sativa* L.). *J. Soils Crops* 6(2): 187-189

Udayasoorian, C., Krishnamoorthy, K. K. and Sreeramulu, U. S. 1988. Effect of continuous application of organic manures and fertilizers on organic carbon, cation exchange capacity and exchangeable cations in submerged soil. *Madras agric. J.* 75(9-10): 346-350

Vachhani, M.B. and Murthy, K.S. 1964. Green manuring for rice. ICAR Research Report Series No. 17, ICAR, New Delhi, p.50

Vendan, R.T. and Rajeswari, C. 1999. Effect of green manuring and inorganic nitrogen on the post harvest soil fertility. *J. Ecobiol.* 11(3): 225-228

Verma,T. S. and Bhagat, R. M. 1992. Impact of rice straw management practices on yield, nitrogen uptake and soil properties in a wheat-rice rotation in northern India. *Fert. Res.* 33: 97 – 106

Vig, A.C., Singh, D., Chand, M. and Saroa, B.S. 1997. Release of Phosphorous from added *Sesbania aculeata*. *J. Indian Soc. Soil Sci.* 45(3): 449-455

Watanabe, F.S. and Olsen, S.R. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. *Proc. Soil Sci. Soc. Am.* 29: 677-678

Watanabe, I. and Ventura, W. 1992. Long term effects of azolla and sesbania on rice yield and fertility of tropical wetland rice soil. Proceedings of International symposium on paddy soils, September 15-19, Nanjing, (ed. Li , J) p. 331-342

Yodkeaw, M. and De Datta, S.K. 1989. Effects of organic matter and water regime on the kinetics of iron and manganese in two high pH rice soils. *Soil Sci. Pl. Nutr.* 35(3): 323-335

Yoshida, S. Forno, A.S., Cook, H.J. and Gomez, A.K.,1972. *Laboratory manual on Physiological studies*. IRRI, Manila, pp. 36-37

Yoshida, T. and Padre, B.C. 1975. Effect of organic matter application and water regime in the transformation of fertilizer nitrogen in a Phillipine soil. *Soil Sci. Pl. Nutr.* 21: 281 – 292

Yoshida, T. and Padre, B.C. 1977. Transformations of soil and fertilizer nitrogen in paddy soil and their availability to rice plants. *Pl. Soil.* 47: 113 – 123

* Originals not seen

APPENDIX

Appendix –1

Weekly weather data   1 July, 2000 – 14 October, 2000

Date	Temperature		Relative humidity (%)		Wind speed (kmph)	Sushine hrs.	Rainfall (cm)	Evaporation (mm)
	Max. ^{0}C	Min. ^{0}C	Morning	Evening				
4/6-10/6	28.9	22.4	96	83	2.0	3.1	31.97	2.5
11/6 - 17/6	29.9	22.8	94	75	3.6	3.3	10.69	3.7
18/6 - 24/6	29.6	23.2	95	74	3.7	3.1	5.59	3.3
25/6 - 1/7	29.4	27.5	94	75	4.0	4.1	10.43	2.8
2/7 - 8/7	28.9	22.0	93	76	3.8	1.5	8.78	2.5
9/7 - 15/7	29.2	21.5	94	74	3.8	3.5	17.0	3.1
6/7 - 22/ 7	30.1	22.8	93	66	4.0	5.7	4.89	3.6
23/7 - 29/ 7	30.9	23.2	92	62	3.7	8.5	0.59	4.3
30/7 - 5/8	31.1	23.6	92	69	3.2	6.4	0.9	3.6
6/8 - 12/8	29.0	22.8	94	80	3.6	2.5	9.33	3.7
13/8 - 19/ 8	29.4	22.6	93	78	2.7	4.1	13.95	2.9
20/8 - 26/ 8	27.7	22.0	95	88	3.8	0.3	23.28	2.3
27/9 - 2/9	29.4	22.1	94	73	3.6	4.6	4.42	3.2
3/9 - 9/9	30.6	22.9	92	69	3.1	7.1	3.19	3.5
10/9 - 16/9	31.2	23.3	90	65	3.4	7.5	0.0	7.6
17/9 - 23/ 9	30.4	22.9	92	72	2.9	3.9	1.62	3.1
24/9 - 30/ 9	30.7	23.3	90	76	3.2	4.6	15.00	2.7
1/10 - 7/ 10	28.9	22.2	92	79	2.9	3.2	7.93	2.7
8/10 - 14/10	30.9	22.1	91	65	2.7	7.1	1.81	3.6

SOURCE - EFFICACY RELATIONS OF ORGANICS IN WETLAND RICE CULTURE

By

RAJAGOPAL PRASHANT

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the
requirement for the degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA
2002

Abstract

A field experiment was carried out during the Kharif season of 2000 at the Agricultural Research Station, Mannuthy to assess the efficacy of various sources of green leaf and organic manures in relation to nutrient accretion, rice growth and yield. The interactive effect of decomposition products on nutrient mineralization, chemical properties of the soil and subsequent elemental composition of the plant were studied in relation to rice growth. The changes in carbon: nitrogen relations in the soil and the pattern of nitrogen mineralization were monitored through an incubation study conducted at the College of Horticulture, Vellanikkara.

The field experiment was laid out in randomized block design with three replications. The treatments consisted of twelve organic amendments of both plant and animal origin, three synthetic fertilizer combinations and an absolute control. All organic treatments were incorporated at 5t/ha on dry weight basis. The short duration HYV, Matta Triveni was used in the experiment.

Treatments had a significant effect on the content of major nutrients both in soil and plant. Micronutrients did not affect the yield by their inadequacy, however, Fe content in plants was found to be excess and may have negatively influenced the yield

The growth characters of the plant like height of tillers, number of tillers, weight of roots, plant dry matter and total plant weight were largely affected by the treatments. The height of tillers was highest in plots treated with poultry manure at all stages of the crop, while number of tillers especially after 25 DAT was maximum in FE treated plots and this was also the case in the number of productive tillers.

Among the yield attributes, the number of spikelets per panicle and the length of panicle was maximum in poultry manure treated plots. The chaff percentage was highest in sesbania treated plots. The number of productive tillers was maximum in FE treated plots.

The highest yield of grain (4.37 t/ha) and straw (5.20 t/ha) were from FE treated plots but the grain straw ratio (0.84) was the lowest in this treatment. In case

of FE treatment, the high yield was as a result of increase in number of productive tillers, while in case of pongamia and gliricidia, it was due to reduced chaff percentage and enhanced test weight. A higher yield was obtained in case of poultry manure treatment due to enhancement of number of spikelets per panicle

The treatments in the field experiment were replicated as an incubation study to understand the pattern of nitrogen mineralization and to observe the variations in carbon nitrogen relations. A measured quantity of soil (100g) was placed in glass conical flasks and corresponding quantity of organic manures so as to maintain a ratio of 5 t/ha and the fertilizer treatments also in the same ratio were incorporated and incubated for a period of 100 days.

The mineralization of nitrogen was studied and in case of organic manures cow dung, gliricidia and sesbania were the first to do so. Straw and acacia treatments were the slowest to mineralize achieving peak levels at 70 days after incubation that were due to the quantities of lignin carbon and fibre in the organic manures. In case of phosphorus mineralization, it was noticed that mineralization in all the treatments irrespective of it being organic or inorganic in nature, tended to decrease rapidly after incubation up to 40 days and then gradually increase to levels higher than the initial level and in case of potassium mineralization, a slow and gradual increase in the levels of K were observed which was noticed even after 70 days with a slight decrease being noticed towards the end in some treatments. The rate of decomposition and mineralization was affected by the C/N ratio, lignin/N ratio and also moisture content, content of fibre and nutrients present in the organic material.

Substitution of a major quantity of inorganic fertilizers is possible by the use of organic manures. However, considering the mineralization patterns, a better option would be the combined use of inorganic and organic manures whereby the synthetic fertilizers would meet the initial nutrient need of the crop as they are readily available to the crop during the initial exponential growth phase and in the later stages the organic manures would provide the required nutrients.