EFFECT OF FERTILIZERS AND MANURES ON NITROGEN SUPPLYING CAPACITY OF AN INCEPTISOL UNDER CONTINUOUS RICE-RICE CROPPING

A THESIS SUBMITTED TO
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MASTER OF SCIENCE IN AGRICULTURE

(AGRICULTURAL CHEMISTRY, SOIL SCIENCE AND BIOCHEMISTRY)

By

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COLLEGE OF AGRICULTURE

Orissa University of Agriculture & Technology

BHUBANESWAR, ORISSA

2001

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Dedicated to

My Beloved Parents

Dedicated to

My Beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled "Effect of fertilizers and manures on nitrogen supplying capacity of an inceptisol under continuous rice-rice cropping," submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (Agricultural Chemistry, Soil Science & Biochemistry)** of the Orissa University of Agriculture & Technology, Bhubaneswar is a record of *bonafied* research work carried out by **Pradipta Majhi** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma or published in any form. It is further to certify that the help and sources of information availed during the course of investigation have been duly acknowledged.

20/12/01

Dr. D. Sahoo.

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2001

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Bhubaneswar.

Pradipta Majhi

PRADIPTA MAJHI.

Date: 20th December 2001

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Student : Pradipta Majhi *Advisor : Dr. D. Sahoo*

ABSTRACT

In order to investigate the cumulative effect of continuous fertilization and manuring with various inorganic and/or organic sources of nutrients on the indicators of nitrogen(N) availability and N mineralisation potential of an acid Inceptisol planted to rice-rice double cropping under irrigated system the Long Term Fertiliser Experiment conducted in the Central Research Farm of OUAT was used for study. The experiment that was started in 1997 contained 12 treatments including an unmanured control. The eleven manured treatments received 100% NPK (80:40:60) in both the seasons. Five treatments (T_1, T_2, T_3,T_4 and T_8) received the nutrients in inorganic form with T_1 taken as standard with S+Zn+B and T_2, T_3, T_4 and T_8 were standard devoid of S, Zn, B and all the three nutrients respectively. T_9 received 100% N entirely in organic form, P as rock phosphate and K as straw. T_5, T_6, T_7 and T_{10} received N in both inorganic and organic forms viz. FYM, green manure, straw and green manure respectively. The difference between T_6 and T_{10} was with respect to P and K which were applied as rock phosphate and @ 150% K as MOP in T_{10}. T_{11} received 100% NPK in inorganic form with silicate slag amendment @ 100 kg SiO_2/ha. Besides the field experiment, one laboratory incubation study was conducted on the post kharif 2000 soil samples of all the treatments for 8 weeks following the method of Stanford and Smith (1972) in order to assess the effect of continuous manuring on N mineralisation potential.

Crops of two consecutive seasons viz.rabi, 1999-2000 and kharif,2000 and soil samples of post rabi, pre kharif and post kharif were used for the study.

Results of soil analysis revealed that with continuous cropping of rice-rice there is decrease in soil organic carbon content and increase in total N and mineralisable N. Inorganic fertilizer application along with silicate slag amendment @ 100Kg SiO_2/ha could maintain higher levels of total N, mineralisable N and inorganic N over years of cropping and produce higher yield in both rabi and kharif.

The yields were 170 % and 128 % higher than the control in rabi and kharif respectively. Integrated use of both organics and inorganics over performed the inorganics or organics after 3 years of continuous cropping and manuring. The cumulative positive effect of integration was achieved earlier in rabi crop than in kharif. Organic sources, viz. FYM, green manure and straw used for integration did

not differ significantly in their influence on N fertility and grain yield. However, among the three sources, FYM proved to be the best followed by green manure. Substitution of N entirely through organics in kharif and partially in rabi could not produce good yield be cause of poor N supplying capacity.

Continuous addition or exclusion of micro (B and Zn) and secondary (S) nutrients for three years did not make any significant difference on grain yield.

Among the indicators of N availability soil organic carbon proved to be a very poor indicator. The suitable chemical and biological indicators in order of merit were found to be total hydrolysable N (THN) > inorganic - N > urease activity > amidase activity > mineralisable N > total N.

Among the hydrolysable N fractions of soil amino acid N (AAN) and hydrolysable NH_4^+ (HAN) contributed most to N uptake and can thus be good indicators of N availability. Integrated use of inorganics and organics that over performed the inorganics in rabi in terms of yield also had higher mineralisation potential than either inorganics or organics. This indicates the cumulative positive effect of integration on N supplying capacity of an acid Inceptisol planted to rice-rice under an irrigated system.

CHAPTER-I
INTRODUCTION

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INTRODUCTION

Due to rapid increase in population the pressure on agriculture to produce more has been increased immensely throughout the world. In India, the total food grain production must reach about 300 mt by the year 2020 (Bhalla *et.al.*, 1999). To achieve this target India's food grain production must increase at the rate of 5 mt/year over the next 2 decades.

Rice *(Oryza sativa L.)* is the second most important food crop of the world and most important in India. More than 40 % of the world's population and 63-65% of India (Prasad, 1999) depend on rice as the major source of calories. Projections based on population growth rates in countries, where rice is the main food crop, indicates that rice production must increase by almost 70% over the next 35 years to match the demand. In India, the production level has to increase by 25-30% from the present level of 1.9 t/ha to meet the demand in 2010 (Siddiq, 2000).

Of the world's total rice area of about 146 mha, irrigated rice ecosystem accounts for 55% contributing 75% of total rice production. In India rice is grown throughout the country on an area of more than 42 mha in both Kharif and Rabi season. About 92% of the rice is cultivated during Kharif season on a variety of physiographic land situations such as rainfed uplands, irrigated medium lands and rainfed lowlands. The Rabi crop is raised entirely with irrigation mostly in the traditional areas. With the introduction of short to medium duration high yielding varieties evolved during the last 3-4 decades, double or triple cropping of rice has replaced the single cropping in irrigated areas (Mohanty and Sharma, 2000).

In India, irrigated rice in India constitutes about 45% of the total area and contributes more than 56% of the total production. The average productivity of Rabi rice is higher (2.84 t/ha) than kharif rice (1.84 t/ha). The per hectare average production in rainfed upland is very low (< 2 t/ha). In view of the low yields and fragility of rainfed and upland rice systems, the current lack of investment in irrigation and the pressures of urbanization and industrialization, most of the

required extra production in future will have to come from increased productivity in today's irrigated systems.

But continuous decline in yield growth rates in recent years under irrigated double-cropped rice systems has already raised concern about its long-term sustainability. Yield trends in long term continuous cropping experiments conducted in Philippines, India, Indonesia, Thailand and Bangladesh indicate that even with best cultivars and scientific management rice yields have declined over time since the early 1980s (Flinn and De Datta, 1984; Nambiar and Ghosh, 1984, Cassman and Pingali, 1995). Current data seem to show a long term degradation of the rice resource base resulting from continuous flooding and puddling associated with intensive double or triple rice production (Kundu and Ladha, 1995b). In long-term field experiments at IRRI plant nitrogen (N) deficiency has been identified as a major factor limiting to yield despite constant or increasing total soil N (Cassman and Pingali, 1995). In India, N availability to irrigated rice has declined over the years even when recommended levels of inorganic fertilizers were used (Nambiar, 1994). The subsistence rice farming of the pre-chemical era efficiently sustained the N-status of soils by maintaining a balance between N loss and N gain from biological N-fixation. But now intensive monocropping with excessive use of chemical N fertilizers has raised many concerns about the N sustainability in low land rice soils over the years.

Nitrogen is a costly input. Despite large investment in fertilizer N, the efficiency with which fertilizer N is used by wetland rice crops is generally poor. A significant portion of the applied N is either lost through various processes such as runoff, leaching, denitrification and volatilization and a significant portion also gets converted to various organic forms in soil and is not available to the crops. Under lowland situation recovery is only within 20-40% (Craswell *et.al.*, 1984; De Datta, 1981; Prasad and Power, 1997). Thus under wetland situation rice has to largely depend on native N.

More than 60% of the absorbed N in wetland rice comes from soil (Wada *et.al.*, 1986; Rout, 1998). Mineralisation of organic N to NH_4^+ - N is the key process in the nutrition of low land rice (Sahrawat, 1983b). The mineralisation of organic

matter under waterlogged conditions is governed mainly by the prevailing chemical and biological conditions (Prasad *et.al.*, 1986). Cassman and Pingali (1995) hypothesized that the yield declines are associated with decreased availability of native soil N despite conservation of total C and N in the soil.

The N fertility of a rice soil primarily depends on: (1) total N content in the soil (2) N transformation in the soil and (3) various factors that influence N absorption by rice roots. Indian soils, in general are poor in organic carbon and have low total and available N. To sustain N-fertility of soil it is necessary to maintain total N content and to improve other soil properties so that the required N is supplied to rice in the long run.

As soil properties change slowly, long-term studies provide valuable information on transformations related to soil N supply capacity. Previous long-term studies done in the last 25 years evaluated the effect of continuous manuring with either N or NP or NPK or NPK + FYM on sustainability of crop production. Results have confirmed that yield decline in rice is relatively low and sustainability is better with balanced dose of NPK + FYM thus justifying better maintenance of N fertility with integration. In India there is vast potential of organic resources other than FYM. Green manure is another important source of organic manure. Its contribution to N fertility of soil is already established. Apart from these manures, crop residues are also important renewable organic resources available to farmers. About 236 mt of cereal crop residues are annually produced in India (Babalad, 1998).

In view of the practical considerations and economic viability it is necessary to evaluate all these potentially available organic sources for integration with inorganic fertilizers in regards to their effect on sustainability of crop production and maintenance of soil fertility. Keeping the above facts in view a new long term fertility experiment was started in 1997 at OUAT, Bhubaneswar with balanced NPK applied in various forms of organic and inorganic resources with or without some secondary (S) and micronutrients (Zn and B) which are likely to be limiting in the long run.

Behera (2000) studied the effect of various organic and inorganic sources of nutrients on N availability to the rice crop under such a system and could be able to generate some knowledge on the N relationship between soil and plant. However,

the knowledge is insufficient to evaluate the N supplying capacity of the soil as influenced by continuous rice cropping and manuring with various sources of nutrients.

N supplying capacity depends on both the quality and quantity of organic N fractions and their rate of transformations. Both cropping and manuring have tremendous influence on these fractions.

Therefore, keeping the importance of maintaining better N fertility for sustainable rice production in view, the present study was conducted on the same long term fertility experiment at Bhubaneswar as a continuation to the work done by Behera (2000) to generate more knowledge and better understand the precious resource base under rice-rice cropping system with the following three primary objectives:

Objectives:

1. To study the direct and cumulative effect of sole and combined application of organic and inorganic sources of nutrients on various organic and inorganic N fractions of soil.
2. To identify and assess the indicators of N availability under rice-rice cropping system subject to continuous manuring.
3. To evaluate the mineralisation potential of the soil and assess the N supplying capacity of the soil.

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CHAPTER-II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Keeping the objectives of the present investigation in view, attempt has been made to present a brief account of review on the following heads:

1. **Nitrogen requirement of high yielding rice**
2. **Nitrogen supply from soil and indicators of its availability.**
3. **Nitrogen mineralisation in soil and factors affecting it**
   - 3.1. Characteristics of organic matter in soil
   - 3.2. Cropping
   - 3.3. Edaphic factors
     - 3.3.1. Soil Temperature
     - 3.3.2. Soil moisture
     - 3.3.3. Soil pH
     - 3.3.4. Soil texture
     - 3.3.5. Soil enzymes
   - 3.4. Management factors
     - 3.4.1. Inorganic fertilizer application
     - 3.4.2. Organic amendment
       - 3.4.2.1. FYM
       - 3.4.2.2. Green manure
       - 3.4.2.3. Straw incorporation
4. **Evaluation of nitrogen supplying capacity of soil**

2.1 Nitrogen Requirement of High Yielding Rice

For optimum production of yield components, nitrogen (N) supply must match the requirement. In a study Wada *et.al.*, (1986) have reported that N requirement of rice plants to produce 100 kg paddy is about 1.5 to 1.7 kg in Japan; while in case of high yielding rice at least 1.9 kg of N is absorbed to produce 100 kg paddy. Thus in a double crop system of rice, recording a grain yield of 4.5-5.0 t/ha in kharif and 5.0-6.0 t/ha in rabi season, the total N uptake has been estimated to be more than 200

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kg/ha. Mohanty and Sharma (2000) reported that the soils where rice is generally grown are invariably low in N and therefore, there is a widespread response to the application of N fertilizers.

Tsuboi (1975) and Murayama (1975) compiled data on high yielding rice cultivars and demonstrated that the ratio of the amount of N absorbed by plant at different stages of growth to total N at maturity is 35-50% from transplanting to panicle initiation stage, 30-40% from panicle initiation to the heading stage and 15-30% for the ripening stage. The N absorption pattern of the high yielding cultivars has been reported to be biphasic. The amount of N in the plant increases exponentially during early growth stages and linearly during middle and late stages of growth. The rate of N absorption by rice plant increases after transplanting and attains a peak at the young panicle formation stage (Shoji *et.al.*, 1986; Wada *et.al.*, 1989). In the tropics N requirement of rice plants to produce a ton of rough rice is 20 kg that must be absorbed from the soil over 3-5 months.

2.2 Nitrogen Supply from Soil and indicators of its availability

Partitioning the total N in plant at maturity, Wada et.al., (1986) showed that 26% of N at harvest originated from fertilizer, 11% from soil by priming effect and the balance from soil. In a similar study Bouldin, D. R. (1988) showed that one third of the total N absorbed by rice comes from fertilizer and rest two thirds from soil. The soil originated N in plant is composed of 2 parts: one from rapidly decomposable soil organic N and the other from slowly decomposable organic N. The former is absorbed by rice plants at the early growth stage (exponential phase, $y = ab^x$) and the latter is largely absorbed by rice plants at the middle and late stages of growth (linear phase, $y = a+bx$) (Shoji *et.al.*, 1986)

Among soil organic matter fractions, microbial biomass holds a key position. Ahmed *et.al.*, (1973) found that the newly immobilized N by microbes was more susceptible to degradation than the native soil N. Marumoto *et.al.*, (1982) reported the N turnover from dead microbial cells to be about five times faster than that from

native soil organic N where as Krantz *et.al.,* (1968) reported that a portion of immobilized N is mineralized during the immediate cropping year and becomes available to growing crops. The balance of the immobilized N mineralized at about the same rate as the native soil rate in subsequent years. Asami (1971) and Kai (1984) observed that remineralisation of immobilized fertilizer N after submergence proceeds rapidly (Watanabe and Inubishi, 1986) and almost ceases at an early stage; whereas soil organic N mineralisation may continue at a steady state for long period.

Kai *et.al.*, (1984) in a study concluded that the main sources of mineralized N in Thailand rice soils were amino acid nitrogen (AAN) and amino sugar nitrogen (ASN) whereas Ramamoorthy and Agarwal reported that hexosamine fraction of N contributed most to the N nutrition of paddy. Mohapatra (1988) and Rout (1998) showed that AAN and hydrolysable ammonia nitrogen (HAN) are the fractions that contributed most to N nutrition. Perumal *et.al.*, (1986) also reported amino acid fraction to be quantitatively more important among the hydrolysable fractions. In contrast Prasad *et.al.,* (1986) showed that non-hydrolysable N (NHN) in waterlogged soil constituted the bulk of soil N that also contributed substantially to plant N .

Under wetland condition root associated N-fixation contributed 1-7 kg N/ha per crop season (Roger and Ladha, 1990). This biologically fixed N mineralizes faster than the native soil N and becomes available to the rice plant (Ito and Watanabe, 1985).

Past studies on contribution of fixed NH_4^+ reveal that the availability to plants from recently fixed NH_4^+ is higher (Mengel and Scherer, 1981; Weimer and Scherer, 1992) than that from the native fixed NH_4^+ (Allison *et.al.*, 1953). The initial exchangeable NH_4^+ and in certain cases a part of the native fixed NH_4^+ are also the sources of N to rice plants (De Datta, 1987). In paddy soils a pronounced swelling of clay minerals after flooding may also facilitate the diffusion of NH_4^+ out of the

interlayers. Keertisinghe *et.al.*, (1984, 1985) showed higher release of fixed NH_4^+ in an Alfisol with vermiculite as the dominant clay mineral than Vertisols with smectites as the main clay minerals.

Lowland rice can also derive significant part of its N requirements from the subsoil. In a microplot experiment about 40% of total N absorbed by the unfertilized rice plant came from below 20 cm (Ventura and Watanabe, 1978). Similarly, in Tai lake region of China, Che and Zhu (1986) found that the subsoil contributed 16-19% to the total soil N supply to the rice plants.

Results of numerous studies suggest that parts of the soil N rather than the total N content are important for N supplying capability Major known fractions of soil nitrogen are amino nitrogen (proteins, peptides) polymers of aminosugars and NH_4^+ fixed in interlayers of 2:1 minerals (Mengel, 1996) Only a small percentage of the total soil organic N is easily mineralisable and contributes to the pool of mineral soil N. Predominant sources of mineralisation are amino-N and polymers of amino-sugars present in the soil microbial biomass. Influx into this pool occurs with the application of organic matter (green manure, straw), organic carbon released by plant roots, N assimilation by leguminous species and inorganic N.

Garz and Chaanin (1990) found in long term experiments in Germany that about 90% of the organic N was very resistant to mineralisation and only about 5-6% of the total soil N was accessible to mineralisation during a long lasting incubation according to the technique of Stanford and Smith (1972).

In a study Schnier *et al* (1987) showed that N mineralisation potential and soil N uptake were neither related to total organic carbon content nor to total N content of the soils, Poor correlation between total soil N and N uptake were also reported by Fox and Piekielek (1978). Total soil N and organic matter seem to be reliable parameters only for N- Uptake if biomass is proportional.

Behera (2000) working on the same soil reported that mineralizable N correlates significantly with N uptake and can be a better indicator of N availability than organic C and total N under irrigated rice-rice system cropped for 2-3 years. Dehydrogenase activity of the soil was found to be poorly correlated with organic carbon (r =0.44), mineralisable N (r =0.49) and N- uptake (r =0.68).

2.3 Nitrogen Mineralisation and Factors Affecting it

Mineralisation and immobilization are two opposing processes that determine the N availability to the growing rice crop. These two processes occur simultaneously in flooded soils with their rates and magnitudes influenced by quality of organic matter, cropping, edaphic and management factors (Broadbent, 1978; Savant and De Datta, 1981)

2.3.1 Characteristics of Organic Matter

Organic matter characteristics determining decomposition and mineralisation kinetics include N-content, C-N ratio, lignin, and lipid content etc.

In general C-N ratio appears to be the decisive factor in the mineralisation and immobilization of N. The critical limit of C-N ratio is 25:1. Higher C-N ratio favours immobilization (Broadbent, 1953). Thus additions of nitrogenous organic residues such as leguminous residues, green matter and succulent plant residues decompose faster than that of wide C-N ratio organic materials like cereal residues (Somani and Saxena, 1976). Mineralisation of humified FYM or compost is a slow and steady process (Gaur, 1982). Generally crop residues containing 1.5 percent N or more will decompose at normal rates without bringing about a net immobilization of soil N. Crop residues containing less than 1.5 percent N are considered deficient in N and will lead to depletion of available forms of soil N during decomposition (Allison, 1973).

A comparative study on the mineralisation of Azolla and Sesbania revealed that at the same N rate, mineralisation of Azolla microphylla was slower and lower

than that of Sesbania rostrata despite similar C-N ratio (Nagarajah *et.al.*, 1986). This was due to high lignin content of Azolla, which is known to retard decomposition of plant constituents (Alexander, 1977).

2.3.2 Cropping

Relatively little information is available on the influence of growing plants on mineral N availability in flooded soils. Some preliminary studies recorded more mineral N in flooded soil planted to rice than in unplanted soil (Broadbent and Tusneem, 1971; Fillery and Vlek, 1982; Cai and Zhu, 1983). The excretion of organic matter of variable C and N content from the roots of growing plants, together with sloughing and dying back of roots could result in the addition of a large amount of decomposable organic materials to the soil. This may stimulate N mineralisation in soils. The substrates exuded from roots may also cause a dramatic change in the microbial activities within a volume of soil (Cai and Zhu, 1983).

An experiment conducted in Bulgaria on eutric fluvial soil to study the effect of cropping on microbial activity showed that soil with rice plants had higher biological activity, biomass-C and nitrogen fixing ability compared with soils without plants.

2.3.3 Edaphic Factors

Important edaphic factors such as soil temperature, soil moisture, soil pH, soil texture and soil microbial activity significantly influence the N-mineralisation.

2.3.3.1 Temperature

Ammonification is primarily an enzymatic decomposition of organic N. soil temperature is an important factor controlling kinetics and magnitude of ammonification in the wetland soil. There is an increase in ammonification rate with increase in temperature in the range of 15-45 degree Celsius. The temperature co-efficient value (Q_{10}) for ammonification varies from 1.0 to 1.8 with soil types and temperature range. Net mineralisation of soil organic N in four Philippine soils under

anaerobic incubation increased with an increase in temperature from 15 to 45 degree Celsius (IRRI, 1974). Similarly, Myers (1975) reported that the ammonification of organic N in a tropical soil increased with an increase in temperature from 20 to 50 degree Celsius with maximum at 50 degree Celsius and then decreased slightly with further increase.

Temperature of about 30 degree Celsius has been reported to be optimum for nitrification in soils. Nitrifiers, in general, are more sensitive to high temperature than to low temperature (Goswami and Sahrawat, 1982). Sahrawat (1980b) observed no nitrification of soil or fertilizer ammonium after drying at 60 degree Celsius. Nitrification was observed to occur at a temperature as low as 1.5 degree Celsius and it increased with the rise in temperature up to 32 degree Celsius (Ramamoorthy and Velayutham, 1976).

Bonde and Roswall (1987) studied the seasonal variation of potentially mineralisable N in four cropping systems. A steady decline of N-mineralisation from spring to harvest and a subsequent increase from harvest to autumn was observed in all cropping systems tried. Poorvarodam *et.al.,* (1988) observed that N mineralisation exhibited distinct seasonal patterns with maximum in summer and minimum rates in the winter.

2.3.3.2 Moisture Regime

Moisture regime of a soil is critical for mineralisation of organic N. It has been found that soil drying prior to flooding changes the pattern of mineral N release (Sahrawat, 1983b) and enhances soil N mineralisation and thus its availability to rice (Ventura and Watanabe, 1978; Sahrawat, 1981). In a study Stanford and Epstein (1974) showed that highest N mineralisation rates occurred between matric suction of 1/3 to 0.1 bar. In another study, the results suggest that drying and rewetting not only generate N pool but also increase the mineralisation rate with more stable N pool in the soil (Carbera, 1993).

De Bruin *et.al.*, (1989) quantified the rates of net mineralisation, net immobilization and net nitrification at field capacity and alternating wet and dry conditions. The rate of net mineralisation at field capacity was twice as high as under alternating wet and dry conditions.

2.3.3.3 Soil pH

A review on the effect of acidity on soil biochemical properties showed that nitrification, denitrification and mineralisation were affected by soil pH (Tabatabai, 1985). Goswami and Sahrawat (1982) reported that acidity decreases ammonification but does not stop it. Sahrawat (1982) studied the nitrification of soil N in several rice soils. He found that the rate of nitrification increased with increase in soil pH from 5.5 to 10.0. Investigating on effect of soil pH on N mineralisation, Patric Jr. (1982) concluded that N mineralisation under submerged conditions is usually not limited as much as would be expected by adverse pH conditions since submergence tends to drive pH of both acid and alkaline soils towards the neutral point.

Study made by Singh and Beauchamp (1986) on N mineralisation and nitrifier activity in lime and urea treated soils showed that nitrifier activity had a significant role in net N mineralisation in lime acid soils. They observed that significant net N mineralisation did not occur until sufficient lime was added to raise the soil pH above 6.0.

2.3.3.4 Soil Texture

Soil texture also significantly influenced the rate of mineralisation of organic N. van Veen *et.al.*, (1985) observed that rates of mineralisation and immobilization were more rapid in sandy loam soil. Hasan and Ghosh (1984) observed a significant correlation of clay percentage with the ratio of ammonia released under submerged condition to organic carbon and total N. However, Sahrawat (1983a) did not find any significant correlation of organic N mineralisation with soil texture.

2.3.3.5 Soil Enzymes

Most of the biochemical reactions involved in the soil N cycle are catalysed by enzymes. Ammonification is primarily an enzymatic decomposition of organic N. The primary source of soil enzymes is believed to be microorganisms (Skujiins, 1978).

Urease (urea amidohydrolase) is an enzyme that catalyzes the hydrolysis of urea to CO_2 and NH_3 . Urease is widely distributed in nature and it has been detected in microorganisms, plants and animals . It has been shown to be a strong discriminator between effects on soils amended with plant residues, N fertilizer and animal manures(Bandick *et al,* 1994.)

Pattnaik *et.al.*, (1999) showed that surface soil had the highest urease activity followed by subsurface soil and flooded soil. Urease bound to the surface of rice roots (exocellular urease) may hydrolyse organic substances in the soil (Mohapatra *et.al.*, 1977). Sahrawat (1983) observed that urease activity was significantly correlated with total N (r = 0.91**) and organic carbon (r = 0.89**) but not with CEC, clay and pH. Multiple regression showed that organic matter content of soil measured by organic C and total N accounted for most of the variation in urease activity.

Amidase (acylamide amidohydrolase) is another important enzyme in the N cycle that is involved in N mineralisation releasing NH_4^+ from linear amides by acting on C-N bonds other than peptide bonds(Franken berger and Tabatabai , 1980). In an incubation study Magid and Tabatabai (1991) showed a significant correlation between N mineralized under waterlogged conditions and amidase activity when the soil was incubated for 14 days at 30^0C. A pot experiment with flooded rice showed significant positive correlation between organic carbon and amidase activity (Sriramachandrashekharan, 1999)

2.3.4 Management Factors

The management practices meant for improving the efficiency of both fertilizer and soil N influence the soil N mineralisation. Effect of nutrient management practices particularly sources of nutrients on soil N-mineralisation has been discussed below.

2.3.4.1 Inorganic Fertilizers

Stimulation of soil N uptake following N fertilization has been reported by Bouldin, 1986; Broadbent and Reyes, 1971; Mian and Stewart, 1985; Azam, 1990 and Rout, 1998. The stimulation may be due to a greater exploitation of the soil profile by the fertilized plot than the unfertilized plot (Broadbent, 1981) or due to priming effect of the material or apparent soil N mineralisation due to the biological interchange of applied N with the native soil N (Jenkinson *et.al.,* 1985). The occurrence and extent of a priming effect has long been a subject of controversy. Jenkinson *et.al.*, (1985) have introduced the term "added nitrogen interaction" (ANI) for both positive and negative priming effect. According to them ANI may be real or apparent. It will be real if fertilizer N increases the volume of soil explored by roots and apparent if it is caused by pool substitution which comes about by rapid incorporation of labeled ammonium into microbial cells and into their organic molecules via enzyme mediated reactions with subsequent release of N into the inorganic pool. Pool substitution causes greater incorporation of N in the soil organic N pool. Apparent ANI resulting from pool substitution will in turn contribute to real ANI and cause substantial increase in the amount of soil N taken up by the plants and thus resulting in low recovery of applied N by rice.

^{15}N study conducted by Rout, (1998) revealed that inorganic N application to an *Inceptisol* tremendously influenced release of soil N. In a study, Pathak (1991) showed that higher level of N increased the amount of aminoacid N (AAN) content of the soil.

Nitrogen fertilizer additions imply a tremendous interference in the soil nitrogen turnover. There are numerous examples from studies with labeled fertilizers that 10-20% of the added amounts are assimilated by soil microbes and thus flow into organic soil N – pool Mahli *et.al.,(*1994), Schier *et. al.*, (1988). Microbial assimilation depends on microbial activity and particularly on the availability of organic carbon. There is evidence that organic carbon release by plant roots feeds this assimilation process and thus promotes the propagation of micro organism in the rhizosphere (Helal and Sauer beck, 1989, Jensen and Sorensen, 1994). The release of photosynthates by roots, has a direct impact on microbial assimilation of nitrate , ammonium and N_2 (Neyra and Dobereiner, 1977). The fertilizer N thus immobilized in early summer may be mineralized in autumn and may later be leached by winter rains and thus lost from the system (Mengel, 1996). Weller (1977) reported that drying of soil stimulated nitrification. It is feasible that soil dryness leads to the death of numerous microbes which are prone to mineralisation after rewetting and loss by various mechanisms if the conditions are favourable.

Application of other nutrients also influences nitrogen mineralisation. Application of zinc alone or in combination with N increased the uptake of N (Khanda *et.al.,* 1997; Singh *et.al.*, 1996). In contrast, working on the same soil Behera (2000) reported no significant effect of S, Zn and B on N mineralisation.

Increase in uptake of N due to application of silicate slag has been reported by Zhang *et.al.,* (1996). At higher levels of N fertilizer application of calcium silicate often significantly increased the rice yield. Okuda and Takahasi (1964) reported that the oxidizing power of roots increased with increase in silica content. Ponnamperuma, (1964) has suggested Si increased the volume and rigidity of the gas channels in the shoots and roots, thereby increasing the oxygen supply to the roots.

2.3.4.2 Organic Amendments

Nitrogen mineralisation was also greatly influenced by the integrated use of organic and inorganic sources of nutrients.

2.3.4.2.1 FYM

Improvement of soil health due to application of FYM in combination with inorganic fertilizers is well documented. In a study, Basumataray *et.al.*, (1998) showed that 50% NPK along with FYM substituting 50% N resulted in higher available NPK than 100% NPK. Continuous manuring for 14 years resulted in an increase in organic C, N, P and K status of soil amended with FYM (More *et.al.*, 1994; Dinesh *et.al.*, 1999 and Mandal *et.al.*, 1991). Rao *et.al.*, (1995) reported application of FYM increased the total and available N content at 45 and 60 DAT of rice due to soil N transformation. Mohapatra *et.al.*, (1991) showed that FYM along with inorganic N increased hydrolysable N and decreased non-hydrolysable N as compared to control. Santhy *et.al.,* (1993) observed that continuous cultivation with addition of 100% optimal level of NPK along with 10 tons of FYM per hectare enhanced the organic matter fractions. Humic acid fraction was higher than Fulvic acid and the content of both increased with depth.

Soil enriched in organic N, e.g. by regular FYM application may mineralize N at periods when it is not used by crops which may lead to N losses (Johnston and Powlson, 1994) presumably in form of NO^-_3 leaching (Powlson *et.al.*, 1989).

In a study Liu *et.al.,* (1990) reported that the use of organic manures in addition to chemical fertilizers increased soil organic matter and total N and increased the population of soil organisms and activities of enzymes such as urease. A fertilizer management study involving incorporation of FYM into soils of a rice-rice system demonstrated that soils freshly amended and soils previously amended with organic manures resulted significantly greater microbial biomass and enzyme activity than the un-amended control. A significant and positive relationship of enzyme activity with organic C and total N suggested that addition of organic

manures to soils increased C turnover, N synthesis and accumulation in the soil matrix. FYM acts as a source for increased microbial activity which results in enhanced enzymatic reaction in soil (Chendrayan *et al.,* 1980). Continuous application of N,P and K fertilizers with FYM resulted in the increased activities of the enzymes viz, amylase, catalase, cellulase, dehydrogenase, phosphatase and urease. Absence of P and K and lower levels of N,P and K resulted in reduced enzyme activities (Singaram and Kamalakumari ,2000).

2.3.4.2.2 Green Manuring

The ability of legume green manure to supplement fertilizer N is well documented (Meelu and Morris 1988; Bouldin, 1988). Sahoo and Nayak, (1971) studied the effects of inorganic fertilizer incorporation alone or in combination with FYM and green manure and observed that green manure gave higher yields than that with 22 kg N / ha as inorganic fertilizer. In rice, Sesbania aculeata substituted for 120 kg inorganic N / ha where 60 kg inorganic N plus green manure gave rice yield equivalent to 180 kg inorganic N / ha (Khind *et.al.*, 1985). As compared to FYM and straw residue, green manure application increased N uptake in both the seasons with better synchrony at all the stages (Sreedevi *et.al.*, 1991; Clement *et.al.*, 1998). In a field experiment Manguiat *et.al.,* (1997) showed that liming significantly increased N availability in a soil green manured with Sesbania rostrata. Liming, P application and inoculation significantly increased dry matter production, N content and N uptake of S rostrata thus enhancing its usefulness as a green manure. In another study, Bharadwaj *et.al.*, (1995) observed significant improvement in microbial biomass, dehydrogenase activity and bacterial population in a rice soil green manured for 3 years as compared to fertilizer application. In a recent study Ravichandran *et.al.*, (1999) observed that Sesbania aculeata registered higher amidase activity than FYM, composted coir pith and paddy straw.

2.3.4.2.3 Straw Incorporation

The importance of rice straw as a crop residue and its impact on soil fertility has been largely overlooked until recently. According to Williams *et.al.*, (1986) N

addition to rice straw for decomposition under low land condition is neither necessary nor desirable. Incorporating large quantities of rice stubble at wheat sowing reduced N uptake and yield by 38% (Bacon, 1987). Azam *et.al.*, (1991) reported that incorporation of rice straw residues reduced the dry matter yield of wheat by reducing the availability of soil N rather than that of the applied fertilizer N. Huang *et.al.*, (1996) showed that there is no significant difference in grain yield between urea applied alone and when mixed with rice straw. Subbaiah *et.al.*, (1997) also reported that crop residue application was not of any additional advantage. Suzuki *et.al.*, (1990) showed that the yields in the organic fertilizer plot in which 60% N was derived from the rice straw compost were clearly lower than those in the inorganic plots.

On the other hand, experiments conducted at IRRI for 7 years demonstrated that in-situ incorporation of straw twice a year caused an average increase of 48 kg N / ha / season (Kundu and Ladha, 1997). Anaerobic soil condition compared with dryland soils not only preserve more straw N and guard against nitrification and subsequent leaching but also favour N conservation and biological N fixation (Roger and Ladha, 1995). Combined application of residue and organic manure improved the soil physical properties (Prasad *et.al.*, 2000). Liu *et.al.*, (1990) reported that the use of organic fertilizers in addition to chemical fertilizer increased soil organic matter and total N, increased the effectiveness of P, increased the population of soil organisms and enzyme activity particularly of Urease. Gotoh *et.al.*, (1986) studied that the application of rice compost, rice straw and Italian Rye grass residues led to a marked increase in all forms of soil N, whose content was greatest in the surface soil. In an incubation study Fujii *et.al.*, (1972) reported increased population of protein decomposing microorganisms in the early stages of incubation of rice straw / sand mixtures at 20^0C under water logged condition. In another incubation study Pathak, (1991) showed that application of straw alone caused net immobilization of soil N and remineralisation of this immobilized N was extremely slow because of the formation of relatively complex and recalcitrant components of microbial origin (Jansson and Persson, 1982; Patil, 1990). However, application of urea along with

straw was found to be beneficial as far as cumulative amount of inorganic N and rate of N release were concerned.

In a field study, Uhlen (1973) observed that incorporation of straw in autumn resulted in a slight reduction in the crop N uptake the following year. This indicated that the straw incorporation resulted in net immobilization of N not only in autumn but also during the following spring. However, this depression in crop N uptake was relieved after 2 to 3 years with repeated annual straw incorporation indicating the remineralisation of immobilized N compensated for the effect of the newly incorporated straw. According to Bakken (1986) the incorporation of straw into soil in autumn may potentially reduce nitrate leaching since net immobilization of N occurs in soil during the early phase of straw decomposition. However, straw incorporation may also reduce nitrate concentration in soil by stimulating denitrification (Aulakh *et.al.,* 1984).

Smith *et.al.*, (1978) reported that addition of C sources such as Sorghum stover along with fertilizer caused an increase in non-hydrolysable N (NHN) status of soil and suggested that this fraction of organic N was less biodegradable and did not contribute to plant available N. this finding was later supported by study made by Pathak (1991) who reported poor correlation between NHN and grain yield (r = 0.10) and between NHN and N uptake (r = 0.15). Pathak (1991) also reported that straw plus urea recorded higher amount of N than integration with any other source of N both after rice and wheat harvest.

2.4 Evaluation of Nitrogen Supplying Capacity of Soil

Unlike fertilizer N uptake, soil N uptake by rice continues until maturity in all soils, but the amounts taken up differs markedly among soils. These differences represent the various N supplying capacities of soil.

Stanford and Smith (1972) and Stanford *et al.,* (1974) have reported on development of an incubation approach to define the mineral sable (or labile) soil N

pool. This approach involves estimations of the N mineralized from a soil over an extended period of time with inorganic N being removed at various times during the incubation. The N mineralization potential (N_0)is assumed to follow first order kinetics (-dN/dt =kN) and is estimated as $\log(N_o-N_t) = \log N_o - kt/2.303$ (Stanford , 1977). The initial work with 39 widely differing soils gave an average k(rate constant) of 5.4 $\pm$ 0.9% of the total N mineralized for week (range 3.9 to 9.5%) with an average N_o (N mineralization potential as percentage of total soil N) of 18.4 $\pm$ 7.9% (range 4.6 to 40.6%). They concluded that k and N_o are definite soil characteristic upon which quantitative estimates of soil N mineralization could be based).

Stanford and Smith (1972) defined the potentially mineralisable N, N_0 as the total quantity of soil organic N that is susceptible to mineralisation at time zero according to first order kinetics. N_0 is a definable soil characteristic, which may be of value in estimating N supplying capacities of soils under specified environmental conditions. Moreover, N_0 provides a common basis for evaluating various chemical and biological availability indices under a broad range of soil conditions and for making quantitative estimates of N mineralisation in the field (Stanford, 1982). The approach of Stanford and Smith (1972) is promising since it seems to conform to the assumption that N mineralisation is related to an active N fraction and not to the total soil N.

Oyanedel and Rodriguez (1977) determined the N mineralisation potentials of 23 soils in the central zone of Chile following the method of Stanford and Smith (1972). Values of N_0 ranged from 100 to 520 ppm and mineralisation rate constant 'k' were similar to those reported by Stanford and Smith (1972) i.e., 0.054 $\pm$ 0.012 $week^{-1}$.

Char-Fen-Lin (1981) estimated N_0 of paddy soils of Taiwan over a prolonged period of submergence values of N_0 ranged from 84.2 to 247.6 ppm, rate of mineralisation (b) from 0.0202 to 0.66 week / ppm and 'k' from 0.1288 to 3.077

week^{-1}. Estimated N_0 value by incubation – leaching method showed a good relationship with N uptake by rice in pot culture with limited soil, but no correlation was found under field conditions.

Nitrogen supplying capacities of paddy soils of Thailand were studied by Kai *et.al.*, (1984). They concluded that the main sources of mineralized N were the aminoacids and amino sugar fractions. N uptake by rice was well correlated with N mineralisation in incubation of air-dried soil. Dalal and Mayer (1987) studied the dynamics of N mineralisation potential and observed that N_0 decreased with cultivation in moist soils. The mineralisation rate constant 'k' appeared to be less affected by cultivation.

Khanif and Rahimabivi (1988) determined mineralisable N (N_0) and rate constant (k) of 14 rice soils under submerged condition in a laboratory study. The N_0 ranged between 20.0 and 154.1 ppm, which represented between 1.0 and 7.3 percent of total N. the 'k' value ranged between 0.11 and 0.72 week^{-1}. The results showed a good correlation between calculated and observed mineralized N. The N_0 and k values were not affected by total N, organic C and C/N ratio; however, there was a significant correlation between N_0 and k (r = 0.76) El-Haris *et.al.*, (1983) and Woods *et.al.*, (1987) reported that application of N fertilizer increased the N mineralisation potential of soils. Pathak (1991) reported a 30 times higher mineralisation rate with urea than straw amendment. However, there was.93 – 6.19x indicating a decrease in N_0 with increase in C/N ratio. The correlation coefficient (r) was found to be 0.92. substantial improvement in the N supplying capacity of soils when straw was applied in combination with urea.

Pathak (1991) expressed the relationship between N_0 (y) and C/N ratio (x) of various organic sources of N by the regression equation y = 235.93-6.19x indicating a decrease in No with increase in C/N ratio. The correlation coefficient (r) was found to be 0.92.

Literature reviewed above suggest that for sustainable yield of rice under intensively irrigated rice system we must understand cumulative effect of various nutrient management practices on N transformations in soil over years of cropping in relation to N supplying capacity.

CHAPTER-III
MATERIALS & METHODS

MATERIALS AND METHODS

In order to fulfill the objectives of the present investigation, The Long Term Fertility Experiment of the All India Coordinated Research Project (AICRP),ICAR conducted at Orissa University of Agriculture and Technology (OUAT), Bhubaneswar since 1994 was used. A laboratory incubation study was also made on the soils of this experiment.

The materials used and the methods followed in this study are described here under.

3.1 FIELD EXPERIMENT

The long term fertility experiment at Bhubaneswar was started in 1994 and after conducting three years (1994-1996) of uniformity trial with a kharif rice each year. Systematic study with imposed treatments was made since kharif 1997 with rice-rice cropping system. For the present investigation, the rice crops of rabi 1999-2000 and kharif 2000 were used for study.

3.1.1 MATERIALS

3.1.1.1 Location of the Experiment

The experimental plot is located in the 'E' block of the Central Research Station, O.U.A.T., Bhubaneswar, which lies between longitude of 85° 48' E and 85° 49' E and latitude at 20°16' N and 20° 17' N.

3.1.1.2 Climate

The climate of Bhubaneswar is humid tropical with the dry season from October to June and wet season from July to September. The important weather parameters during rabi 1999-2000 and kharif 2000 are presented in Appendix table.1and Fig.1

3.1.1.3 Soil

The soil of the experimental field belongs to moderately well drained lateritic sandy loam (*Udic Ustochrept*). The physico-chemical properties of the Soil are listed in Table 2.

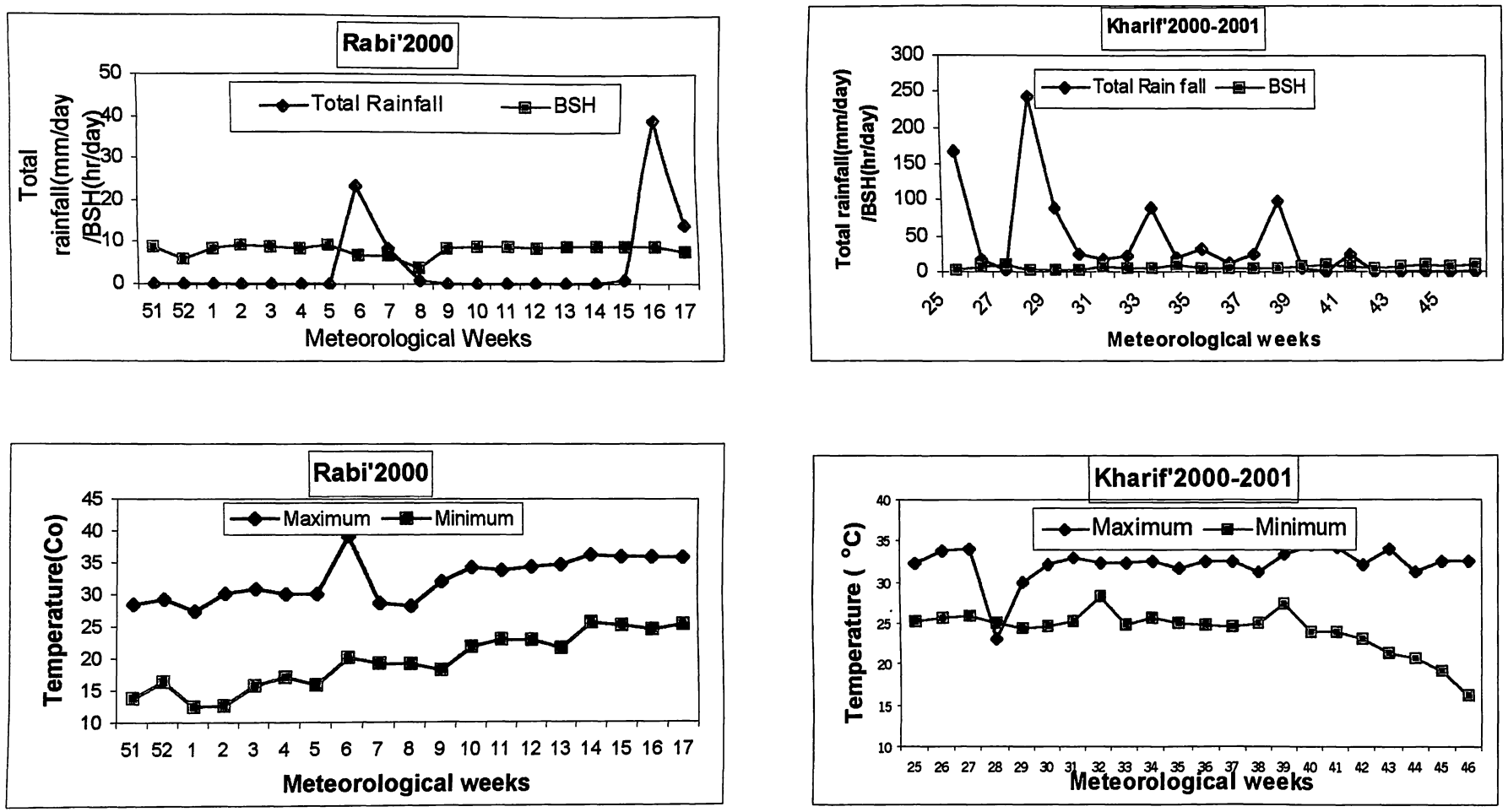

Fig.1: Mean weekly variation of meteorological parameters during cropping season

Table 2: Physico-chemical properties of the soil (composited sample) of the experimental field on air dry basis.

Properties	Values
Sand(%)	76
Silt(%)	6
Clay(%)	18
Textural class	Sandy loam
PH	5.8
EC (dS/m)	0.1
Organic Carbon(%)	0.5
Available N (kg/ha)	187
Available P (kg/ha)	19.36
Available K (kg/ha)	43.36
Total N (kg/ha)	1280

3.1.1.4 Test crop

The popular rice cultivars, Lalat (125 days) and Swarna (145 days) with a yield potential of 3.5 t/ha and 5t/ha at standard level of management practice were used as the test crop, for rabi 1999-2000 and kharif-2000 respectively.

3.1.1.5 Sources of Nutrients

3.1.1.5.1 Organic Sources

Three organic sources such as green manure, straw and FYM were used in the study.

The nutrient contents and C-N ratio of the three organic sources are presented in Table 3(a)

Table 3(a): Chemical Composition and C-N Ratio of Organic Sources of Nutrients (Oven-dry basis).

Properties	Organic Sources		
	Dhaincha	FYM	Rice straw
Carbon(%)	40.9	20.8	32.4
N(%)	2.01	0.79	0.60
P(%)	0.22	0.50	0.08
K(%)	2.03	0.80	1.28
C-N ratio (value)	20.34	26.28	53.73

3.1.1.5.2 Inorganic Sources

Common fertilizers such as Urea, DAP and MOP were used to supply nitrogen (N), Phosphorus (P) and Potassium (K). In some treatments rock-phosphate was used to supply P. To supply other nutrients such as Zn, S and B, inorganic sources such as $ZnSO_4$ (Or Zn-EDTA) gypsum and borax were used respectively.

For reducing the soil acidity, silicate amendment was done with powdered Tata slag collected from IPITATA, Dhenkanal, Orissa. The composition with respect to important constituents is presented in Table.3(b).

Table 3(b) : Composition of the Tata slag used for Amendment.

Constituents	Percentage
CaO	40-45
MgO	4-5
P_2O_5(Citrate-soluble)	2-5
SiO_2	18-20

3.1.2 Methods

3.1.2.1 Treatments and Design

The experiment was laid out in randomized block design with 12 treatments replicated 4 times. The manurial schedule of the treatments in both kharif and rabi rice are presented in table 3(c).

Table. 3(C) : Manurial Schedule of the Tretments for Both Kharif and Rabi rice.

Treatments	Kharif Rice	Rabi Rice
T_1	Standard = NPK + Zn + B+S	Standard=NPK+Zn+B+S (Residual)
T_2	Standard – S	Standard – S
T_3	Standard – Zn	Standard – Zn
T_4	Standard – B	Standard – B
T_5	FYM 5t/ha + NPK (Adjusted)	FYM 5t/ha + NPK (Adjusted)
T_6	Green manure+standard (N adjusted)	Green Leaf Manure / Azolla + standard (N adjusted)
T_7	Straw incorporation+standard (-P)	Standard (P raised to 150%)
T_8	100% NPK as per standard	100% NPK as per standard
T_9	N though organic + P as rock phosphate+K as straw incorporation	Straw burning + N as (organic + inorganic)
T_{10}	Green manure+N(adjusted) +P as rock phosphate +150% K+S+Zn+B	Standard (N raised to 150%)
T_{11}	Silicate amendment + Standard (P as per soil test)	Straw compst with rock phosphate and P.S.M. + Standard-P
T_{12}	Control (No fertilizer)	Control (No fertilizer)

Standard dose of NPK for both the seasons was N-P_2O_5 - K_2O = 80 : 40 : 60

3.1.2.2 Method and Time of Application of Manures and Fertilisers

Nitrogen was applied in 3 splits (25% basal+50% at 30 days after transplanting (DAT) +25% at panicle initiation (PI). Full doses of phosphorous as DAP and potassium as MOP were applied as basal. However, rock phosphate as source of P is applied prior to sowing of the green manure crop in T_9 and T_{10}. Zinc application is done @12.5 kg/ha as $ZnSO_4$ before planting in kharif and as two sprays of chelated Zn (0.25% solution) in rabi. Sulphur was applied @30kg/ha as gypsum (after adjusting the S from $ZnSO_4$) only in kharif and the residue used in rabi. Two sprays with 0.25% borax were done between panicle initiation and heading to supply B. Silica was applied as an amendment in T_{11} @ 100kg SiO_2/ha in form of silicate slag power only in kharif.

The required amount of FYM, Dhaincha and rice straw were incorporated one week before transplanting. Dhanicha (*Sesbania*

aculeata) was grown *in situ* in the field and incorporated at the age of 50 days i.e. 1 week before transplanting of kharif crop. For rabi green leaf manuring was done. In T_9, the straw of kharif crop was burnt and mixed with soil before rabi planting. Similarly in T_{11}, the enriched straw compost prepared with rock phosphate and phosphate solublising microbes were incorporated before planting in rabi rice.

3.1.2.3 Field Preparation and Planting

After applying 50mm of water the field was first worked with power tiller. Two more puddling were done at 5 days interval and finally the plots were leveled. Standing water of 3cm was maintained through out and 30days old seedlings of variety Lalat and Swarna were transplanted @ 2-3 plants/hills at a spacing of 15cm x 10cm and 15cm x 15cm in rabi1999-2000 and kharif 2000 respectively.

3.1.2.4 Irrigation and Intercultural Operations

Irrigation was provided to the plots intermittently as and when required in order to maintain 3-5 cm of standing water until 2 weeks before harvesting. Normal intercultural operations and pest control measures were undertaken in both the crops.

3.1.2.5 Collection and processing of soil samples

Soil samples were collected at post rabi(30th April, 1999-2000) and pre-kharif(20th May,2000) , 30 DAT, 60 DAT and post kharif–2000 periods following the method of composite sampling. Samples were dried under shade , crushed and sieved (10 mesh) and stored in clean polythene bags with proper labels.

3.1.2.6 Collection and processing of plant samples

For determination of nutrient uptake, rice plant samples were collected at harvest of both rabi and kharif crops. Four sampling spots were located just outside the four corners of net harvested area of each plot and two clumps (hill) from each sampling spot were cut at 5cm, above ground level. The grains were separated from straw. The samples were dried under sun and then inside oven at 75 $\pm$ 5°C temperature. The straw samples were chopped to small pieces. Straw and grain samples were ground by Wiley – mill to pass 20 mesh sieve and preserved in clean containers for analysis.

3.1.2.7 Methods of Analysis

3.1.2.7.1 Soil Analysis

The processed soil samples were subjected to various physical, chemical and microbiological analysis, which are given below.

Soil pH(w)

The soil pH was determined in 1:2 soil and water suspension by using glass electrode pH meter (Jackson, 1967).

Soil Organic Carbon (SOC)

The organic carbon content of soil sample was determined by Walkley and Black's rapid titration method (Piper, 1950).

Available Nitrogen

Available nitrogen was determined by the method described by Subbaiah and Asija, (1956). Nitrogen released as ammonia during distillation of 20gm soil with 100ml 0.32% of $KMnO_4$ and 100ml of 2.5% NaOH was received in 2% boric acid containing mixed indicator and ammonia was titrated against standard 0.02N sulphuric acid.

Total Nitrogen

Total N in soil was determined by standard Kjeldahl procedure given by Bremner (1965a). One gram sample was digested in 10 ml of salicylated H_2SO_4 in presence of 1g digestion mixture and 1 crystal of sodium thiosulphate in Gerhadt digestion assembly. After cooling, the samples were distilled with NaOH by the distillation unit of the same instrument. The liberated NH_3 was absorbed in 0.02N H_2SO_4 containing mixed indicator and back titrated with 0.1 N NaOH

Inorganic forms of Nitrogen

The dry soil samples were subjected to analysis for NH_4^+ and NO_3^- form of N by the method given by Bremner and Keeney (1966).

About 10g dry soil was extracted with 50ml 2 M KCl by shaking for one hour. In the extract, NH_4^+-N was determined with MgO and NO_3^-N with MgO+ Devarda's Alloy by steam distillation.

Organic nitrogen fractions

Preparation of soil hydrolysate

Soil samples after extraction with 2M KCl were hydrolysed 6M HCl by heating on water bath under reflux for 12 hours. On cooling, the mixture was filtered into a 200ml beaker marked at 50ml capacity.The residue was washed with 5ml portions of distilled water until the filtrate reached 50ml mark. Then the beaker was put into a tray containing crushed ice and the pH of the filtrate was neutralized pH 6.5 by adding 5M NaOH. The neutralized hydrolysate was transferred to 250ml volumetric flask and diluted with distilled water.

Analysis of the hydrolysate for various organic fractions

(i) *Total hydrolysable Nitrogen (THN):* Ten ml of nutralised hydrolysate was digested with H_2SO_4 and K_2SO_4 catalyst mixture and Nitrogen content was determined by steam distillation procedure.

(ii) *Hydrolysable Ammonium Nitrogen (HAN):* It was determined with steam distillation of 25ml hydrolysate with MgO.

(iii) *Ammino Sugar Nitrogen (ASN) + HAN:* 25ml hydrolysate was steam distilled with phosphate borate buffer (pH 11.2) for the determination of ASN + HAN.

(iv) *Ammino Sugar Nitrogen (ASN):* This was calculated by the difference between above two fractions.

(v) *Ammino Acid Nitrogen (AAN):* It was determined by steam distillation of 10ml hydrolysate with phosphate borate buffer (pH 11.2) after treatment with 1N NaOH at 100 °C to remove ammonium + amino sugar and with ninhydrin + $CuSO_4$ to convert amino nitrogen to ammonium nitrogen.

(vi) *Unidentified Hydrolysable Nitrogen (UHN):* This was determined by the difference of THN and (HAN + ASN + AAN).

Urease Activity

To a soil sample of 5g, 0.2ml toluene, 9ml Tris (hydroxymethyl) aminomethane (THAM) buffer and 1ml of 0.2M urea solution were added and incubated at 37 °C for 2 hours. After 2 hours, 35ml of KCl-Ag_2SO_4 solution was added and diluted to 50ml. 40ml aliquot with 0.4g of MgO was taken for steam distillation and released ammonia in boric acid medium was titrated against 0.002 N H_2SO_4 (Tabatabai and Bremner, 1972).

Amidase Activity

To a soil sample of 5gm, 0.2ml toluene, 9ml THAM buffer and 1ml of 0.2M formamide solution were added and incubated at 37°C for 2 hours. After 2 hours, 35ml of KCl-Ag_2SO_4 solution was added and diluted to 50ml. 40ml aliquot with 0.4g of MgO was taken for steam distillation and released ammonia in boric acid medium was titrated against 0.002 N H_2SO_4 (Tabatabai and Bremner, 1972).

3.1.2.7.2 Plant Analysis

The processed plant samples collected at harvest of both rabi and khairf rice analysed for total N by following microkjeldahl method. Straw and grain samples of 0.3g each were taken in a digestion tube and 2g of digestion mixture ($CuSO_4$: K_2SO_4 = 1:10) were added to it followed by 10ml conc. H_2SO_4. It was digested by heating. After digestion was completed, distillation was done in microkjeldahl method by addition of

40% NaOH. The distillate was collected in 4% boric acid containing mixed indicator and titrated against standard H_2SO_4 (0.02 N).

3.2 *Laboratory Incubation Experiment*

A laboratory incubation study was undertaken to determine the mineralisation potential of the soils collected from the plots of the LTFE used in this investigation. For this study , 10g soil samples (composited) from each of the treatments was incubated at 37^0C under anaerobic condition. Destructive sampling was done for estimation of mineral(NH_4+NO_3)-N at weekly intervals upto 8 weeks.

3.2.1 *Mineral (NH_4^+ + NO_3^-)-N*

The incubated samples were subjected to 2M KCl extraction and the extract was analysed for total mineral N using MgO and Devarda's alloy by steam distillation. The distillate was collected in a 2% boric acid medium containing. mixed indicator and titrated against 0.002 N H_2SO_4.

3.3 Calculation

3.3.1 N- mineralisation potential (N_o).

Mathematical expression given by Stanford and Smith (1972) was used to assess mineralisation potential (N_o). The approximate estimate of N_0 was obtained by using the expression.

$$1/N_t=1/N_0+b/t$$

where N_t=mg N/g soil mineralized (cumulative) during specific period of incubation time, t=time in weeks, b=slope or rate of mineralisation and N_0=N mineralisation potential(mg N/g soil).

3.3.2 Statistical Analysis.

Data in respect of nutrient availability in soil, uptake of N and grain and straw yields in various treatments were subjected to analysis of variance following standard statistical procedure (Gomez and Gomez, 1984). Standard analysis of variance with single degree of freedom contrasts were also used to compare the effect of inorganic sources.(T_1, T_2, T_3, T_4 and T_8), organic sources (T_9),their integration (T_5,T_6,T_7 and T_{10}) and silicate amendment (T_{11}) after classifying the treatments into above groups basing on the source of N used in kharif. Relationship between different sets of variables was worked out by running linear regression equations.

CHAPTER-IV
RESULTS AND DISCUSSION

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The experimental results of the field experiment and the laboratory incubation Study carried out during the course of investigation are reported and discussed in this chapter under the following heads.

4.1 Effect of continuous fertilization and manuring on soil nitrogen availability.

4.1.1 Soil organic carbon (SOC)
4.1.2 Soil mineralisable N
4.1.3 Soil total N
4.1.4 Soil inorganic (NH_4^++NO_3^-)-N
4.1.5 Soil organic N fractions
4.1.6 Soil urease activity
4.1.7 Soil amidase activity

4.2 Effect of continuous fertilization and manuring on dry matter and grain yield of rice.

4.2.1 Dry matter yield.
4.2.2 Grain yield.

4.3 Effect of continuous fertilization and manuring on N-uptake by rice.

4.4 Effect of continuous fertilization and manuring on N-mineralisation potential and N supplying capacity of soil.

4.5 Assessment of indicators of soil N-availability.

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4.4 Effect of continuous fertilization and manuring on N-mineralisation potential and N supplying capacity of soil.

4.5 Assessment of indicators of soil N-availability.

4.1 Effect of continuous fertilization and manuring on soil nitrogen availability:-

Nitrogen availability in soil is mostly governed by the twin processes of mineralisation and immobilization. Both the processes are microbe mediated and influenced by many soil and environmental factors. Soil organic carbon, mineralsable-N, inorganic and organic N fractions, soil total- N and microbial activity determine the rate and magnitude of N mineralisation. Evaluation of various organic and inorganic sources of nutrients applied alone or in combination has been done in regards to their direct and cumulative effect on some of these important properties related to N availability in the following section.

4.1.1 Soil Organic Carbon.

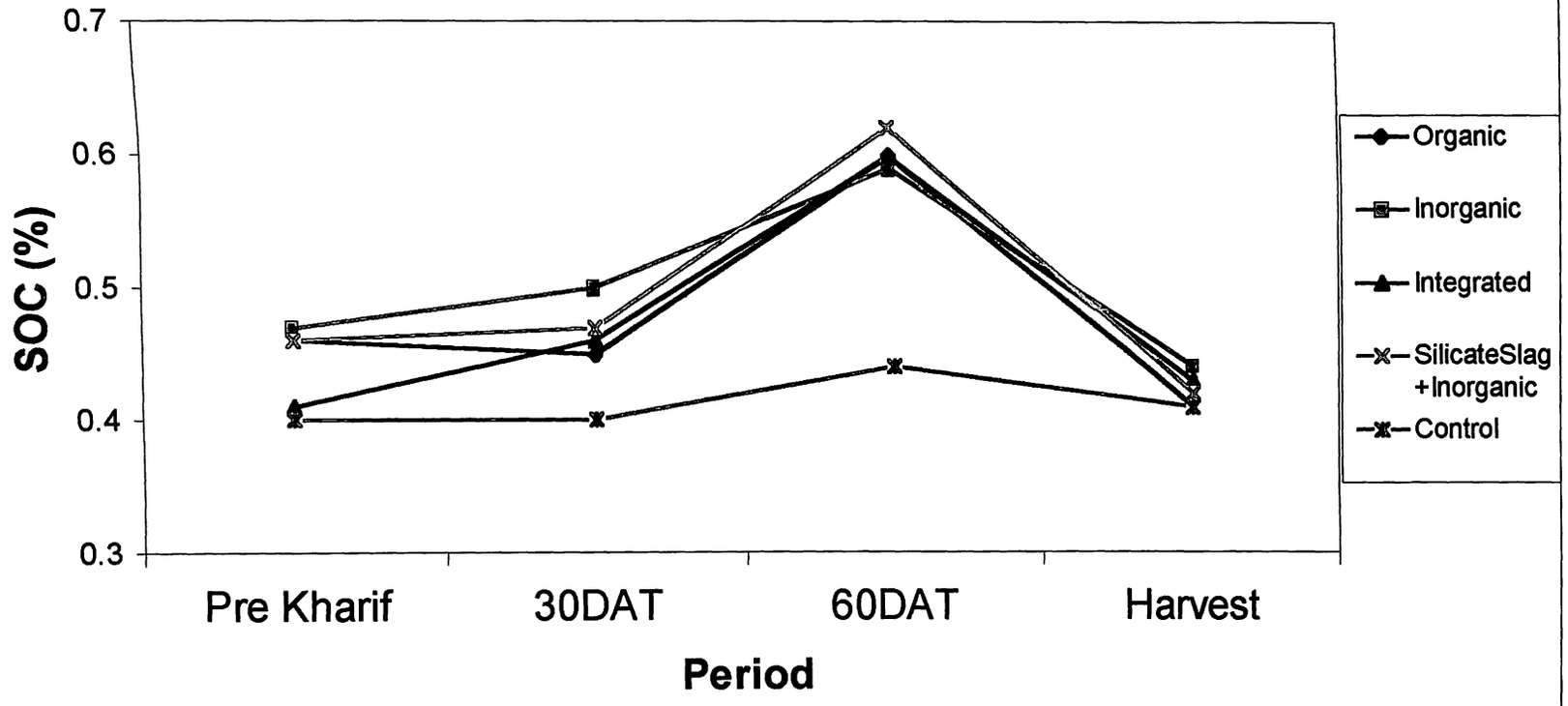
Data Pertaining to soil organic carbon (SOC) content of the soil measured at different periods of the year viz, post -rabi, 1999-2000, pre-kharif – 2000, during kharif, 2000 and post kharif , 2000 recorded in table.4 and depicted in fig.2 showed almost on change during post rabi to pre kharif spanning a gap of one month followed by an increase during crop growth and a drop at harvest almost to the level of pre kharif stage. During the kharif season, highest increase in SOC was observed in treatments where FYM (T_5) and silicate slag (T_{11}) were applied along with NPK fertilizers. Similar observations were also made by Behera (2000). The increase at 30 DAT and 60 DAT might be due to conservation of C resulting from degeneration of rice roots during tillering and panicle initiation stage (Rout, 1998). Subsequent decrease after harvest of kharif crop might be due to C-mineralisation at a greater rate caused by drying of the field and prevalence of aerated condition. During post kharif period the content varied between 0.38 and 0.49%. Although higher values of SOC were observed in FYM amended plots, the difference was non significant. Built up of SOC with continuous application of FYM has also been reported by many workers (More, 1994; Mandal *et. al.*, 1991). From the results it can be inferred that neither the organic sources nor the inorganic sources had

Table 4: Effect of organic and / or inorganic sources of nutrients on soil organic carbon (SOC) during different periods.

Treatments (kharif)	SOC(%)				
	Post rabi 1999-2000	Pre khar 2000	30 DAT	60 DAT	Post kharif 2000
T_1Standard =100% NPK +S+Zn+B	0.45	0.45	0.50	0.57	0.38
T_2 Standard(-S)	0.51	0.49	0.38	0.60	0.46
T_3 Standard (-Zn)	0.49	0.49	0.43	0.64	0.39
T_4 Standard (-B)	0.42	0.38	0.49	0.58	0.38
T_5 FYM 5t/ha +NPK (adjusted)	0.47	0.45	0.51	0.70	0.50
T_6 GM+ standard N (adjusted)	0.42	0.39	0.45	0.51	0.41
T_7 Straw Incorporation + Standard (-P)	0.42	0.38	0.44	0.52	0.38
T_8 100% NPK	0.48	0.48	0.44	0.62	0.45
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	0.50	0.47	0.50	0.59	0.44
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	0.46	0.41	0.43	0.66	0.41
T_{11} Silicate amendments +Standard(P as per soil test)	0.46	0.46	0.55	0.67	0.45
T_{12} Control fertilizer)	0.40	0.40	0.40	0.44	0.41
Mean					
Inorganic sources.	0.47	0.46	0.45	0.60	0.41
Organic sources.	0.50	0.47	0.50	0.59	0.44
Integration.	0.44	0.41	0.46	0.60	0.43
Silcate slag + Inorganic sources	0.46	0.46	0.55	0.67	0.45
C.D.(0.05)					
Treatments.	0.06	0.13	0.15	0.18	0.21
Inorganic Vs Organic.	NS	NS	NS	NS	NS
Inorganic Vs Integration.	NS	NS	NS	NS	NS
Organic Vs Integration.	NS	NS	NS	NS	NS
Inorganic Vs Inorganic+ silicate slag.	NS	0.05	NS	NS	NS

In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Fig. 2: Cumulative effect of organic and/or inorganic sources of nutrients on changes in soil organic carbon (%) during Kharif season



any significant effect on SOC within three years of their application. The micro (B and Zn) and secondary (S) nutrients also did not have any influence on it. However, due to cropping, there was a decrease in SOC by 10-20% from the initial value (0.5%).

4.1.2 Soil Mineralisable Nitrogen.

Results on mineralisable N in the soil measured at different periods of the year, viz, post rabi-1999-2000, pre-kharif-2000 and post kharif 2000-presented in table.5 and depicted in fig.3 (a-b) showed a substantial decrease in mineralisable N content from post rabi to pre kharif period and an increase there after at post kharif period irrespective of treatments. However, the content at post kharif period was slightly less than that measured at post rabj period. After post rabi perid as the field was dry and devoid of any crop there might be more minerallisation of soil N due to wetting of dry soil (Ventura and watanabe, 1978 ; Sahrawat, 1981) and subsequent loss in the first few showers of rain fall through leaching (Weller, 1977 and Mengel, 1996).

The increase in mineralisable N during kharif rice as measured at post kharif period might be due to greater mineralisation brought about by cropping under water logged situation (Broadbent and Tusneem, 1971 Fillery and Vlek, 1982 and Cai and Zhu, 1983 , Kundu and Ladha, 1997 or due to root associated N_2 fixation (Roger and Ladha , 1990 or due to photosynthetic free living BGA. This result is in contrast to the finding of Saito (1991) who reported a fall in the size of the mineralisable soil N pool after each of the three consecutive rice crops.

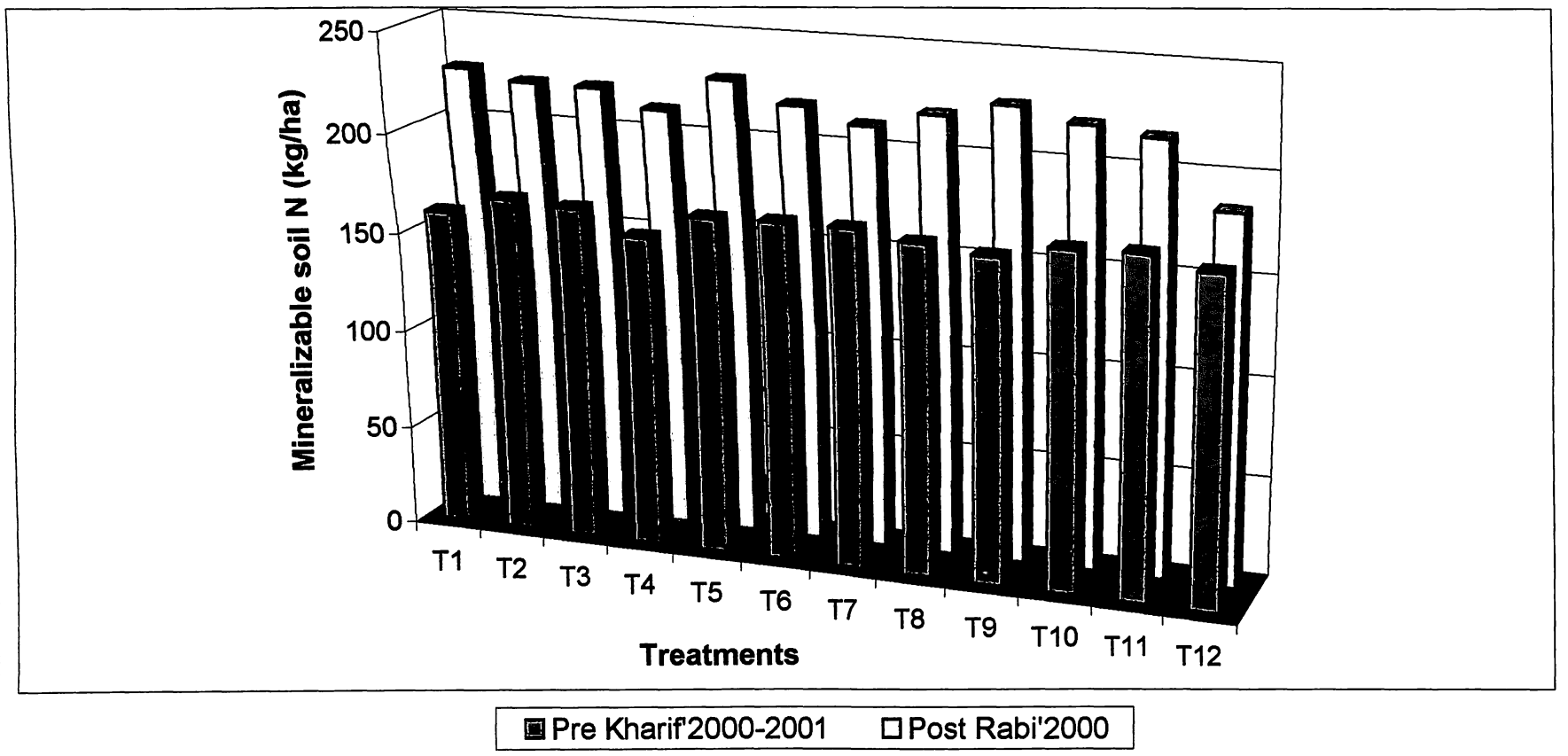
During post rabi period minerlisable N in soil varied from a lowest value of 184 kg/ha in unmanured control to a highest of 229 kg/ha in T_5 (FYM + NPK). Similarly at pre kharif stage the content varied form 156 kg/ha (T_4) to highest of 170 kg/ha in T_6 (green manure + NPK) and T_{11}(silicate slag + NPK). Highest content (211kg/ha) of mineralisable N was also recorded in T_6 at post kharif period.

Table 5: Effect of organic and /or inorganic sources of nutrients on soil mineralizable-N, inorganic-N and total-N measured at different periods.

Treatment (kharif)	Mineralizable –N (kg/ha)			$(NH_4^+ + NO_3^-)$-N (kg/ha)	Total – N (kg/ha)	
	Post rabi (1999-2000)	Pre kharif, 2000	Post kharif, 2000	Post kharif -2000	Pre kharif, 2000	Post kharif, 2000
T_1Standard =100% NPK +S+Zn+B	225	160	195	39.5	1305	1426
T_2 Standard(-S)	221	169	194	42.43	1293	1371
T_3 Standard (-Zn)	220	167	206	42.85	1069	1368
T_4 Standard (-B)	212	156	204	45.41	1060	1395
T_5 FYM 5t/ha +NPK (adjusted)	229	169	208	52.57	1379	1594
T_6 GM+ standard N (adjusted)	219	170	211	49.89	1253	1350
T_7 Straw Incorporation + Standard (-P)	211	169	203	40.76	1448	1485
T_8 100% NPK	219	165	190	45.75	1468	1275
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	226	162	195	42.27	1320	1328
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	219	168	197	50.98	1247	1371
T_{11} Silicate amendments +Standard(P as per soil test)	216	170	208	56.99	1438	1606
T_{12} Control fertilizer						
Mean	184	164	188	37.41	1211	1315
Inorganic sources.	219	163	198	43.19		1367
Organic sources.	226	162	195	42.27		1328
Integration.	220	169	205	48.55		1450
Silicate slag + Inorganic sources	216	170	208	56.98		1606
C.D.(0.05)						
Treatments.	20.51	15.25	21.00	21.83		346.76
Inorganic Vs Organic.	NS	NS	NS	NS		NS
Inorganic Vs Integration.	NS	NS	NS	NS		NS
Organic Vs Integration.	NS	NS	NS	NS		NS
Inorganic Vs Inorganic+ silicate slag.	NS	NS	5.78	2.99		131.92

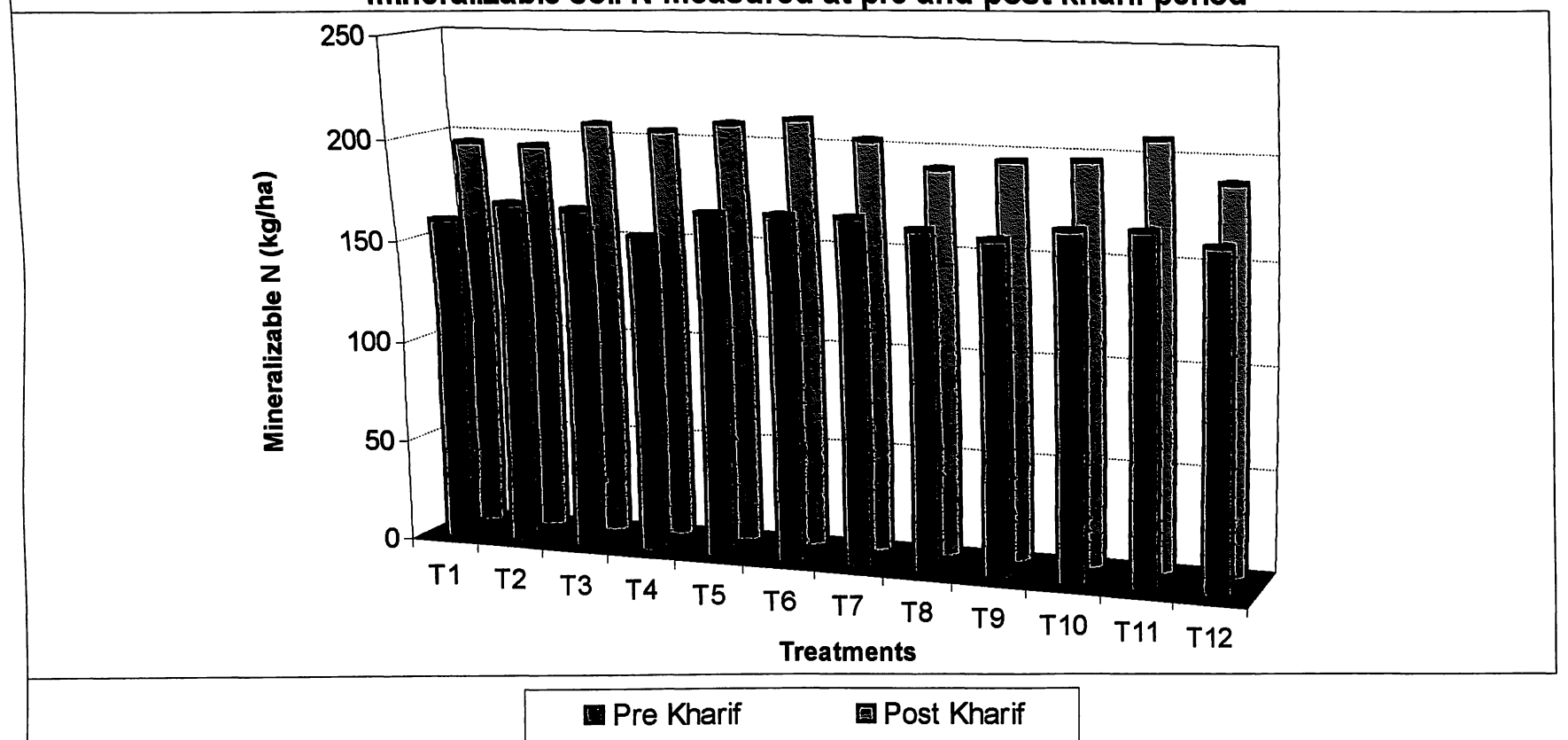
In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Fig. 3(A): Cumulative effect of organic and/or inorganic sources of nutrients on mineralizable soil N measured at Post Rabi and Pre Kharif period



T_1 = Standard 100% NPK + S + Zn +B
T_2 = Standard (-S)
T_3 = Standard (-Zn)
T_4 = Standard (-B)
T_5 = FYM 5tha^{-1} + NPK (adjusted)
T_6 = GM + Standard (N adjusted)
T_7 = Straw incorporation + Standard (-P)
T_8 = Standard 100% NPK
T_9 = N through org. + P as RP + K as straw incorporation
T_{10} = GM + N (adj.) + P as RP + 150 % K + S + Zn + B
T_{11} = Silicate amend. + Standard (P as per soil test)
T_{12} = Control

Fig. 3(B): Cumulative effect of organic and/or inorganic sources of nutrients on mineralizable soil N measured at pre and post kharif period



T_1 = Standard 100% NPK + S + Zn +B
T_2 = Standard (-S)
T_3 = Standard (-Zn)
T_4 = Standard (-B)
T_5 = FYM 5tha^{-1} + NPK (adjusted)
T_6 = GM + Standard (N adjusted)
T_7 = Straw incorporation + Standard (-P)
T_8 = Standard. 100% NPK
T_9 = N through org. + P as RP + K as straw incorporation
T_{10} = GM + N (adj.) + P as RP + 150 % K + S + Zn + B
T_{11} = Silicate amend. + Standard. P (as per soil test)
T_{12} = Control

Results show that continuous manuring and/or fertilization significantly enhanced the mineralisable N in most of the cases. Similarly silicate slag amendment significantly increased the mineralisble N pool. Which may be due to liming effect of silicate slag. However, the influence of continuous application of various sources of nutrients was non-significants.

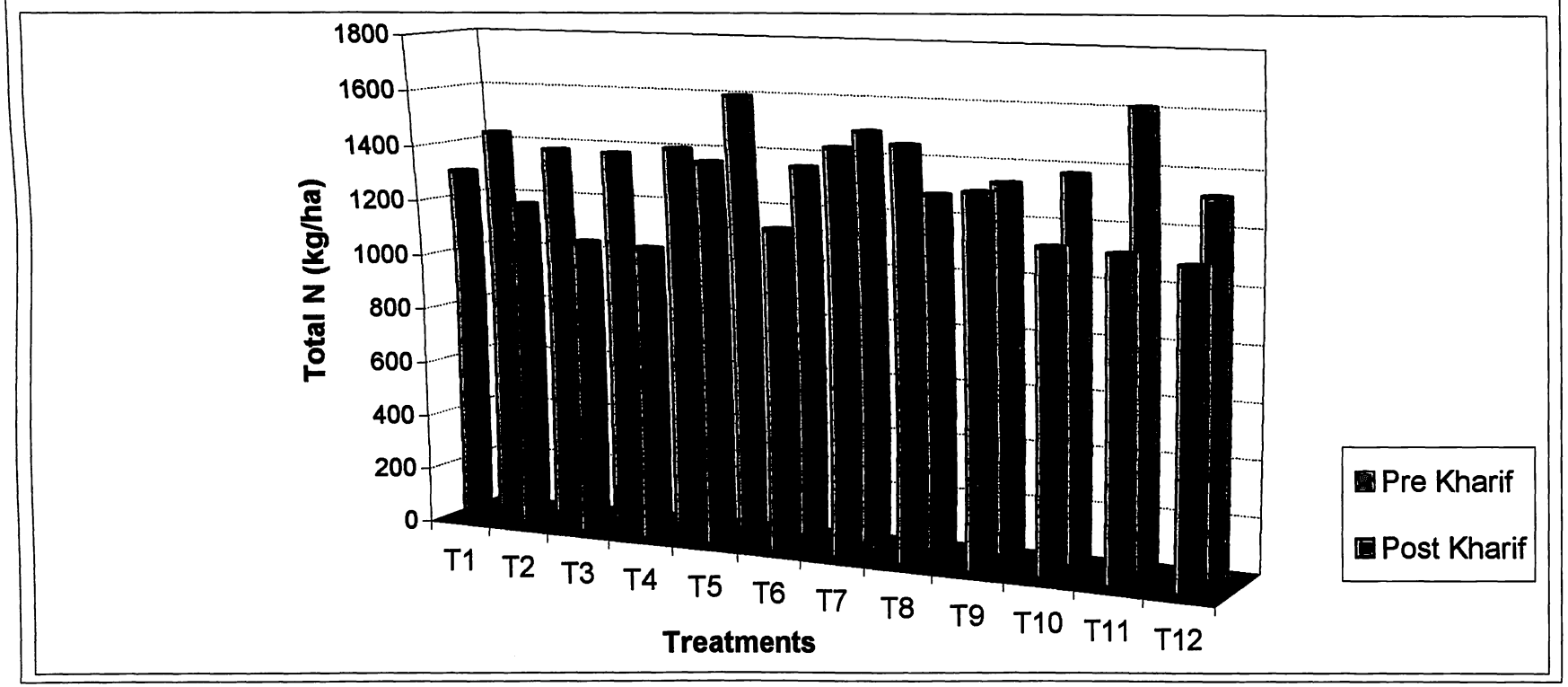
Although the N dose remained same in all the treated plots higher mineralisable N in green manured, silicate slag and FYM amended treatments shows their stimulatory effect on conservatory N transformation, Maintenance of a higher mineralisable N pool might be possible due to the oxidised zone around the root rhizosphere in silicate slag amended soil (Okuda and Takahasi, 1964) and its liming effect on microbial activity and N mineralisation. Working on the same experiment Behera (2000) reported highest pool of mineralisable N in silicate slag amended soil. The stimulatory effect of FYM has been reported by Rao *et. al.,* (1995) and of green manuring by Biswas *et. al.*, (1996). Straw application reduced the available soil N (Azam *et. al.*, 1990).

However, the differences between various sources such as inorganics or organics and their combination in influencing soil mineralisable N were nonsignificant.

4.1.3 Total Soil Nitrogen

The total N content of a soil gives an indication to sustainability of N fertility in a particular cropping system and agro-eco region. Results on total N of surface soil measured at different periods of time viz, pre-kharif and post-kharif 2000 recorded in table.5 and depicted in fig.4 show an increase from pre kharif to post kharif period irrespective of treatments. The increase might be due to addition of N through biological N_2 – fixation either by BGA or heterotrophic bacteria. Roger and Ladha (1995) reported that anaerobic soil conditions compared with dry land soils, not only preserve more straw N and guard against

Fig.4: Cumulative effect of organic and/or inorganic sources of nutrients on total soil N measured at pre and post kharif period



T_1 = Standard 100% NPK + S + Zn +B
T_2 = Standard (-S)
T_3 = Standard (-Zn)
T_4 = Standard (-B)
T_5 = FYM 5tha^{-1} + NPK (adjusted)
T_6 = GM + Standard (N adjusted)
T_7 = Straw incorporation + Standard (-P)
T_8 = Standard 100% NPK
T_9 = N through org. + P as RP + K as straw incorporation
T_{10} - GM + N (adj.) + P as RP + 150 % K + S + Zn + B
T_{11} = Silicate amend. + Standard (P as per soil test)
T_{12} = Control

nitrification and subsequent leaching but also favour N conservation and biological N_2^- fixation. The annual N input through BNF is estimated to be 105kg N/ha (Cassman *et. al.*, 1995). Relatively large inputs of C and N resulting from biological activity in the soil flood water system in lowland soil was also reported by Dei and Yamasaki (1979).

Total N at pre kharif stage varied from a lowest of 1211 kg/ha in the unmanured control (T_{12}) to a highest of 1468 kg/ha in 100% NPK plot (T_8). The plot that received silicate amendment also recorded higher value (1438 kg/ha) of total N. On the other hand the total N at post kharif period varied from a lowest of 1315 kg/ha in control (T_{12}) to a highest of 1606 kg/ha in the silicate slag amended plot (T_{11}). Although some treatments recorded higher total N , there was no significant difference between the treated plots.

Among the sources of nutrients, viz; organic , inorganic and their integration, plots with integrated use recorded higher total N followed by organic source and then oinorganic source. This does not agree with the findings of Behera (2000) who reported highest values with inorganic sources. Thus these results indicate that with 3 years of continuous cropping integrated use of both organic and inorganic sources becomes more efficient in maintaining higher levels of both mineralisable and total N than either of the sources. This result is in conformity with the findings of Tiwari *et. al.*, (1980) and Khind *et. al.*, (1985).

As compared to the initial values there is substantial increase in total N, slight in mineralisable N and decrease in SOC. This indicates accumulation of N in more recalcitrant form under wetland conditions.

4.1.4 Inorganic (NH_4^++NO_3^-)-N

Data pertaining to inorganic N fractions (2M KCl extractable) are presented in table.5. A close scrutiny of the data shows that inorganic (NH_4^+ + NO_3^-)-N in the mineral N pool of soil varied from a lowest of 37.41 kg/ha in the unmanured control (T_{12}) to a highest of 56.99 kg/ha

in silicate slag amended treatment (T_{11}) followed by 52.57 kg/ha in FYM amended treatment (T_5). Among the organic sources used for integration, FYM and green manure were more efficient in maintaining higher level of $NH_4^+ + NO_3^- - N$ than the straw incorporation. Integrated use could maintain a slightly higher level of inorganic N than sole application of either organic or inorganic sources. The order was, integration > Inorganic > organic. However the differences were not significant. In contrast, working on the same experiment Behera (2000) reported highest values with inorganic fertilizers followed by integration and least with organics.

4.1.5 Organic N -fractions

Data on organic N fractions measured during post kharif period are presented in tables. 6-8 and depicted in figs. 5 (a-c). Perusal of data in table.7 show that about 2/3rd of the total N were hydrolysable and about 1/3rd non hydrolysable. The total hydrolysable N (THN) varied from a lowest of 61.21% in straw incorporated treatment (T_7) to a highest of 78.64% in T_{10} where integration was done with green manure and P was applied as rock phosphate. Results show that organic sources maintained a higher proportion (75%) of THN followed by inorganic sources (69.67%) and their integration (68.43%). In the silicate slag amended treatment (T_{11}) the THN constituted 68.43% of total N. But in terms of absolute values (table.6) the THN was highest (1097 kg/ha) in T_{11} followed by T_{10} (1078 kg/ha) and the FYM amended treatment (T_5) (1020kg/ha. The unmanured control (T_{12}) registered lowest value (866 kg/ha) of THN which was significantly lower than that in T_5, T_{10} and T_{11}. Increased hydrolysable fraction and decreased non hydrolysable fraction due to application of FYM along with urea was also reported by Mohapatra *et. al.*, (1991). After three years of continuous application, the sources of nutrients were in the order of silicate slag + inorganics > organic sources > Integration > Inorganic sources. Among the organic sources used for integration, rice straw increased the non hydrolysable fraction NHN (561 kg/ha) to a great

extent. Smith *et. al.*, (1978) reported that addition of carbon sources such as sorghum stover along with fertilizer caused an increase in non hydrolysable-N status of soil. They also suggested that this fraction of organic N was less biodegradable and did not contribute to plant available N.

Among the hydrolysable fractions table.7 and fig 5.(a) unidentified hydrolysable N (UHN) constituted the highest (33.34-41.34%) fraction followed by the amino acid N (AAN) with a range of 27.97% to 35.30% and hydrolysable ammonia N (HAN) with a range of 16.34% to 24.49%. The aminosugar fraction (ASN) constituting only 3.34 to 13.79% formed the smallest. Rout (1998) and Mohapatra (1995) also reported similar ranges with respect to the above fractions. In terms of absolute value, the inorganic source with silicate slag amendment recorded highest levels of HAN (269kg/ha) and AAN (387 kg/ha) which were the easily mineralisable fractions of soil organic N (Rout, 1998).

Higher contents of HAN were also observed under integrated use of organics and inorganics particularly with FYM and green manuring. With sole application of organic sources the content remained low. The results indicated that continuous liming, addition of inorganic N or its integrated use with organics particularly with FYM or green manure increased HAN content of rice soil. Increase in HAN with application of N fertilizers has also been reported by Pathak and Sarkar (1991) and Rout (1998). However no significant differences were observed between various sources in influencing the HAN content. Similar observations were also made with amino acid N which is an important fraction of soil organic N. Although the silicate slag amended treatment maintained highest pool of AAN, it did not significantly differ from organic source or inorganic source or their integration.

On the other hand, amino sugar- N (ASN) which formed the smallest fraction showed a different pattern. Highest accumulation of

ASN (138 kg/ha) was observed with sole application of organics (T_9) followed by T_7 (100 kg/ha) where straw in corporation was done along with NPK fertilizer. Lowest value was recorded in unmanured control (38kg/ha). Although highest accumulation was observed with organics, the differences between organic and integration were not significant. Accumulation with inorganics was however significantly lower than that with organics. Application of micro and secondary nutrients had negative effect on ASN accumulation in soil.

Unidentified hydrolysable N (UHN) measured after harvest of kharif rice was found to be highest (436kg/ha) in T_{10} followed by 390 kg/ha in T_6. Both the treatments received green manuring + inorganic fertilizer application. This is in contrast to other fractions that always measured low in green manured treatment. However the differences were non significant when the treatments were grouped into organics, inorganics and their integration. As compared to unmanured control, the treated plots recorded higher values of UHN.

In terms of percentage, organic sources maintained lower proportion of HAN and higher proportion of ASN fig.5(c). A comparison of various organic sources used for integrated use depicted in fig.5(b) show that straw incorporation resulted in accumulation of higher proportion of AAS and lower proportion of HAN than FYM and green manure. In green manure treatment the proportion of AAN was lowest.

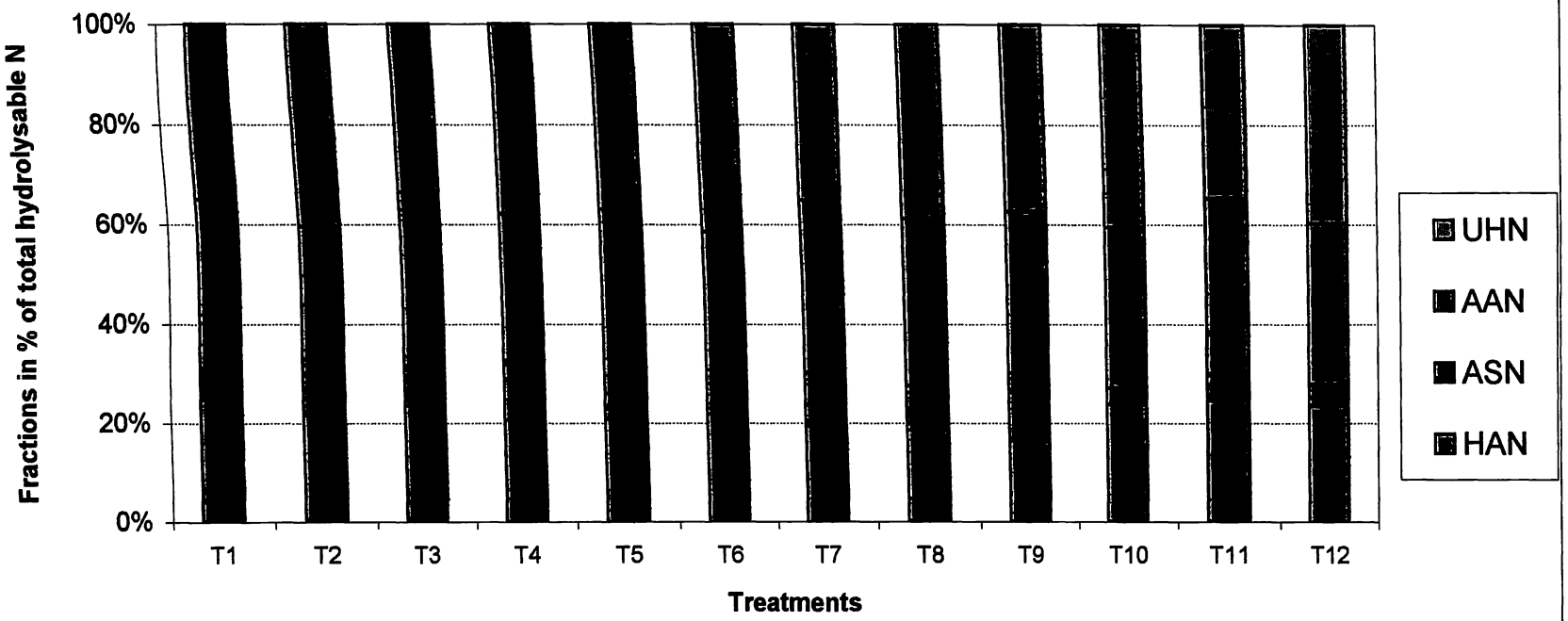
A close scrutiny of the correlation matrix (table.8) reveals that THN had significant positive correlation with AAN (r=0.81**) and UHN (r=0.66*) thus indicating a build up of UHN and AAN in such a soil with increase in THN. Very small correlation of THN with HAN (r=-0.20), ASN (r=-0.01) and NHN (r=-0.16) indicates very little change or no change in these fractions with increase in THN. The results also show significant positive correlation of total N with AAN (r=0.58*) and NHN (r=0.78**) and moderate correlation with THN (r=0.48). Thus increase in total N of soil is also associated with increase in AAN, NHN and THN.

Table 6: Effect of organic and /or inorganic sources of nutrients on soil organic-N fractions (Kg/ha) of soil measured during post kharif period (2000)

Treatment (kharif)	Total N	THN	HAN	ASN	AAN	UHN	NHN
T_1= Standard 100% NPK +S+Zn+B	1426	924	227	61	313	323	502
T_2 Standard(-S)	1371	963	207	65	303	388	408
T_3 Standard (-Zn)	1369	963	227	75	340	321	406
T_4 Standard (-B)	1395	943	197	78	315	356	451
T_5 FYM 5t/ha +NPK (adjusted)	1594	1020	211	91	342	376	573
T_6 GM+ standard N (adjusted)	1350	943	206	83	264	390	403
T_7 Straw Incorporation + Standard (-P)	1485	924	179	100	320	325	561
T_8 100% NPK	1475	964	178	86	326	372	512
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	1328	1001	164	138	326	374	326
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	1372	1078	256	36	350	436	292
T_{11} Silicate amendments +Standard(P as per soil test)	1606	1097	269	61	387	380	508
T_{12} Control fertilizer)	1316	866	203	38	281	344	448
Mean							
Inorganic sources.	1407	951	207	73	319	352	456
Organic sources.	1378	1001	164	138	326	374	326
Integration.	1450	991	213	78	319	382	457
Silcate slag + Inorganic sources	1606	1097	269	61	387	380	508
C.D.(0.05)	346.76	153.40	74.07	40.17	65.39	19.70	22.21
Treatments.	NS	NS	NS	31.17	NS	15.28	17.21
Inorganic Vs Organic.	NS	NS	NS	NS	NS	NS	17.57
Inorganic Vs Integration.	NS	NS	NS	NS	NS	9.36	NS
Organic Vs Integration.	131.92	58.35	28.19	NS	24.88	15.28	17.21
Inorganic Vs Inorganic+ silicate slag.							

In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Fig. 5(A): Cumulative effect of different organic and/or inorganic sources of nutrients on various organic N fractions of soil nitrogen



T_1 = Standard 100% NPK + S + Zn +B
T_2 = Standard (-S)
T_3 = Standard (-Zn)
T_4 = Standard (-B)
T_5 = FYM 5tha^{-1} + NPK (adjusted)
T_6 = GM + Standard (N adjusted)
T_7 = Straw incorporation + Standard (-P)
T_8 = Standard 100% NPK
T_9 = N through org. + P as RP + K as straw incorporation
T_{10} = GM + N (adj.) + P as RP + 150 % K + S + Zn + B
T_{11} = Silicate amend. + Standard (P as per soil test)
T_{12} = Control

Table-7: Effect of organic and/or inorganic sources of nutrients on Hydrolysable **organic-N** fractions(%)measured during post kharif period (2000).

Treatment (kharif)	% of total N		% of Total hydrolysable-N			
	THN	NHN	HAN	ASN	AAN	UHN
T_1 Standard= 100% NPK +S+Zn+B	64.79	35.21	24.61	6.60	33.85	34.94
T_2 Standard(-S)	70.18	29.75	21.47	6.75	31.45	40.33
T_3 Standard (-Zn)	70.31	29.66	23.56	7.79	35.30	33.34
T_4 Standard (-B)	67.62	32.33	20.59	8.27	33.40	37.73
T_5 FYM 5t/ha +NPK (adjusted)	64.00	35.95	20.69	8.92	33.50	36.89
T_6 GM+ standard N (adjusted)	69.85	29.84	21.89	8.80	27.97	41.34
T_7 Straw Incorporation + Standard (-P)	61.21	37.77	19.34	10.82	34.66	35.17
T_8 100% NPK	75.47	24.46	18.56	8.94	33.87	38.62
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	75.40	24.55	16.34	13.79	32.52	37.35
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	78.64	21.30	23.77	3.34	32.43	40.46
T_{11} Silicate amendments +Standard(P as per soil test)	68.33	31.63	24.49	5.56	35.30	34.65
T_{12} Control (No fertilizer)	65.88	34.07	23.47	4.38	32.47	39.67

In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Fig. 5(B): Cumulative effect of various organic sources used for integration on hydrolysable N fractions of soil during post kharif period

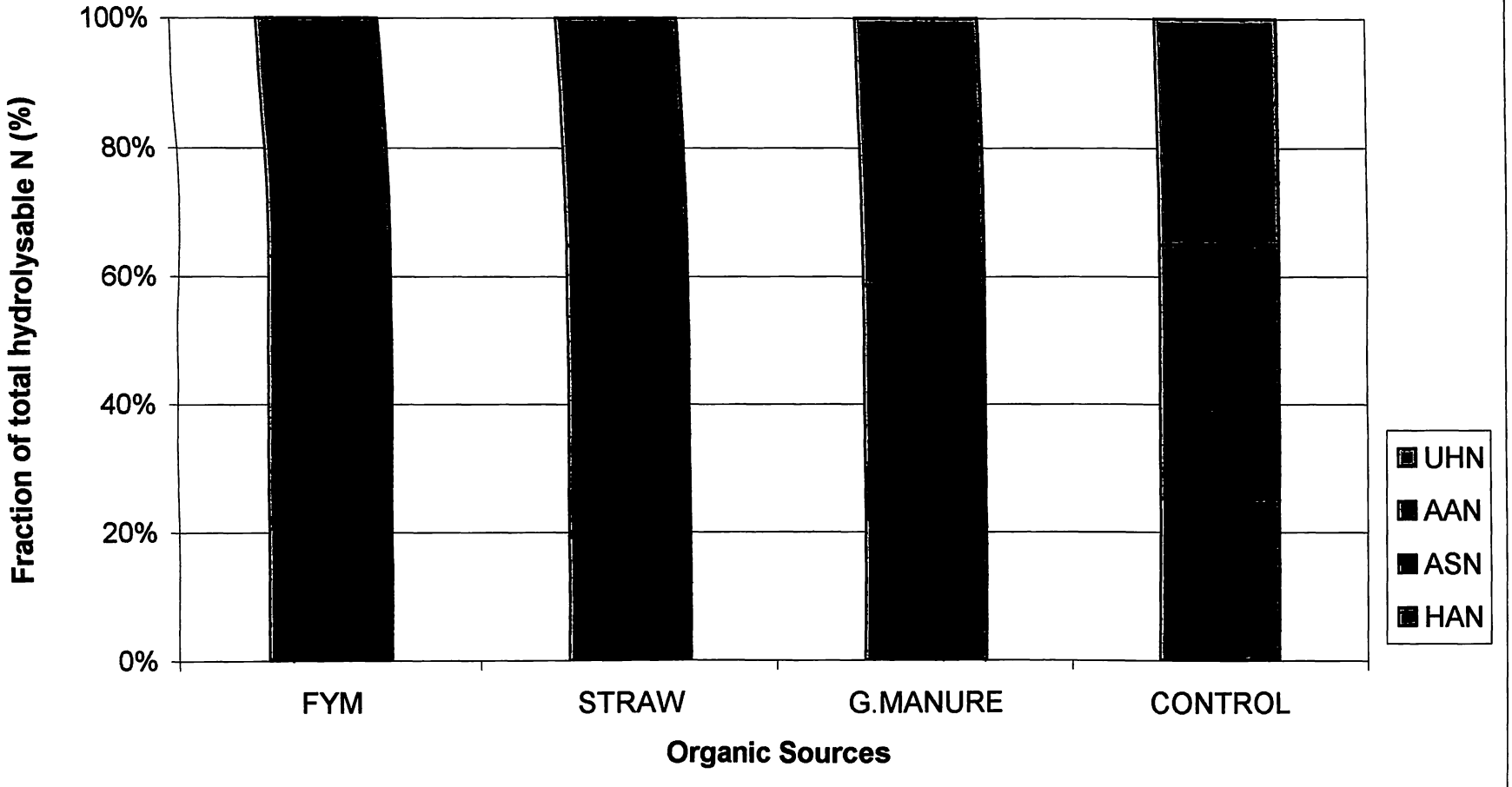


Fig. 5(C): Cumulative effect of organic sources, inorganic sources and their effect on soil hydrolysable organic N fractions in soil during post kharif period

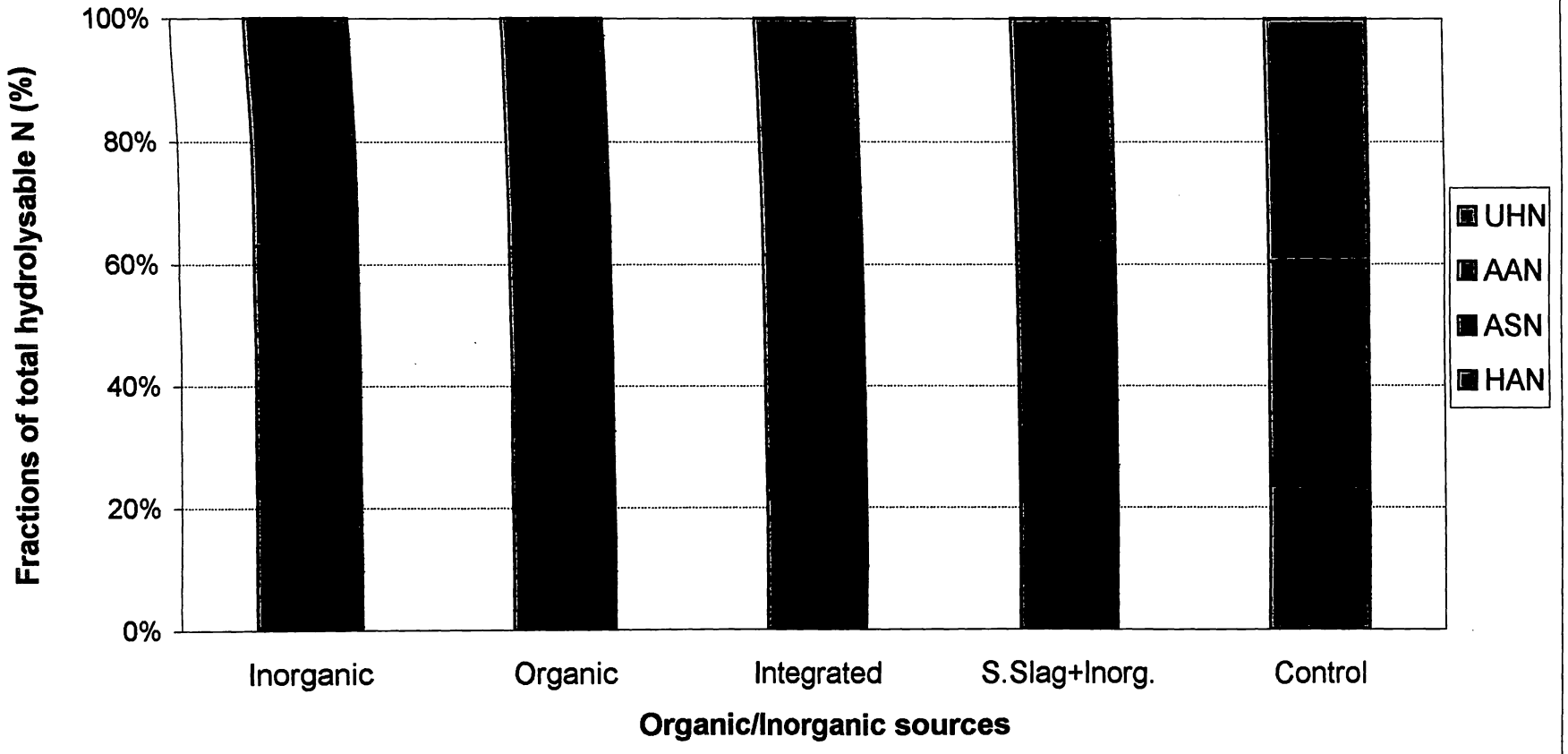


Table 8:Relationship between various fractions of soil N as expressed in terms of coefficient of correlation (r)

	Total N	THN	HAN	ASN	AAN	UHN	NHN
Total N	1	0.485	0.077	0.045	0.588*	-0.036	0.783**
THN		1	-0.204	-0.012	0.810**	0.657*	-0.162
HAN			1	-0.206	-0.063	-0.375	0.238
ASN				1	-0.011	-0.180	0.012
AAN					1	0.162	0.093
UHN						1	-0.512
NHN							1

THN – Total hydrolysable Nitrogen , HAN – Hydrolysable ammonium Nitrogen.
ASN – Aruino Sugar Nitrogen , AAN – Amino Acid Nitrogen
NHN – Non Hydrolysable Nitrogen , UHN – Unidentified hydrolysable Nitrogen.

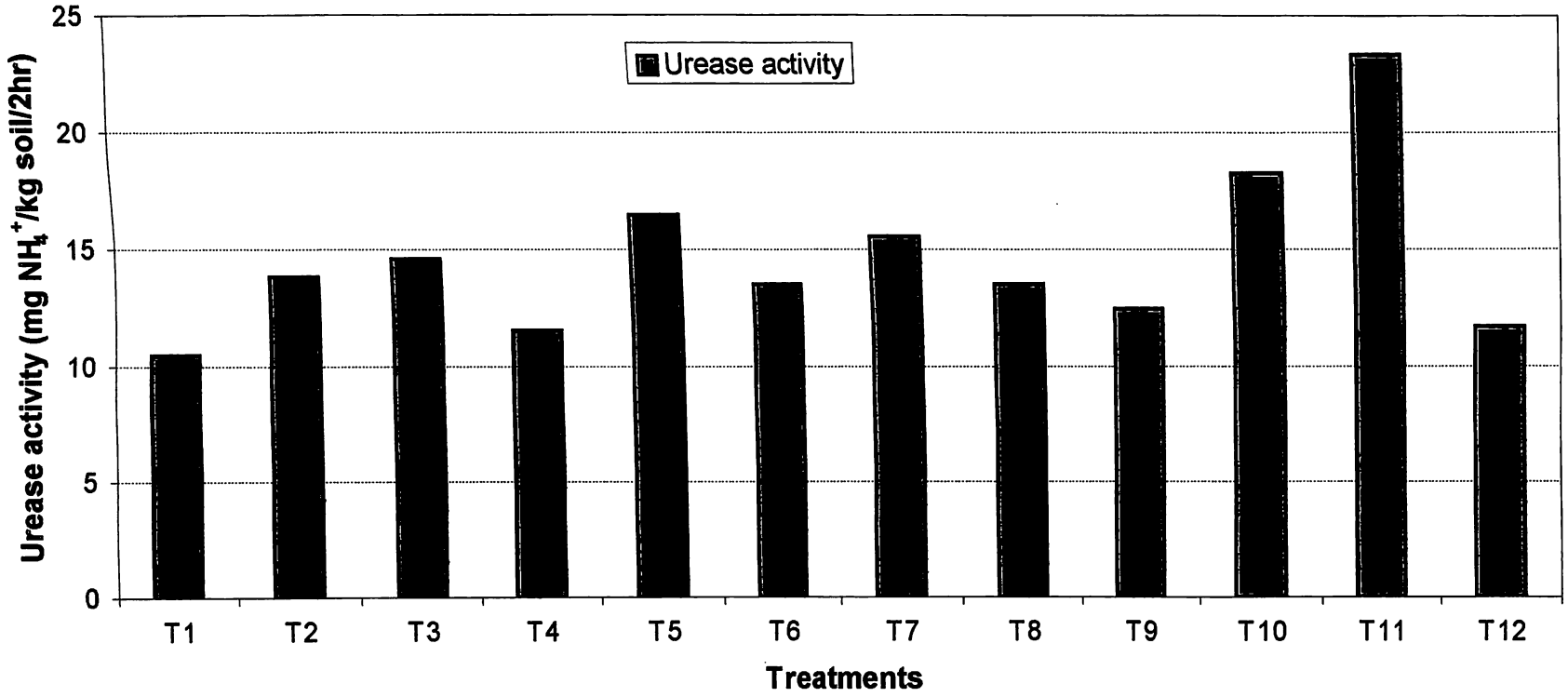
In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Table- 9: Effect of organic and/or inorganic sources of nutrients on urease and amidase activities measured on soils of post kharif (2000) period .

Treatment (kharif)	Enzyme activities (mg NH_4^+ - N/ kg soil/2h)	
	Urease (mg NH_4^+ -N/kg soil/2h)	Amidase (mg NH_4^+ -N/kg soil/2h)
T_1 Standard= 100% NPK +S+Zn+B	10.50	9.77
T_2 Standard(-S)	13.87	6.84
T_3 Standard (-Zn)	14.68	6.84
T_4 Standard (-B)	11.51	7.81
T_5 FYM 5t/ha +NPK (adjusted)	16.50	11.72
T_6 GM+ standard N (adjusted)	13.52	9.77
T_7 Straw Incorporation + Standard (-P)	15.59	7.81
T_8 100% NPK	13.52	8.79
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	12.47	10.75
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	18.27	9.77
T_{11} Silicate amendments +Standard(P as per soil test)	23.34	12.69
T_{12} Control (No fertilizer)	11.67	4.89

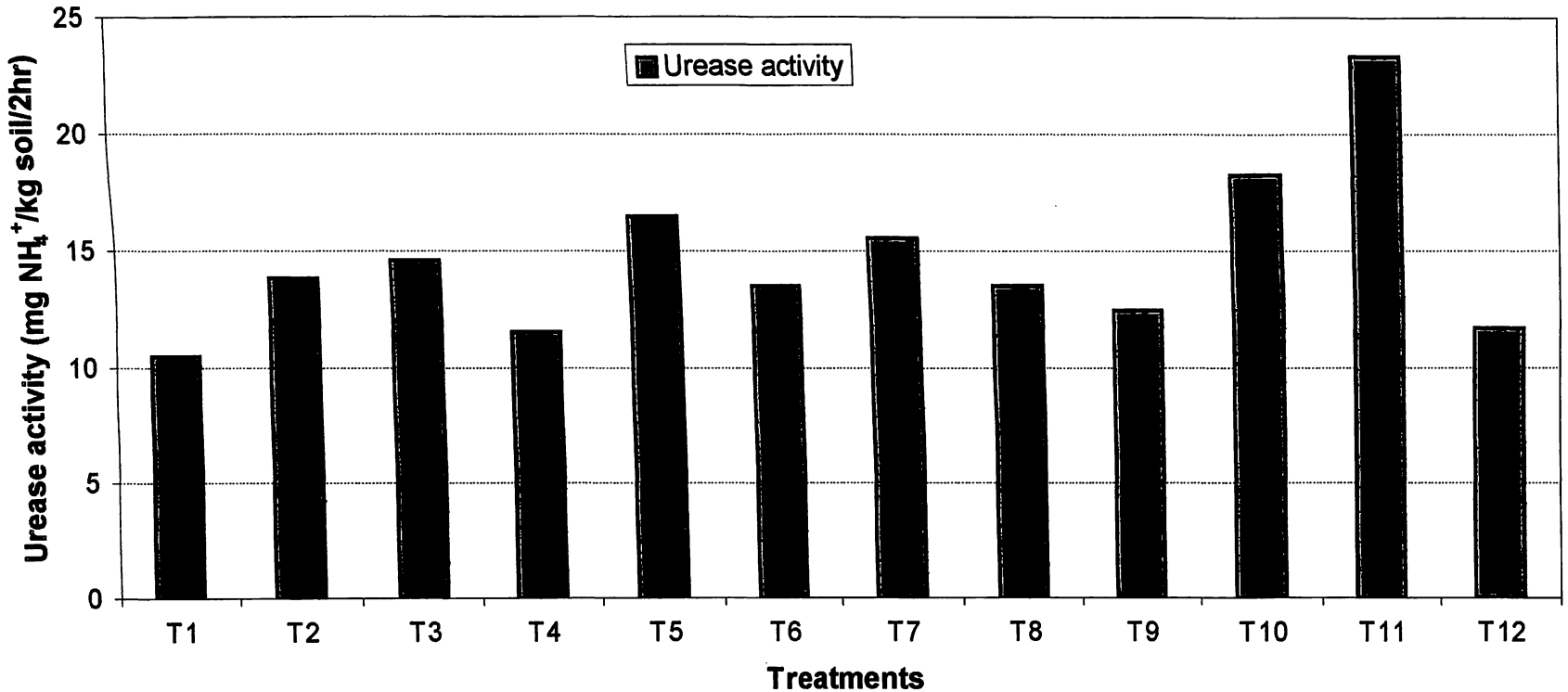
In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Fig. 6(A):Cumulative effect of organic and/or inorganic sources of nutrients on Urease activity in soil as measured during post kharif period



T_1 = Standard 100% NPK + S + Zn +B
T_2 = Standard (-S)
T_3 = Standard (-Zn)
T_4 = Standard (-B)
T_5 = FYM 5tha^{-1} + NPK (adjusted)
T_6 = GM + Standard (N adjusted)
T_7 = Straw incorporation + Standard (-P)
T_8 = Standard 100% NPK
T_9 = N through org. + P as RP + K as straw incorporation
T_{10} = GM + N (adj.) + P as RP + 150 % K + S + Zn + B
T_{11} = Silicate amend. + Standard (P as per soil test)
T_{12} = Control

Fig. 6(A):Cumulative effect of organic and/or inorganic sources of nutrients on Urease activity in soil as measured during post kharif period



T_1 = Standard 100% NPK + S + Zn +B
T_2 = Standard (-S)
T_3 = Standard (-Zn)
T_4 = Standard (-B)
T_5 = FYM 5tha^{-1} + NPK (adjusted)
T_6 = GM + Standard (N adjusted)
T_7 = Straw incorporation + Standard (-P)
T_8 = Standard 100% NPK
T_9 = N through org. + P as RP + K as straw incorporation
T_{10} = GM + N (adj.) + P as RP + 150 % K + S + Zn + B
T_{11} = Silicate amend. + Standard (P as per soil test)
T_{12} = Control

Fig. 6(B): Cumulative effect of organic and/or inorganic sources on Urease activity in soil as measured during post kharif period

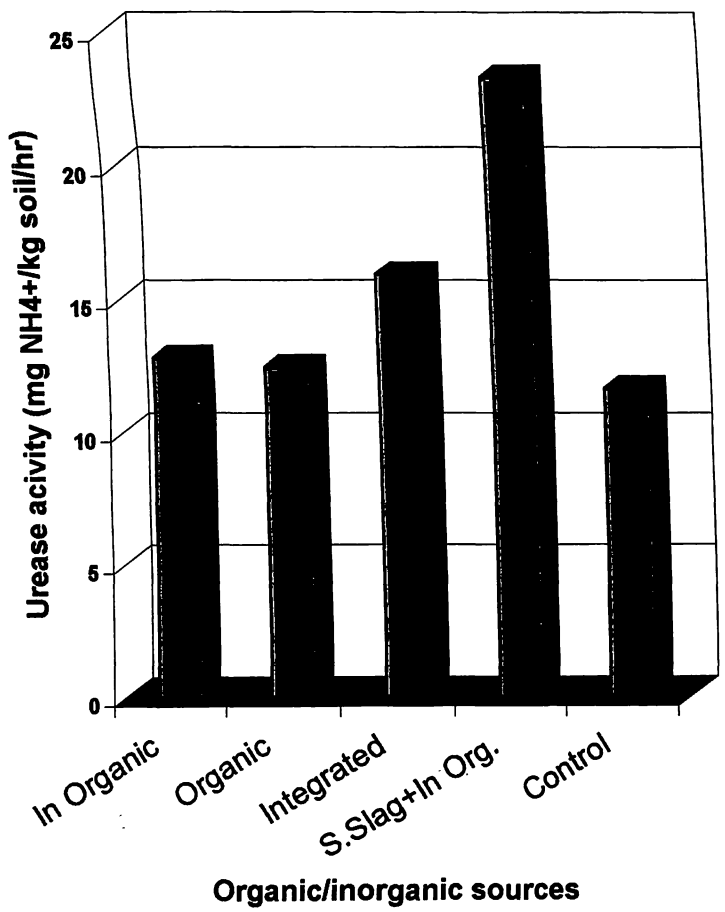
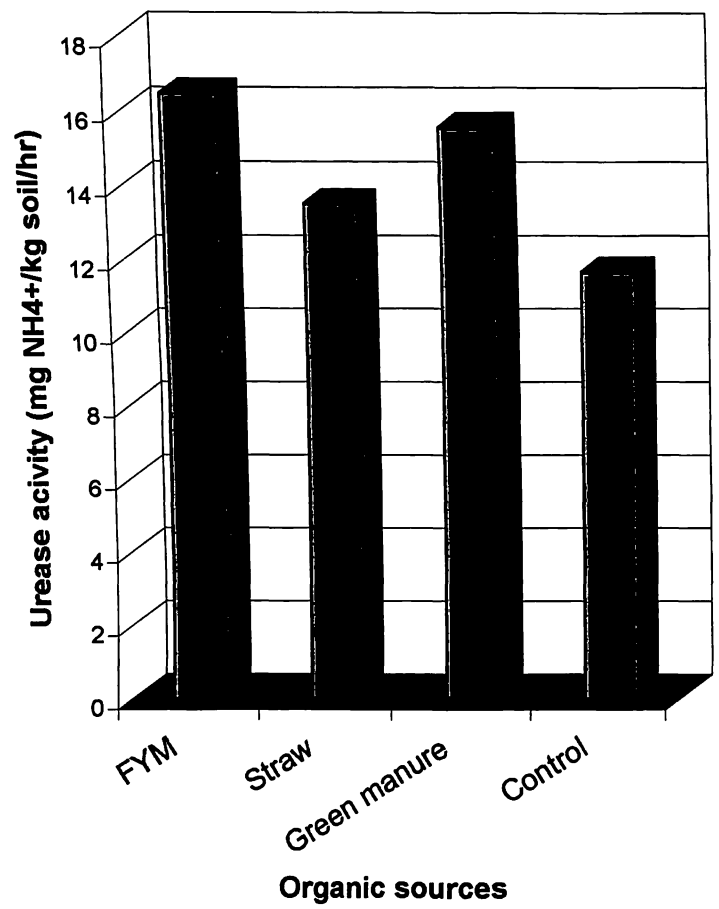


Fig. 6(C) : Cumulative effect of various organic sources used for integration on Urease activity in soil as measured during post kharif period



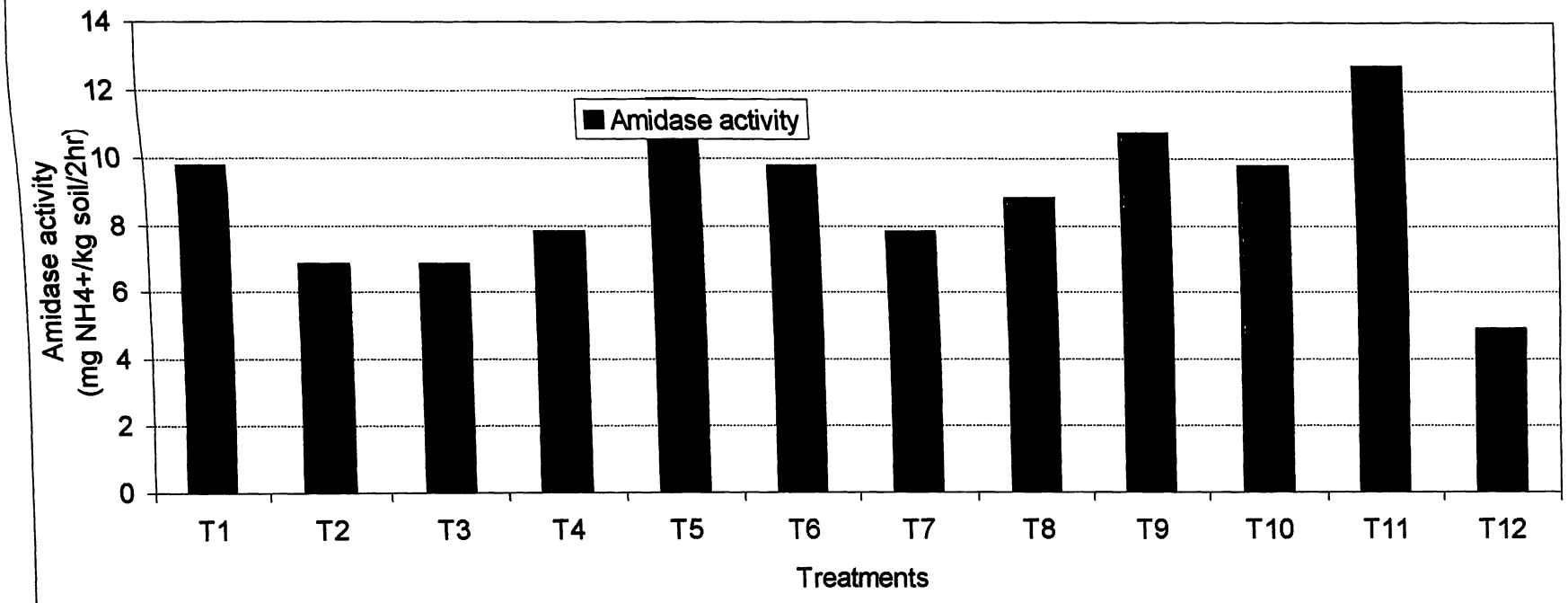
4.1.6 Urease Activity

Perusal of data on urease activity of soil measured after harvest of kharif rice-2000 presented in table.9 and depicted in fig.6 (a-c) show that the enzyme activity varied from a lowest of 10.50 mg NH_4^+N/kg soil/2h in T_1 that received 100% NPK in inorganic form along with S, Zn and B to a highest of 23.34 mg NH_4^+N/kg soil/2hr in T_{11} (Silicate slag + NPK) which was 100% higher than the control. The values were lower than the range of 22 to 305 mg NH_4^++N/kg soil/2hr reported by Dick *et. al.*, (1996). T_{10} that received N in both green manure and inorganic form, P as rock phosphate and S registered the second highest (18.27 mg NH_4^+N/kg soil/2hr). Higher values of urease activity in T_{10} and T_{11} might be due to the liming effect and addition of S that stimulated higher bacterial and fungal population. Exclusion of S, Zn and B registered an increase in urease activity with highest being observed due to Zn exclusion (T_3). This might be due to higher fungal activity in absence or low concentration of Zn as Zn had antifungal effect (Rout, 2001). Among the three sources of organic manures, FYM and straw registered higher urease activity than green manure (fig.6-b). Integrated use of organics and inorganic fertilizer resulted in higher urease enzyme activity than their sole applications. This agrees with the findings of Chendrayan *et. al.*, 1980 and Liu *et. al.*, 1990).

4.1.7 Amidase Activity :

Data on amidase activity recorded in table.9 and depicted in (fig.7(a-c) show that the enzyme activity of soil measured after harvest of kharif rice ranged from 4.89 mg NH_4^+-N /kg soil /2 hr in unmanured control (T_{12}) to a highest of 12.69 mg NH_4^+-N /kg soil /2hr in (T_{11}) that received silicate slag amendment @ 100 kg SiO_2 /ha. Treatment (T_9) that received N entirely from organic source and T_5 that received FYM along with NPK also measured higher values (10.75 and 11.72 mg NH_4^+/Kg/2hr respectively) of amidase activity. This range is much below the range of 22 to 175 mg NH_4^+N/kg soil/2hr reported by Dick *et.*

Fig. 7(A): Cumulative effect of organic and/or inorganic sources of nutrients on Amidase activity in soil as measured during post kharif period



T_1 = Standard 100% NPK + S + Zn +B
T_2 = Standard (-S)
T_3 = Standard (-Zn)
T_4 = Standard (-B)
T_5 = FYM 5tha^{-1} + NPK (adjusted)
T_6 = GM + Standard (N adjusted)
T_7 = Straw incorporation + Standard (-P)
T_8 = Standard 100% NPK
T_9 = N through org. + P as RP + K as straw incorporation
T_{10} = GM + N (adj.) + P as RP + 150 % K + S + Zn + B
T_{11} = Silicate amend. + Standard (P as per soil test)
T_{12} = Control

Fig. 7(B): Cumulative effect of organic and/or inorganic sources of nutrient on amidase activity in soil as measured during post kharif period

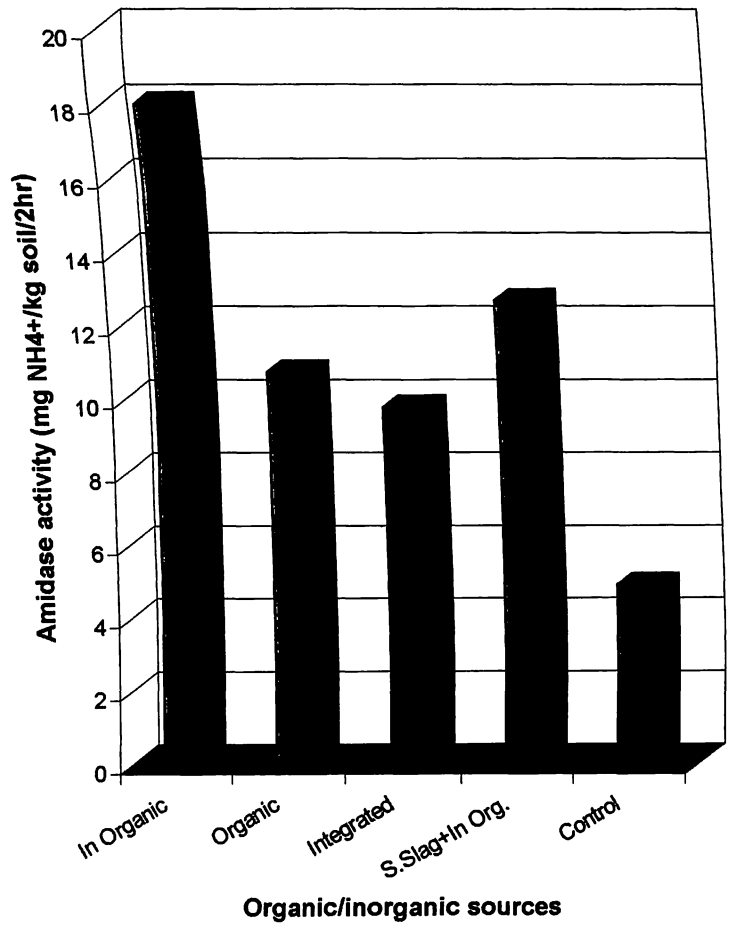
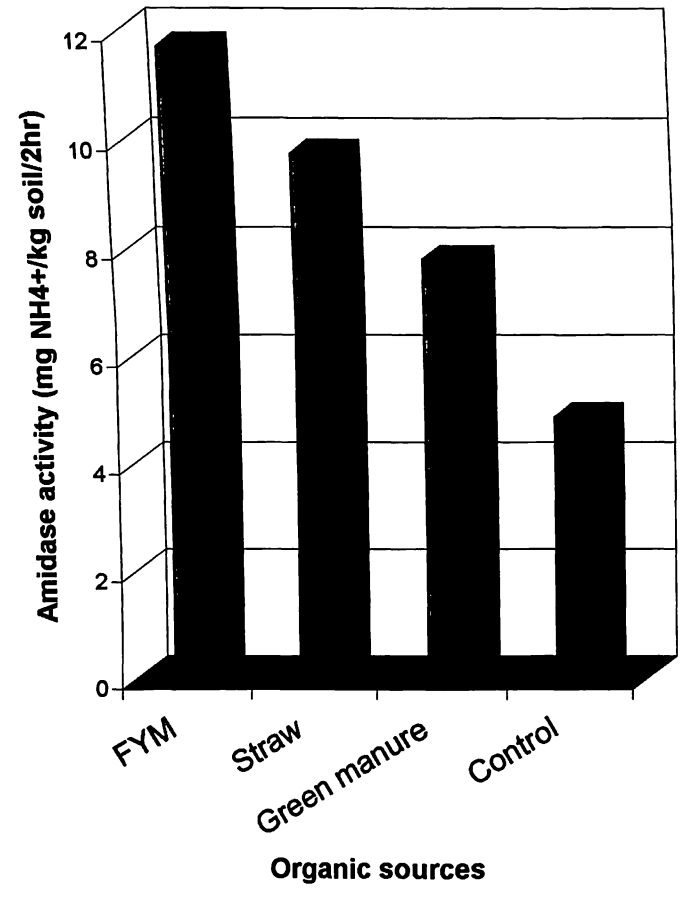


Fig. 7(C): Cumulative effect of various organic sources of nutrients used for integration on Amidase activity in soil as measured during post kharif period



al., (1996) in USA. In contrast to urease activity, amidase activity was low with straw incorporation . Application of inorganic fertilizer nutrients either with or without micro and secondary elements also registered lower activity than either organic source or their integrated use fig.7(c).

4.2 Effect of continuous fertilization and manuring on drymatter and grain yield.

Results recorded on the above ground biomass yield are presented in table.10 and depicted in fig.8. Both dry matter and grain yield are good indicators of soil fertility. Evaluation of various nutrient management practices in maintaining soil fertility can thus be made on the basis of both dry matter and grain yield.

4.2.1 Dry matter yield.

A perusal of the data on dry matter yield presented in table. 10 shows that in both rabi-1999-2000 and kharif-2000 highest dry matter yield was obtained in T_{11}. In rabi dry matter yield in T_{11} was 73.38 q/ha as compared to only 24.96 q/ha in unmanured control. The yield in T_{11} was significantly higher than organic and/or inorganic sources indicating the significant positive effect of liming and Si on dry matter yield. The micro and secondary nutrients had no effect on dry matter yield Integrated use of inorganics and organics produced higher dry matter than their sole applications. Among the three organic sources used for integration, FYM proved to the better than green manure and straw.

Similar results were also obtained in khairf-2000.However, in kharif the inorganics accumulated more dry matter their integration with organics. The sources in the order of merit were : Inorganics + silicate slag > Inorganics > Integration>organics.But the differences were not significance.

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Table- 10:Effect of organic and/or inorganic sources of nutrients on dry matter and grain yield of the rice in both the seasons.

Treatment (kharif)	Yield (q/ha)			
	Rabi 1999-2000 (Cv. Lalat)		Kharif 2000 (Cv. Swarna)	
	Dry matter	Grain yield	Dry matter	Grain yield
T_1Standard =100% NPK +S+Zn+B	58.43	28.18	60.65	25.9
T_2 Standard(-S)	59.88	27.70	56.65	23.65
T_3 Standard (-Zn)	58.40	27.85	60.33	24.98
T_4 Standard (-B)	57.85	27.35	55.85	23.85
T_5 FYM 5t/ha +NPK (adjusted)	63.66	29.28	50.50	22.00
T_6 GM+ standard N (adjusted)	57.33	27.25	50.45	22.30
T_7 Straw Incorporation + Standard (-P)	58.65	27.85	49.10	21.80
T_8 100% NPK	55.86	26.68	56.18	23.75
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	53.96	25.18	42.83	18.80
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	69.63	32.33	64.66	28.38
T_{11} Silicate amendments +Standard(P as per soil test)	73.38	34.58	73.26	32.93
T_{12} Control fertilizer	24.96	12.83	33.55	14.45
Mean				
Inorganic sources.	58.08	27.55	57.91	24.43
Organic sources.	53.96	25.18	47.50	18.80
Integration.	62.24	29.18	53.94	23.62
Silcate slag + Inorganic sources	73.38	34.58	73.75	32.93
C.D.(0.05)				
Treatments.	6.55	3.01	8.46	3.45
Inorganic Vs Organic.	NS	NS	6.46	2.29
Inorganic Vs Integration.	5.71	NS	NS	2.33
Organic Vs Integration.	3.1	NS	NS	NS
Inorganic Vs Inorganic+ silicate slag	2.77	2.34	6.64	1.12R

In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Fig. 8: Cumulative effect of organic and/or inorganic sources of nutrients on grain yield

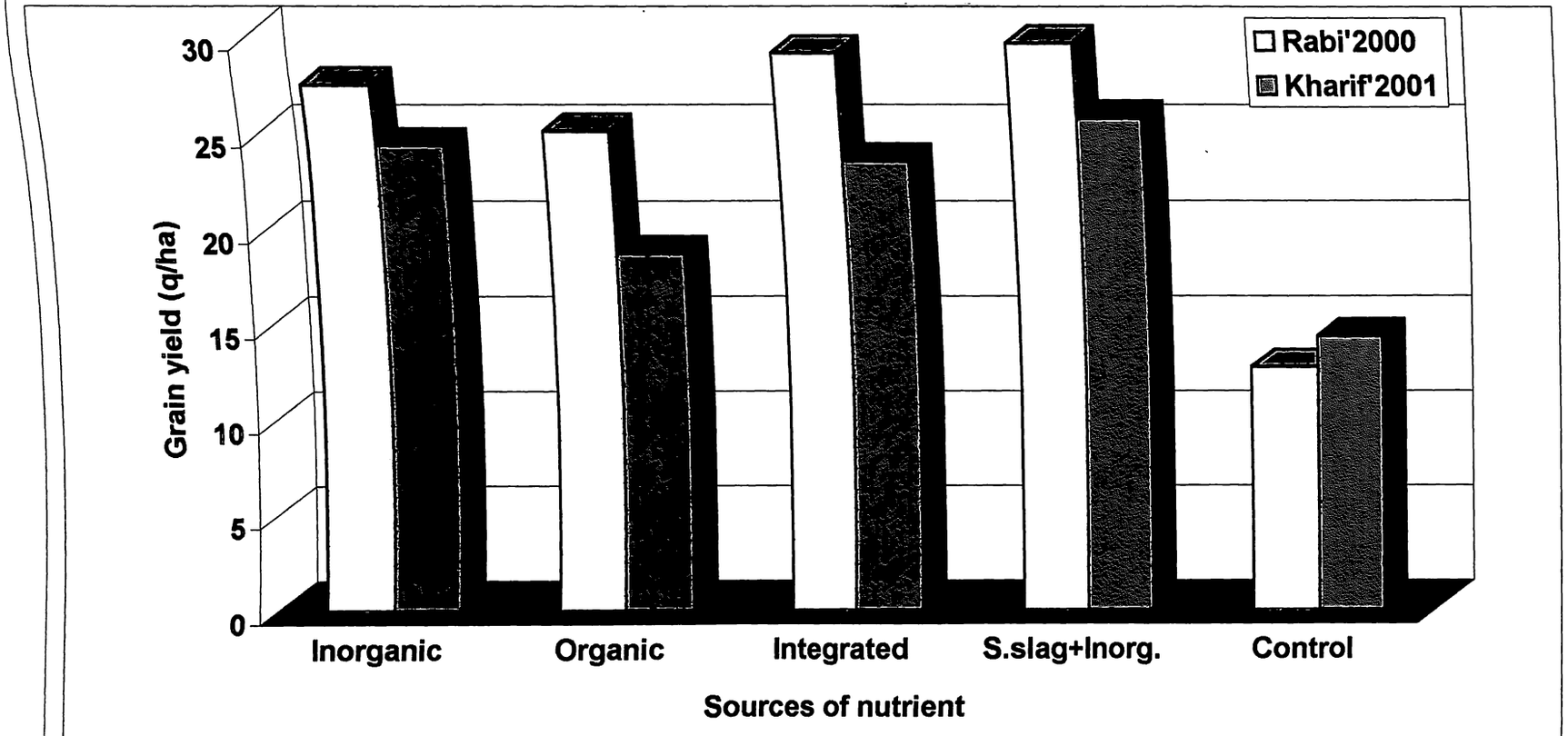
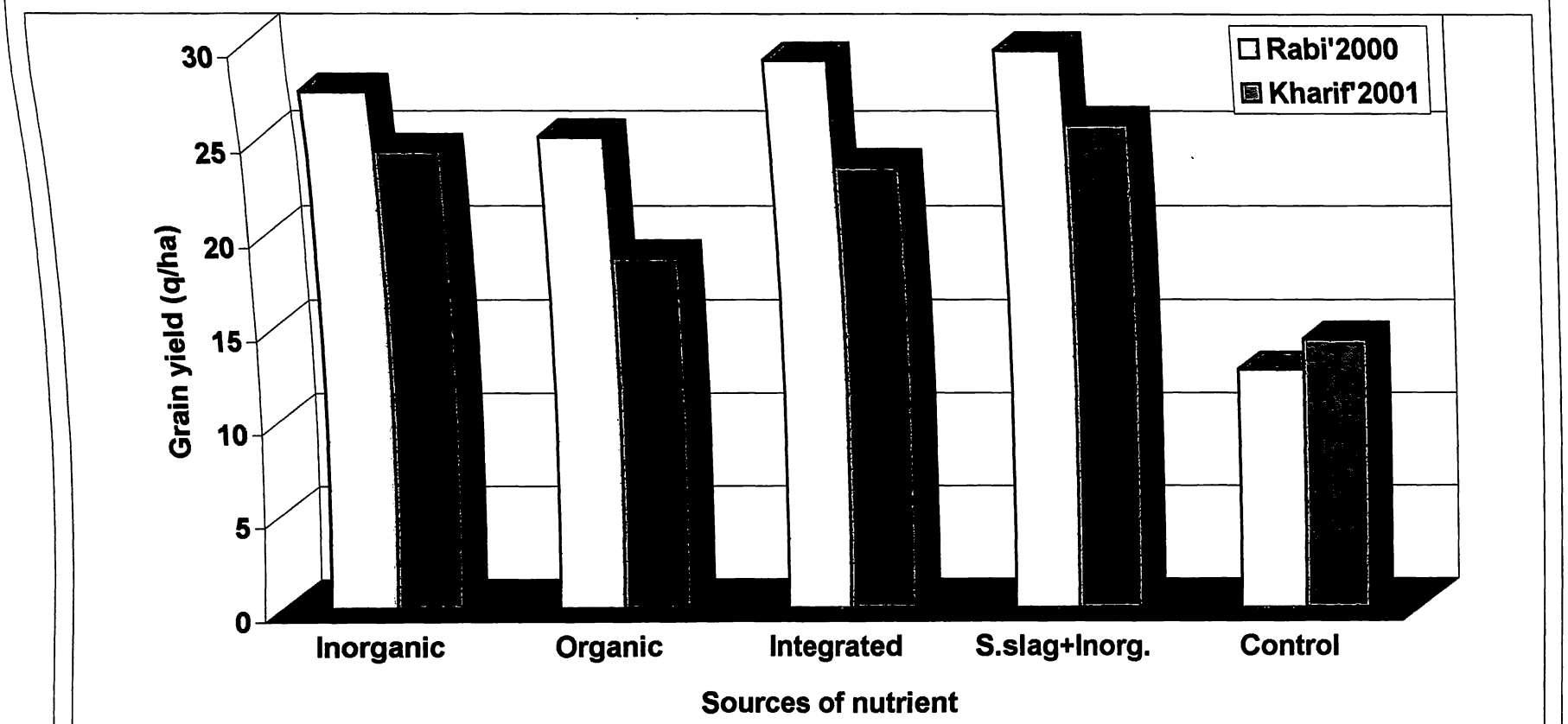


Fig. 8: Cumulative effect of organic and/or inorganic sources of nutrients on grain yield



4.2.2 Grain Yield

Results on grain yield presented in table.10 and depicted in fig.8 show almost similar trend in both rabi-1999-2000 and kharif .2000 with little difference.

In rabi (1999-2000), highest grain yield of 34.58 q/ha was obtained with silicate slag amended plot (T_{11})which was169.52% more than the control (12.83 q/ha), 25.51% more than the inorganic source, 37.33% more than the organic source and 18.50 % more than the their integration . This clearly demonstrates the effect of liming and Si on grain yield . Both organic and inorganic sources were at par and also did not differ significantly from their integration in influencing the grain yield . How ever , the integrated source produced higher yield than the inorganic and organic sources. This results did not agree with the findings of Behera (2000) who reported higher yield with inorganic sources than the integrated sources.

During kharif (2000), highest grain yield of 32.93q/ha was obtained inT_{11} which was 127.88 % higher than the unmanured control, 34.79%more than the inorganic source, 42.90% more than the organic source and 39.41% more than their integration. In contrast to the rabi yield , the yield in kharif with inorganic source was higher than that with the integrated use. However, unlike the previous year's result reported by Behera,2000 the difference was not significant. This result shows that with continuous cropping the increased yield with inorganic source over integration gradually narrowed down and the accrued positive effect of integration was expressed earlier in rabi than in kharif and the yield with integration was higher than the than the inorganic source . The differences between organic vs inorganic and organic vs integration were higher and significant. Substitution of N entirely through organics during kharif and partial substitution in rabi in T_9 could not produce higher yield indicating N availability is a inorganics

with major constraint of increasing rice yield in both the seasons. In both the seasons integration of organic sources viz, FYM, green manure and straw did not differ significantly in their influence on grain yield. Similarly micro (Zn,B) secondary (5) nutrients also did not make any difference in the grain yield of both the seasons. The trend in yield was, $T_{11} > T_{10} > T_5 > T_1 > T_7 = T_3 > T_2 > T_4 > T_6 > T_8 > T_9 > T_{12}$ in rabi.1999-2000 and $T_{11} > T_{10} > T_1 > T_3 > T_4 > T_8 > T_2 > T_6 > T_5 > T_7 > T_9 > T_{12}$ in kharif.2000.

4.3 Effect of continuous fertilization and manuring on N-uptake.

Data pertaining to N uptake in both rabi and kharif seasons are presented in table.11 and depicted in fig.9.

In both the seasons highest uptake of N was obtained in T_{11} (silicate slag + NPK) and lowest in control in both straw and grains. In rabi, T_{11} with 62.00 kg total N uptake /ha accumulated 235% more than control (18.48 kg N/ha), 26.95% more than the inorganic source (48.89 kg/ha), 41.48% more than organic source (43.82 kg N/ha) and 20.48% more than their integration (51.46 kg N/ha). Application of S,Zn, and B was found to have no effect. Among the manure plots N accumulation was lowest (41.36 kg/ha) in T_7 where integration was done with straw incorporation, where as FYM amended treatment accumulated 57.83 kg N/ha. N accumulation in straw and grain followed the same pattern.

The influence of various treatments on total N uptake was in the order of $T_{11} > T_5 > T_{10} > T_6 > T_4 > T_2 > T_3 > T_8 > T_1 > T_9 > T_7 > T_{12}$. When the treatments were grouped the order was: Inorganics+Silicate slag >integration >inorganics>organics.

In kharif-2000 ,T_{11} (64.99 kg N uptake/ha) registered 167% higher N uptake than control (24.33 kg N/ha) and 29.49% higher than inorganics (50.19 kg N/ha), 46.17% higher than organics (44.46 kg N/ha) and 34.52% more than their integration (48.31 kg N/ha).

Table-11: Effect of organic and/or inorganic sources of nutrients on N – uptake by rice in both kharif and rabi seasons.

Treatment (kharif)	N uptake (kg/ha)					
	Rabi 1999-2000 (Cv. Lalat)			Kharif 2000 (Cv. Swarna)		
	Straw	Grain	Total	Straw	Grain	Total
T_1Standard =100% NPK +S+Zn+B	16.35	27.17	47.93	19. 18.69	29.43	48.95
T_2 Standard(-S)	18.65	30.01	48.66	52	27.79	46.48
T_3 Standard (-Zn)	15.66	32.62	48.28	25.88	28.96	54.84
T_4 Standard (-B)	18.58	32.59	51.17	18.90	33.95	52.85
T_5 FYM 5t/ha +NPK (adjusted)	19.83	38.00	57.83	18.72	29.13	47.85
T_6 GM+ standard N (adjusted)	15.25	35.22	50.47	16.30	27.74	44.04
T_7 Straw Incorporation + Standard (-P)	13.90	27.46	41.36	13.73	29.75	43.48
T_8 100% NPK	16.26	31.92	48.18	17.21	30.63	47.84
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	16.98	26.84	43.82	15.48	28.98	44.46
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	22.86	33.38	56.24	23.78	34.09	57.86
T_{11} Silicate amendments +Standard(P as per soil test)	21.91	40.09	62.00	26.62	38.37	64.99
T_{12} Control fertilizer	6.98	11.50	18.48	9.90	14.33	24.33
mean						
Inorganic sources.	17.50	30.86	48.84	20.04	20.03	50.18
Organic sources.	16.98	26.84	43.82	15.48	28.98	44.46
Integration.	17.96	33.52	51.46	18.13	30.18	48.31
Silcate slag + Inorganic sources	21.91	40.09	62.00	26.62	38.37	64.99
C.D.(0.05)						
Treatments.	3.40	7.40	10.88	4.90	6.89	10.05
Inorganic Vs Organic.	NS	NS	NS	3.74	NS	NS
Inorganic Vs Integration.	NS	5.86	NS	NS	NS	NS
Organic Vs Integration.	NS	NS	NS	NS	NS	NS
Inorganic Vs Inorganic+ silicate slag	1.44	3.15	NS	2.08	2.92	NS

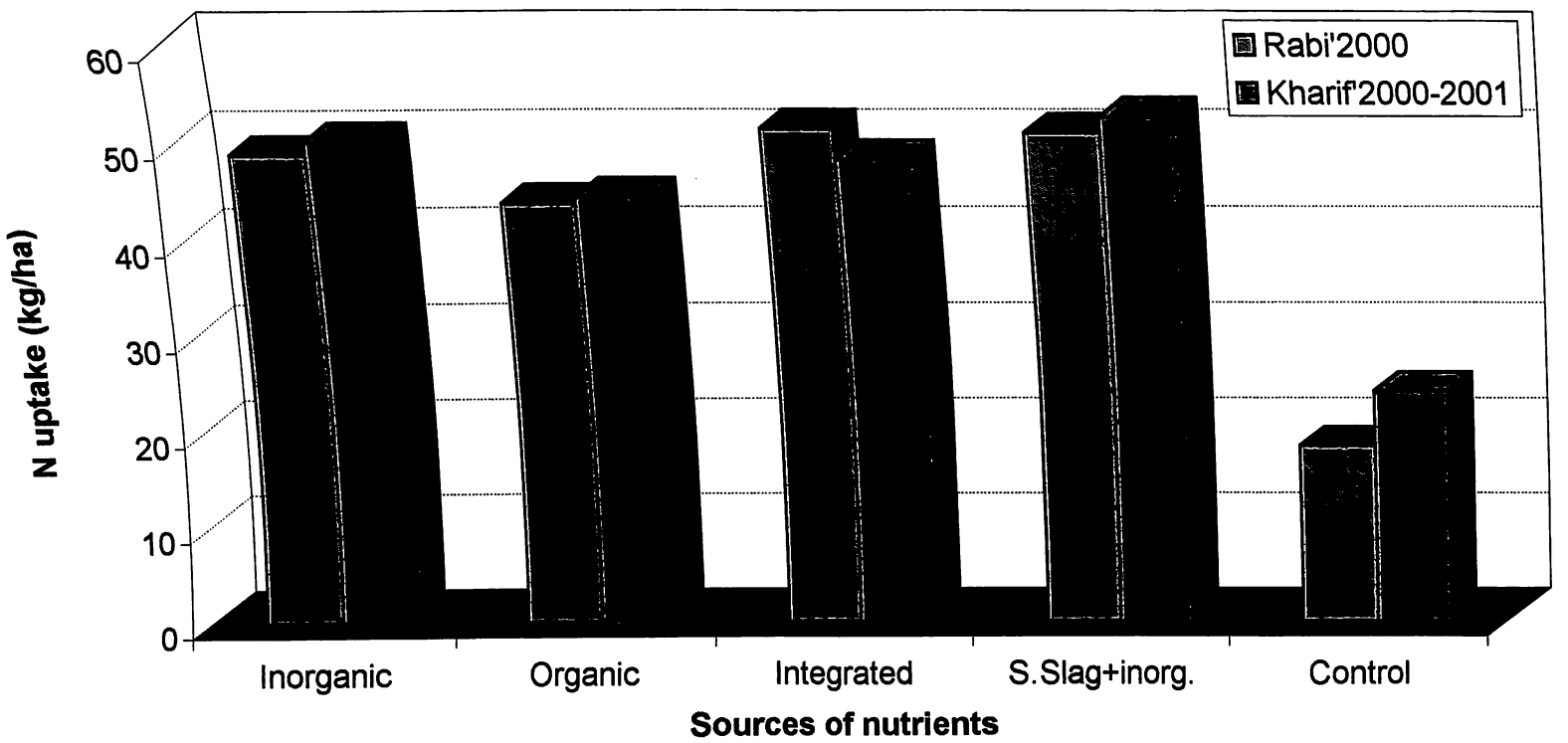
In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Table-11: Effect of organic and/or inorganic sources of nutrients on N – uptake by rice in both kharif and rabi seasons.

Treatment (kharif)	N uptake (kg/ha)					
	Rabi 1999-2000 (Cv. Lalat)			Kharif 2000 (Cv. Swarna)		
	Straw	Grain	Total	Straw	Grain	Total
T_1Standard =100% NPK +S+Zn+B	16.35	27.17	47.93	19. 18.69	29.43	48.95
T_2 Standard(-S)	18.65	30.01	48.66	52	27.79	46.48
T_3 Standard (-Zn)	15.66	32.62	48.28	25.88	28.96	54.84
T_4 Standard (-B)	18.58	32.59	51.17	18.90	33.95	52.85
T_5 FYM 5t/ha +NPK (adjusted)	19.83	38.00	57.83	18.72	29.13	47.85
T_6 GM+ standard N (adjusted)	15.25	35.22	50.47	16.30	27.74	44.04
T_7 Straw Incorporation + Standard (-P)	13.90	27.46	41.36	13.73	29.75	43.48
T_8 100% NPK	16.26	31.92	48.18	17.21	30.63	47.84
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	16.98	26.84	43.82	15.48	28.98	44.46
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	22.86	33.38	56.24	23.78	34.09	57.86
T_{11} Silicate amendments +Standard(P as per soil test)	21.91	40.09	62.00	26.62	38.37	64.99
T_{12} Control fertilizer	6.98	11.50	18.48	9.90	14.33	24.33
mean						
Inorganic sources.	17.50	30.86	48.84	20.04	20.03	50.18
Organic sources.	16.98	26.84	43.82	15.48	28.98	44.46
Integration.	17.96	33.52	51.46	18.13	30.18	48.31
Silcate slag + Inorganic sources	21.91	40.09	62.00	26.62	38.37	64.99
C.D.(0.05)						
Treatments.	3.40	7.40	10.88	4.90	6.89	10.05
Inorganic Vs Organic.	NS	NS	NS	3.74	NS	NS
Inorganic Vs Integration.	NS	5.86	NS	NS	NS	NS
Organic Vs Integration.	NS	NS	NS	NS	NS	NS
Inorganic Vs Inorganic+ silicate slag	1.44	3.15	NS	2.08	2.92	NS

In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Fig. 9: Cumulative effect of organic and/or inorganic sources of nutrients on N uptake



However, all the manured plots were at par. Like rabi season lowest uptake (43.48 kg N/ha) was also recorded in T_7 which might be due to increase in less biodegradable organic N fractions due to addition of straw. Smith (1978) reported that addition of straw along with fertilizer caused an increase in NHN status of soil and suggested that this fraction of organic N was less biodegradable and did not contribute to plant N.

In kharif, the order of the treatments in relation to N- uptake was slightly different from that in rabi. The order was, T11 > T10 > T3 > T4 > T1 > T5 > T8 > T2 > T9 > T6 > T7 > T12. When the treatments were grouped the groups were in the order of Inorganics +Silicate slag > Inorganics > Integration > Organics which was different from that in rabi.

4.4 Effect of continuous fertilization and manuring on N mineralisation potential and Nitrogen supplying capacity of soil.

Approximate mineralisable potential (N_O) values were calculated from the results of the incubation experiment conducted in the laboratory and the data pertaining to mineralisation potential (N_O) values measured in post kharif soil were presented in table.12.

The results showed that mineralisation potential values varied from a minimum of 58.59 mg N/kg soil in unmanured control to a highest of 75.09 mg N/kg in T_6 that received green manure along with inorganic fertilizers. Among the manured plots lowest mineralisation potential was (64.10 mg N/kg soil) recorded in organically manured (T_9). Integration of organic and inorganic sources recorded higher values of mineralisation potential than either organically manured plots or inorganically manured plots. After grouping the treatments into 4 groups viz; organics (T_9), inorganics (T_1,T_2,T_3,T_4, and T_8), integration (T_5,T_6,T_7,T_{10}) and inorganics +silicate slag (T_{11}) the order of mineralisation potential was found to be inorganics + silicate slag (72.30 mg N/kg soil) > integration (72.22 mg N/kg soil) > inorganics (69.09 mg N/kg soil) > organics (64.10 mg N/kg soil).

Table- 12: Effect of continuous fertilisation and manuring on mineralization potential (N_o) measured during post kharif period.

Treatments	Mineralization potential (N_0) (mg N/kg soil)
T_1 Standard= 100% NPK +S+Zn+B	71.65
T_2 Standard(-S)	64.65
T_3 Standard (-Zn)	71.28
T_4 Standard (-B)	65.34
T_5 FYM 5t/ha +NPK (adjusted)	73.42
T_6 GM+ standard N (adjusted)	75.09
T_7 Straw Incorporation + Standard (-P)	72.63
T_8 100% NPK	68.79
T_9 N as Organic+ P as Rock phosphate+ K as Straw incorporation	64.10
T_{10} GM + N (adj)+ P as R.P+ 150% K+S+Zn + B	67.78
T_{11} Silicate amendments +Standard(P as per soil test)	72.30
T_{12} Control (No fertilizer)	58.59

Table- 13:Correlation between mineralization potential (N_o) and other soil/plant parameters.

	Correlation coefficient (r)					
	Total N	Mineralizable N	($NH_4^+ + NO_3^-$)- N	SOC	N-uptake	Grain yield
Mineralization potential (N_o) (Approx.)	0.572*	0.748**	0.522	0.029	0.525	0.534

In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

The No of the experimental plots ranged between 58.59 and 73.42 mg N/kg which represented between 8.90 and 11.12 percent of total N Khanif and Rahimahbivi (1988) reported arranged of 20.0-154.1 mg/kg for No representing 1.0 to 7.3% of total N. Stanford and Smith (1972) reported No within the range of 20 to over 300 mg NH_4^+/kg of air dry soil. Thus the results obtained in this study are well within the range reported by earlier workers.

Results on correlation between No and other soil and plant parameters drawn on he basis of linear regression presented in table.13 showed significant positive correlations between No and soil total N (r=0.57*), No and mineralisable N (0.75**) and moderate correlation between No and inorganic (NH_4^+ + NO_3^-) N (r=0.52). But the correlation was poor with organic carbon (r=0.03).

The correlations between No and N-uptake (r=0.53) and No and grain yield (r=0.53) were also moderate. However higher No values obtained with integrated use of organics and inorganics are indicative of the better potential of integration than inorganics or organics to supply more N.

4.5 Assessment of Indicators of Soil N availability

The amount of N converted from organic) to mineral forms (mineralisation) on an annual basis varies, depending on cropping system followed, past management history, annual climatic variation and inherent soil properties (Sprent, 1987; Paul and Clark, 1989). This capacity of the soil to supply plant available N is very important and needs to be assessed for effective and economic management of the nutrient. Numerous chemical and biological methods have been developed for determination of N mineralisation potential and its availability. Suitability of a particular method depends on the degree to which they correlate with reliable biological measurements of soil N-availability e.g. N uptake and crop yield (Stanford, 1982).

Results on correlation regression analysis recorded in table.14 reveal that N uptake significantly and positively correlated with grain yield (r=0.95**). Important chemical (total N, SOC, mineralisable N, inorganic N, total hydrolysable N, non hydrolysable N and hydrolysable N fractions such as hydrolysable NH_4^+-N, amino sugar N, amino acid N and unidentified hydrolysable N) and biological (urease enzyme activity and amidase activity) parameters have been correlated with N uptake.

Among the parameters soil organic carbon is poorly correlated with N-uptake (r=0.07). Although SOC is a commonly used indicator of N availability in most situations, under rice-rice cropping systems with continuous manuring with organic and inorganic sources of nutrients it is suitability as an indicator is doubtful. Under continuous long term manured situations qualitative rather than quantitative differences in SOM are more prominent (wander *et. al.*, 1994). Thus indicators that are sensitive to SOM quality and that reflect the size of the active soil N pools are needed to fully assess the N supply capacity. Working on the same soil one year back Behera (2000) also reported that SOC is a poor indicator of soil's N supplying capacity. Total N was found to be moderately correlated with N-uptake (r=0.45) which might be due to the same reason. Similarly mineralizable N which represents a fraction of soil N that is easily mineralized also moderately correlated with N uptake (r=0.48). This result does not agree with the finding of Behera (2000) who reported strong correlation (r=0.95**) last year. This type of incongruence in the findings might be due to change in the quantity of the mineralisable N pool of soil which is differentially and continuously manured with various organics and/or inorganics. However, the inorganic (NH_4^++NO_3^-)N in the mineral N pool of soil proved to be a better indicator as it correlated significantly with N-uptake (r=0.68*).

Table –14: Relationship between various indictors of soil of available-N and plant uptake and yield.

Sl. No.	Parameters	Correlation coefficient (r)
1	Mineralization N Vs N-Uptake	0.48
2	Organic carbon Vs N – Uptake	0.07
3	Total N Vs N-Uptake	0.45
4	THN Vs N-Uptake	0.79**
5	HAN Vs N-Uptake	0.59*
6	ASN Vs N-Uptake	-0.03
7	AAN Vs N-Uptake	0.77**
8	UHN Vs N-Uptake	0.30
9	NHN Vs N-Uptake	-0.05
10	Urease Activity Vs N-Uptake	0.66*
11	Amidase Activity Vs N-Uptake	0.61*
12	N-Uptake Vs Grain Yield	0.95**
13	NH_4^++NO_3^- Vs N-Uptake	0.68*
14	NH_4^++NO_3^- Vs Mineralisable – N	0.62*

In rabi, treatments remained same as kharif except T_7, T_9 and T_{10} where T_7 received P @ 150%, T_9 received N as both organic and inorganic and T_{10} received N @ 150%.

Among the organic N fractions total hydrolysable N (THN) very strongly correlated with N-uptake (r=0.79**) in contrast to very poor negative correlation of non hydrolysable fraction (r=-0.05). Among the hydrolysable fractions, amino acid N (AAN) correlated strongly (r=0.77**) followed by hydrolysable NH_4^+ (r=0.59*). This result strongly corroborates the finding of Rout (1998) and Mohapatra (1988). Other fractions such as amino sugar and unidentified hydrolysable N were very poorly correlated (r=-0.03 and r=0.30 respectively) with N-uptake.

Among the biological parameters both the selected enzyme activities viz; urease and amidase were significantly correlated with N-uptake. The correlation coefficient values (r) for urease and amidase were 0.66* and 0.61* respectively.

Thus it can be inferred from the above results and discussion that under continuously manured irrigated rice-rice system soil organic matter quality and composition of total N are more important than their quantity. SOM is a poor indicator of N availability under such a system. Total N and mineralisable N as indicator of N availability are better than SOC. But inorganic N and total hydrolysable N can serve as potential indicators. Among the biological parameters assessed is this study both urease and amidase activities were found to be good indicators of N-availability. The indicators assessed in this study may be placed in the order of merit as ; Total hydrolysable N > Inorganic N > Urease activity > Amidase activity > Mineralisable N > Total N on the basis of their extent of correlation with N-uptake.

CHAPTER-V
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION:

In order to investigate the direct and cumulative effect of continuous fertilisation and manuring on the changes in various fractions of soil N, their availability and supply capacity in a rice-rice cropping system with various organic, inorganic sources of nutrients and their combination the long Term Fertility experiment run at OUAT under the aegis of the All India Coordinated Research Project, ICAR was used. The experiment started in the year, 1994 in the central farm of OUAT on an acidic sandy loam Inceptisol. After three years of uniformity trial to reduce field heterogeneity the experiment was systematically initiated with 12 treatments including an unmanured control (T_{12}) since kharif 1997. Almost all the treatments received uniform doses of the three major nutrients but with different combination of various sources of nutrients. Five treatments (T_1, T_2, T_3, T_4 and T_8) received nutrients (100% NPK) in inorganic form with T1 taken as standard (100% NPK+S+Zn+B) and T_2, T_3, T_4 and T_8 were devoid of S, Zn, B and S+Zn+B respectively. One treatment (T_9) received N solely through organics in kharif and both organic and inorganic in rabi, P as rock phosphate and K as straw. Four treatments (T_5, T_6, T_7 and T_{10}) received both inorganic and organic sources. The organic sourses for (T_5, T_6, T_7 and T_{10} were FYM, green manure, straw and green manure (with 150% N in rabi) respectively. T_{11} received silicate slag @ 100 kg sio2/ha besides the standard dose.

The rice crop of rabi, 1999-2000 and kharif, 2000 were used for studying the yield and N uptake. Soil samples of post, pre-kharif and post-kharif period were collected for analysis of various parameters viz; organic carbon, mineralisable N, total N, inorganic N organic N fractions, urease and amidase activity. The data were subjected to analysis of variance. Standard analysis of variance with single degree of freedom contrasts was also done to compare the effects of inorganic sources (T_1,T_2,T_3,T_4 and T_8), organic sources (T_9), their integration (T_5,T_6,T_7 and T_{10}) and silicate slag amended treatment (T_{11}) after classifying the treatments into above groups basing on the source of N used in kharif.

A laboratory incubation study was also done on post kharif soil samples for 8 weeks in order to determine the nitrogen mineralisation potential (No) following the method outlined by Stanford and Smith (1972)

The salient findings of the study are summarised below

Results on soil organic carbon content measured at post rabi, pre-kharif, during kharif and post kharif period showed almost no change during post rabi to pre-kharif spanning a gap of one month followed by an increase during crop growth and a drop at harvest almost to the level in pre-kharif stage. However, as compared to the initial value (0.5%) there was a decrease by 10-20% over the years from 1994 to 2000. The decrease was minimum in treatments that received FYM and silicate slag amendment and maximum in unmanured or inorganically fertilised plots.

In contrast, the mineralisable N content at post rabi (2000) period was substantially higher (13-22%) than the initial of 187 kg/ha in all the plots except the control. The content decreased at pre-kharif stage followed by an increase to a level slightly higher than the initial at post-harvest period. Silicate slag amendment along with 100% NPK (T_{11}) and integrated use of both organics and inorganics particularly T_5(FYM amendment) and T_6 (green manured) maintained higher pool of mineralisable N. Straw application reduced the in mineralisable N. Inorganics alone maintained a smaller pool of soil mineralisable N than their integration with organics. However, the differences between inorganics and integration or, organics and inorganics/integration were nonsignificant. At post kharif period the order was silicate slag amendment > integration > inorganics > > organics > control in contrast to the order, silicate slag amendment > inorganics > integration > organics > control reported last year by Behera (2000).

Although organic carbon showed a decreasing trend, the total N was found to increase over the years in all the plots with lowest increase (5.3%) in control and highest (28.6%) in T_{11} (silicate slag + 100% NPK). As compared to the mineralisable N, the accumulation of total N was proportionately much higher indicating more accumulation in some forms that are not extractable with alkaline $KMnO_4$ oxidation. There was increase in total N from pre-kharif to post-kharif period which might be due

to biological nitrogen fixation and N-conservation under anaerobic condition. The built up of total N was in the order of $T_{11} > T_5 > T_7 > T_8 > T_1 > T_4 > T_{10} = T_2 > T_3 > T_6 > T_9 > T_{12}$ Like mineralisable N, total N was higher with integration than the inorganic sources alone. This did not corroborate the finding of Behera (2000) who reported the reverse last year.

Inorganic (NH_4^+ + NO_3^-) N measured at post-kharif period followed the same trade as observed with total N. T_{11} (silicate slag +NPK) could maintain highest (52.57 kg/ha) pool of inorganic N which was 53% higher than the lowest (34.41 kg/ha) in control (T_{12}). Among the organic sources used for integration FYM and green manure were more efficient in maintaining higher level of NH_4^+ + NO_3^- – N than straw incorporation. Integrated use could maintain slightly higher level of inorganic N than sole application of either organic or inorganic sources. However the differences were non significant.

About two-thirds of the total N was found to be hydrolysable (6N HCl) and one third non hydrolysable. T_{11} maintained highest (1097 kg/ha) level of total hydrolysable N (THN) which was 68.33% of the total. In terms of percentage of total, the organic sources maintained higher level of THN (75%) than inorganic sources (69.67%) or their integration (68.43%). Rice straw application increased the non-hydrolysable fraction. Among the hydrolysable fractions unidentified fraction (UHN) was highest (33.34 – 41.34%) followed by amino acid N (AAN) (27.97 – 35.30%) and hydrolysable NH_4^+ (HAN) (18.56–24.61%). Amino sugar (ASN) formed the smallest fraction of only 3.34 – 13.79%. Silicate amendment along with 100% NPK (T_{11}) maintained highest levels of both HAN and AAN followed by T_{10}, where integration was done with green manure in kharif and N was raised to 150% in rabi and T_5 where integration was done with FYM. But the differences were non significant. On the other hand highest accumulation of ASN (138 kg/ha) was observed with sole application of organics (T_9) followed by T_7 (straw incorporation + NPK).

There was significant and positive correlations of total N with AAN (r=0.58*) and UHN (r=0.78**) indicating an increase these two fractions with increase in total N. Among the hydrolysable fractions HAN and ASN had poor correlations with THN. But

AAN and UHN were strongly correlated with THN indicating their change with THN.

Results on enzyme activity showed that both urease and amidase activities were highest in T_{11}. T_{11} registered 100 and 160% higher urease and amidase activity than the control respectively. Integration of inorganics with organics maintained a higher level of enzyme activities than inorganics alone. Among the organics used for integration, FYM resulted in higher enzyme activity. The treatments were in the order of $T_{11} > T_{10} > T_5 > T_7 > T_3 > T_2 > T_8 > T_6 > T_9 > T_4 > T_{12} > T_1$ for urease and $T_{11} > T_5 > T_9 > T_{10} = T_6 = T_1 > T_7 = T_4 > T_2 = T_3 > T_{12}$.for amidase.

Results on drymatter yield showed that silicate slag amendment along with NPK produced highest drymatter yield in both rabi (73.38 q/ha) and kharif (73.29 q/ha) seasons which were significantly higher than the seasons which were significantly higher than the organic and/or inorganic sources indicating a significant positive effect of liming and Si on improving soil fertility and increasing drymatter. In both the seasons organically manured treatment produced lower yield than inorganics and their integration. Although the differences were not significant, integration produced more drymatter in rabi than inorganics, where as in kharif inorganics were better.

So far grain yield in both the seasons were concerned the trend remained same as with drymatter. All the fertilised and manured plots registered significantly higher yield than the unmanured control. In rabi, 1999-2000, T_{11} registered highest grain yield of 34.58 q/ha which was 169.52% more than control, 25.51% more than inorganic source, 37.33% more than the organic source and 18.50% more than their integration. This result did not corroborate the findings of Behera (2000) who reported higher yield with inorganics than the integration. During kharif highest grain yield of 32.93 q/ha was obtained with T_{11}. This was 127.88% higher than the unmanured control, 34.79% higher than the inorganic source, 42.90% more than the organic source and 39.41% more than their integration. In contrast to the rabi yield, the yield in kharif with in organic source was higher than that with the integrated use. However unlike the previous years result the difference was not significant.

Substitution of N entirely through organics during kharif and partially in rabi (T_9

could not produce higher yield in both the seasons. FYM, green manure and straw did not differ significantly in their influence on grain yield. Similarly continuous addition or exclusion of micro (B and Zn) and secondary (S) nutrients for three years did not make any difference in grain yield.

Results on N uptake showed that the order of treatments remained same for both N uptake and grain yield in both the seasons. In rabi 1999-2000 the order was silicate slag amendment + inorganics > integration > inorganics > organics > control as compared to silicate slag + inorganics > inorganic > integration > organics > control in kharif, 2000. T_{11} registered highest uptake of 62 kg/ha in rabi and 64.99 kg/ha in kharif which were 235% and 167% higher than their respective controls. However, the differences among manured treatments were nonsignificant.

Results of the incubation study on approximate mineralisation potential (No) show that No varied from a lowest of 58.59 mg N/kg soil in control to a highest of 75.09 mg N/kg in T_6 that received green manure along with NPK fertilisers. Among the manured plots lowest (64.10 mg N/kg) was recorded in organically manured plot (T_9). The order of mineralisation potential was found to be, inorganics + silicate slag > Integration > Inorganics > Organics > Control. Moderate correlations of No with N-uptake (r=0.53) and grain yield (r=0.53) and poor correlation with organic carbon indicates that soil organic carbon is a poor indicator of N availability. Correlation analysis showed very strong correlation of grain yield of kharif rice with N-uptake (r=0.95**).

Results on correlation regression analysis of various indicators of N-availability with N-uptake show that SOC is very poorly correlated with N-uptake (r=0.07). This result substantiates the result obtained in the incubation experiment. These results also corroborate the finding of Behera (2000). Both total N and mineralizable N were moderately correlated with N-uptake in contrast to strong correlation of mineralisable N with N-uptake reported last year by Behera (2000). This type of in congruence in the findings might be due to the change in quantity and quality of total N or SOC of the soil which is differentially and continuously manured. Inorganic ($NH_4^+ + NO_3^-$) - N proved to be a better indicator as it significantly correlated with N-uptake (r=0.68*) than mineralisable N or total N.

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Among the organic fractions, hydrolysable N (HAN) strongly correlated with N-uptake and among the hydrolysable fractions amino acid N (AAN) was strongly correlated (r=0.77**) with N-uptake followed by hydrolysable NH_4^+ (r=0.59*). Other fractions such as ASN and UHN poorly correlated with N-uptake. Activities of both enzymes viz, urease and amidase were also strongly correlated with N uptake with 'r' values of 0.66* and 0.61* respectively.

From the results of the present investigation following conclusions can be drawn.

1. Continuous application of organic materials or inorganic fertilizers or their integration to an acidic Inceptisol planted to rice-rice cropping increases the total N to a large extent and mineralisable N to a small extent. But there was decrease in soil organic carbon.
2. Silicate slag amendment @ 100 Kg SiO_2/ha with 100% NPK (80:40:60) maintained highest total N, mineralisable N and inorganic N and produced highest yield in both rabi and kharif.
3. Integrated use of both organics and inorganics over performed the inorganics or organics after 3 years of continuous cropping and manuring. But in the early years inorganic sources performed better both in maintaining better N fertility and producing grain yield.
4. The cumulative positive effect of integration was achieved earlier in rabi crop than in kharif.
5. Substitution of N entirely through organics in kharif and partially in rabi could not produce good yield because of poor N supplying capacity.
6. Organic sources viz; FYM, green manure and straw used for integration did not differ significantly in their influence on N fertility and grain yield. However among the three sources, FYM proved to be the best followed by green manure.
7. Continuous addition or exclusion of micro (B and Zn) and secondary (S) nutrients for three years did not make any significant difference on grain yield.
8. Among the indicators of N availability, soil Organic carbon proved to be a very poor indicator. The suitable indicators as found in terms of their correlation with N uptake were in the order: total hydrolysable N (THN) > inorganic N > urease activity > amidase activity > mineralisable N > total N.
9. Among the hydrolysable N fractions of soil, aminoacid N (AAN) and hydrolysable NH_4^+ (HAN) contributed most to N uptake and can thus be good indicators of N availability.
10. Higher values of mineralisation potential (N_0) as observed in incubation study with integrated use of both organics and inorganics than sole application of only inorganics or organics indicate the cumulative positive effect of integration on N supplying capacity of an Inceptisol planted to rice-rice under irrigated system.

However, these results need to be verified over more years of study under the same situation. For more clear picture on the N supplying capacity of the soil, the contribution of sub soil fertility and biological N fixation under such a system need to be studied.

BIBLIOGRAPHY

BIBLIOGRAPHY

Ahmed, Z.; Yahiro, Y. and Kai, H. (1973). Factors affecting immobilization and release of nitrogen in soil and its chemical characteristics of the nitrogen newly immobilized. IV. Chemical nature of the organic nitrogen becoming decomposable due to drying of soil. *Soil Sci. Pl. Nutr.* **19**: 287-288.

Alexander, M. (1977). Introduction to Soil Microbiology. 2nd ed. Willey, New York, p. 467.

Allison, F. E.; Roller, E. M. and Doetsch, J. H. (1953). Ammonium fixation and availability in vermiculite. *Soil Sci.*, ***75**: 173-178.*

Allison, F. E. (1973). Soil organic matter and its role in crop production. Elsevier Scientific Publi. Co., New York, p. 637.

Asami, T. (1971). Immobilization and mineralisation of nitrogen compounds in paddy soils. 4. Effect of plant residues on the immobilization and mineralisation of nitrogen compounds in paddy soil under submerged or upland condition. *J. Sci. Soil Manure,* **42**: 97-102.

Aulakh, M. S.; Rennie, D. A. and Paul, E. A. (1984). The influence of plant residues on denitrification rates in conventional and zero tilled soils. *Soil Sci. Soc. Am. J.* 48: 790-794.

Azam, F.; Ashraf, M. and Lodhi, A. (1991). Availability of soil nitrogen and fertilizer nitrogen to wheat following rice straw amendment. *Biol. Fertil. Soils.* **10**: 134-138.

Azam, F. (1990). Comparative effects of organic and inorganic nitrogen sources applied to a flooded soil on rice yield and availability of nitrogen. *Plant Soil.* **125**: 255-262.

Babalad, H. B. (1998). Crop residue management. In: Radder (Ed) Organics in sustaining soil fertility and productivity. UAS, Dharwad: 95-111.

Bakken, L. R. (1986). Straw decomposition in soil, effects on denitrification and mineralisation-immobilisation of nitrogen during autumn and spring. *Meld. Norg. Landbr. Hogsk.*, **65**(13): 1-16.

Bandick, A.; Miller, M and Dick, R. P. (1994). Soil enzyme stabilty as an indicator of soil quality. Agronomy abstracts. ASA, Madison, WI. P. 292.

Basumataray, A. and Talukdar, M. C. (1998). Long-term effect of integrated nutrient supply system on soil properties in an *Inceptisol* of Assam. *Oryza.* **35**(1): 43-46.

Behera, M.M. (2000). Effect of organic and inorganic sources of nutrients on nitrogen availability to rice in an *Inceptisol* of Bhubaneswar. MSc (Ag) Thesis. OUAT, Bhubaneswar.

Bhalla, G.S.; Peter Hazell and John Kerr (1999). Prospect for India's cereal supply and demand to 2020. International Food Policy Research Institute, Washington DC. Discussion Paper – 29. p24.

Bharadwaj, K. K. R. and Dev, S. P. (1995). Production and decomposition of *Sesbania cannabina* in relation to its effect on yield of wetland rice. *Tropical Agric.*, **62**: 233-236.

Bonde, T. A. and Roswall, T. (1987). Seasonal variation of potentially mineralisable nitrogen in 4 cropping systems. *Soil. Sci. Soc. Am. J.* **51**: 1508-1514.

Bouldin, D. R. (1988). Effect of green manure on soil organic matter content and nitrogen availability. In: Green manure in rice farming. IRRI, Los Banos, Philippines. : 151-163.

Broadbent, F. E. and Reyes, O. C. (1971). Uptake of soil and fertilizer nitrogen by rice in some Philippines soils. *Soil Sci.*, **112**(7): 200-205.

Broadbent, F. E. and Tusneem, M. E. (1971). Losses of nitrogen from some flooded soils in tracer experiments. *Soil Sci. Soc. Am. Proc.*, **35**: 922-926.

Broadbent, F. E. (1953). The soil organic fraction. *Adv. Agron.*, 5: 153-156.

Broadbent, F. E. (1978). Transformations of soil nitrogen. In: Soil and Rice. IRRI, Los Banos, Philippines. : 539-543.

Broadbent, F. E. (1981). Methodology for nitrogen transformation and balance in soil. *Plant Soil.* 58: 383-399.

Cai, G. and Zhu, Z. (1983). Effect of rice growth on mineralisation of soil nitrogen. *Acta Pedol. Sin.* **20**(3): 272-280.

Carbera, M. L. (1993). Modeling the flush of nitrogen mineralisation by drying and rewetting soils. *Soil Sci. Soc. Am. J.* **57**: 63-66.

Cassman, K. G. and Pingali, P. L. (1995). Extrapolating trends from long-term experiment to farmers' fields, the case of irrigated rice system in Asia. In: Barne, H. V.; Payne, R. and Steiner, R (eds) Agricultural sustainability; Economic, Environmental and statistical considerations. John Wiley and Sons Ltd. pp 63-84.

Catroux, G. and Schnitzer, M. (1987) chemical, spectroscopic and biological characteristics of the organic matter in particle size fractions separated from an Aquoll. *Soil Sci. Soc. Am. J.* 51:1200-1207.

Char-Fen-Lin, (1981). An evaluation of soil nitrogen mineralisation for predicting nitrogen demand of rice crop. In: Proc. Republic of China – Federal Republic of Germany Seminar on Plant Nutr. and soil sci. 120: 455-460.

Chendrayan, K. ; Adhya, T.K. and Sethunathan, N. (1980) Dehydrogenase and invertase activity of flooded soils. *Soil Bid. Biochem*, **12** : 271-273.

Chen, D. L. A. and Zhu, Z. L. (1986). Nitrogen supply of sub-soil in flooded rice field. *Soils* (China) **18**: 33-34.

Clement, A.; Ladha, J. K.; Chalifour, F. P. (1998). Nitrogen dynamics of various green manure species and the relationship to low land rice production. *Agron. J.* **90**(2): 149-154 .

Craswell, E. T. and Vlek, P. L. G. (1984). Research to reduce losses of fertilizer nitrogen from wetland rice soils. In Proc. FAI Sem. 1980 on Fertilisers in India in the Eighties, Part-2. New Delhi, India. FAI, New Delhi.

Dalal, R. C. and Mayer, R. S. (1987). Long-term trend in fertility of soils under continuous cultivation and cereal cropping in southern Quinsland. VII. Dynamics of nitrogen mineralisation potential and microbial biomass. *Aust. J. Soil Res.* **25**: 461-472.

De bruin, B. D.: Penning, De Vries, F. W. T.; Van Broek Hoven, L. W.; Vertrgt, N. and Van DeGejin, S. C. (1989). Net nitrogen mineralisation, nitrification and carbon dioxide production in alternating moisture conditions in unfertilized low humus soil from the Satel. *Plant Soil.* **130**: 69-78.

De Datta, S. K. ; Filleny, I. R. P. ; Obeema , W.N. and Enanglista, R.C. (1987). Flood water properties, nitrogen utilization and ^{15}N balance in the calcareous low land rice soil. *Soil Sci. Sco. Am. J.***51**: 1355-1362.

De Datta, S.K. (1981). Chemical changes in submerged rice soils. In Principle And Practices Of Rice Production. Wiley Interscience Publication: 89-145.

Dei, Y.and Yamasaki, S. (1979). Effect of water and crop management on the nitrogen supplying capacity of the paddy soil. **In**: *Nitrogen and rice*, IRRI Los Banos, Philippines : 451-453.

Dinesh , R. ; Dubey , R.P. and Prasad, G.S. (1998). Soil microbial biomass and enzyme activities as influenced by organic manure incorporation into soils of a rice – rice system. *J. Agron. Crops Sci.* **180**(3) : 173-178.

El-Haris, M. K.; Cochran, V. L.; Elliott, L. F. and Bezdicek, D. F. (1983). Effect of tillage, cropping and fertilizer management on soil nitrogen mineralisation potential. *Soil. Sci. Soc. Am. J.* **47**: 1157-1161.

Fillery, I. R. P. and Vlek, P. L. G. (1982). The significance of denitrification of applied nitrogen in fallow and cropped rice soils under different flooding regime. *Plant Soils.* 65: 153-169.

Flinn, J.C. and De Datta, S.K. (1984). Trends in irrigated rice yields under intensive cropping at Philippines research stations. Field Crops Res. **9**: 1-15.

Fox, R. H. and Piekielek, W. P (1978). A rapid method of estimating the nitrogen supplying capacity of a soil. *Soil Sci. Soc. Am. J.* **42** : 751-753.

Franken berger , W.T. , Jr. and Tabatabai , M.A. (1980). Amidase activity in soils : I . Methods of assay. *Soil Sci. Soc. Am. J.* **44** : 282-287.

Fujii, K ; Kobayashi , M. and Takahashi, E (1972). Changes in the soil nitroflora and in their metabolic activity. 3. Acumulation of organic acids in a mixture of a plant residue and sand incubated under aerobic and water logged conditions. *J. Sci. Soil Manure. Japan* , **43**(5) : 155-159.

Gaur, A. C. (1982). Organic manures and biofertilisers in review of soil research in India, part 1. Indian Society of Soil Science, New Delhi, p.278.

Garz , J. and Chaanin , A. (1990). Zu den Wechselbeziehungen der stick stoffdungung and dem Umsatz der organization Boden sustract Tag. Ber. Akad. Landwirtsch, Berlin, **289** : 193-200.

Goswami, N. N. and Sahrawat, K. L. (1982). Nutrient transformation in soils – micronutrients. In: *Review of Soil Research in India.* Indian Society of Soil Science. p. 123 .

Gotoh , S ; Araragi, M. ; Koga, H. and Ono, S. (1986). Hydrolysable organic forms of nitrogen in some rice soil profiles as affected by organic matter application. *Soil Sci. plant nutri.* , **32** (4) ; 535-550.

Hasan, R. and Ghosh, A. B. (1984). Availability of soil nitrogen in relation to clay content under submerged conditions. In : Nitrogen in soils, crops and fertilizers. Bulletin of Indian Society of Soil Science. p. 493.

Helal , H. M. and Sauirbeck, D. (1989). Carbon turn over in the rizosphere. *Z. pflanzenernahr.* Bodenkd. **152**; 211- 216.

Huang, Zhi Wu. and Lu, Renjun. (1996). Studies on rice plantation with prefer Co-ordinate fertilization of rice straw and urea. *J. of Sluth* China Agril University, **17** (1) : 61-66.

IRRI (1974). Annual report for 1973. IRRI, Los Banos, Philippines.

Ito, O. and Watanabe, I. (1985). Availability to rice plants of nitrogen fixed by Azolla. *Soil Sci. Pl. Nutr.* **31**: 91-104.

Jansson, S. L. and Persson, J. (1982). Mineralisation and immobilization of soil nitrogen. In: F.J. Stevenson (Ed) *Nitrogen in agricultural soils. Am. Soc. Agron.* Monograph 22, Madison, Wisconsin, USA: 229-252.

Jenkinson, D. S.; Fox, R.H. and Rayner, J. H. (1985). Interaction between fertilizer nitrogen and soil nitrogen, the so-called priming effect. *J. Soil Sci.* 36: 425-444.

Johnston, A. E. and Powlson, D. S. (1994). The setting up , conduct and applicability of long turm , continuing field experiments in agricultural research. **In** : Greenland and Szaboks (ends) . Soil Resilience and sustainable land use. CAB International. Budapest , Hungary : 395-421.

Kai, H.; Masayana, W. and Yamada, Y. (1984). Nitrogen supplying capacities of Thai paddy soils. In: Proc. Of the fifth ASEAN soil conference on *Soil Sci.* as a tool for rural development. Vol. 1. Bangkok, Thailand.

Keertisinghe, D. G.; Mengel, K. and De Datta, S. K. (1984). The release of non-exchangeable ammonium ^{15}N labeled in wetland rice soils. *Soil Sci. Soc. Am. J.* **48**(3): 291-294.

Keertisinghe, D. G. and De Datta, S. K. (1985). Importance of exchangeable and non-exchangeable soil ammonium in nitrogen nutrition of low land rice. *Soil Sci.* **140**: 194-201.

Khanda, C. M.; Dixit, L. and Panda, S. C. (1993). Effect of Zinc and graded levels of nitrogen on growth, yield and nutrient uptake of rice. *Oryza.* **34**: 43-46.

Khanif, Y. M. and Rahimahbivi, O. H. (1988). Mineralisable N in some Malaysian rice soils. *Proc. 1st Intern. Symp. On paddy soil fertility.* Chiangmae, Thailand: 123-129.

Khind, C. S.; Josan, A. S. and Beri, V. (1985). Nitrogen release from Sesbania green manure and effect of time of application of nitrogen on low land rice. *Intern. Rice. Res. Newsletter.* **10**(4): 26-27.

Krantz, B. A.; Broadbent, F. E.; Williams, W. A.; Baghott, K. G.; Ingebresten, K. H, and Stanley, M. E. (1968). Research with nitrogen fertilizer emphasizes fertilize crop not crop residue. *Calif. Agric.,* **22** (8): 6-8.

Kundu, D. K. and Ladha, J. K. (1997). Effect of growing rice on nitrogen mineralisation in flooded soil. *Soil. Sci. Soc. Am. J.* **61**(3) : 839-845.

Kundu, D. K. and Ladha, J. K. (1995b). Efficient management of soil and biologically fixed N_2 in intensively cultivated rice fields. Soil Bio. Biochem. **27:** 431-439.

Kundu, D. K. and Ladha, J. K. (1999). Sustaining productivity of lowland rice soils issues and options related to N availability. Nutrient cycling in agro-ecosystems. **53**: 19-33.

Liu, J. R ; Zhang , K. Y. and Zhou, W. (1990). The effect of mixed application of organic and inorganic fertilizers to paddy soil. Acta – Agriculture Universituties Jianguiensis. – **12** (1) : 37-42.

Mandal, B. C.; Saha, M. N. and Adhikari, M. (1991). Yield of rice and nutrient status of soil due to continuous cropping and manuring in jute-rice-wheat cropping sequence on indo-gangetic alluvial soils. *J. Indian. Soc. Soil. Sci.* 39: 689-692.

Manguiat , I. T. (1997). Effectiveness of Sesbania rostrata and Phaseolus calcaratus as green manure for up land rice grown in acidic soil. *Plant and soil.* **192** (2) : 321-331.

Marumoto, T.; Anderson, J. P. E. and Domsch, K. H. (1982). Decomposition of 14C and 15N labeled microbial cell in soil. *Soil Biol. Biochem.*, 14: 461-471.

Meelu. O. P. and Morris, R. A. (1988). Green manure management in rice based cropping system. In: Green manure in rice farming, IRRI, Los Banos, Philippines.: 209-222.

Mengel, K. and Scherer, H. W. (1981). Release of non-exchangeable soil ammonium under field condition during the summer season. *Soil Sci.* 131: 226-232

Mengel, K. (1996) . Turnover of organic nitrogen in soils and it is availability to crops. *Plant Soil.* **181** : 83-93.

Mian, M. H. and Stewart, W. D. P. (1985). A 15N tracer study to compare nitrogen supply by Azolla and ammonium sulphate to IR-8 rice plants grown under flooded conditions. *Plant Soil.* **83**: 371-379.

Mohanty, S. K. and Sharma, A. R. (2000). Nutrient management in rice-rice cropping system. Fert. News. 45(3): **45**-48 and 51-58.

Mohapatra, S. P. (1998). Fraction of soil nitrogen during different periods of submergence and their effects on yield and nutrition on wetland rice. *Biol. Fertil. Soils.* **6**: 45-49.

Mohapatra, B. S.; Sharma, K.C. and Sharma, G. L. (1991). Effect of integrated nitrogen management on soil nitrogen status and dry matter production of low land rice. *Oryza.* **28**: 87-92.

Mohapatra, B. ; Pattnaik, B. and Mishra, D. (1977). The exocellular Urease in rice roots. *Current Sci.* **46** (19) : 680-681.

More, S. D. (1994). Effect of farm wastes and organic manures on soil properties, nutrient availability and yield of rice-wheat grown on sodic *Vertisol. J. Indian Soc. Soil Sci.* **42**(2): 253-256.

Murayama, N. (1975). Crop production and its improvement in Japan. *Proc. Crop Sci. Soc., Japan.* 44: 492-497.

Myers, R. J. K. (1975). Temperature effects on ammonification and nitrification in a tropical soil. *Soil Biol. Biochem.* 7: 83-86.

Nagarajah, S. (1986). Transformation of green manure nitrogen in low land rice soils. In: Symposium on sustainable agriculture, The role of green manure crops in rice farming systems. IRRI, Los Banos, Philippines.

Nambiar, K. K. M. (1994). Soil fertility and crop productivity under long-term fertilizer use in India. ICAR, New Delhi, p-114.

Nambiar, K. K. M. and Ghosh, A. B. (1984). Highlights of research on long-term fertilizer experiments in India 1971-82. All India Co-Coordinated Research Project On Long Term Fertilizer Experiments. IARI, New Delhi, p-100.

Neyra, C. A. and Dobereiner, J. (1977). Nitrogen fixation in grasses. *Adv. Agron.* **29** : 1-38.

Okuda, A. and Takahasi, E. (1964). The role of silicon in the mineral nutrition of the rice plant. John Hopkins Press, Baltimore: 123-146

Oyanedel, C. and Rodriguez, S. J. (1977). Estimation of nitrogen mineralisation in soils. *Cieno. Invest. Agroria.* **4**: 33-44.

Pathak, H. (1991). Nitrogen supplying capacity of different organic manures in relation to some soil properties. PhD Thesis, IARI, New Delhi.

Pathak, H. and Sarkar, M.C. (1995). Transformation of soil organic nitrogen with manuring under rice wheat cropping system. Fert. News, **40** (10) : 33-35.

Patil, R. G. (1990). Mineralisation – Immobilisation of nitrogen as influenced by green manure and urea in straw amended soils. PhD Thesis, IARI, New Delhi.

Patric, Jr. W. H. (1982). Nitrogen transformation in submerged soils. In: F. J. Stevenson (ed) Nitrogen in Agricultural soils. Madison, Wisconsin, USA.

Pattanaik, P. ; Mallick, K. and Ramakrishna, B. (1999). Urease activity and urease hydrolysis in tropical flooded soil planted to rice. *J. Sci. Flood and Agriculture.* **79** (2) : 227-231.

Paul, E. A. and Clark (1989). Soil microbiology and biochemistry. Academic press, New York.

Perumal, R.; Velayutham, M. and Dhanapalan, M. A. (1986). Forms of soil N and available N status in relation to rice nutrition in alluvial soils of Tanjavur district. *Madras Agric. J.* **73**: 140-146.

Poorvarodam, S.; Tate III, R. L. and Bloom, R. A. (1988). Nitrogen mineralisation rates of the acidic, xeric soils of the New Jersey pinelands. *Soil Sci.* 145(4): 257-263.

Powlson, D. S. ; Poulton , P. R. , Addiscott, T. M. and Mc. Cann, D.S. (1989). Leaching of nitrate from soils receiving organic or inorganic fertilizers continuously for 135 years. In : Hansen and Hendrikasen (eds) nitrogen in organic wastes applied to soils. Academic press. London, UK.

Prasad, S. S.; Sarkar, A. K. and Sinha, N. P. (1986). Forms of nitrogen in water logged soil and their contribution to yield and nitrogen uptake by rice. *J. Agric. Sci., Camb.* **107**: 215-217.

Prasad, R. (1999). A Text Book of Rice Agronomy, Jain Brothers, New Delhi. P-238

Prasad, R. and Power, J. C. (1995). Nutrification inhibitors for agriculture, health and environment. Adv. Agron. **54**: 233-281.

Ramamoorty, B. and Agarwal, R. K. (1972). Prof. N. R. Dhar's eighteenth birthday commemoration volume, Calcutta University, Calcutta.

Ramamoorty, B. and Velayutham, M. (1976). In: J. S. Kanwar(ed) soil fertility theory and practices, ICAR, New Delhi.p.156.

X

Rao, Surinder and Seetaramaya, M. (1995). Changes in total and available soil nitrogen status under integrated nutrient management of rice. *J. Indian Soc. Soil. Sci.* **45**(3): 445-449.

Roger, P. A. and Ladha, J. K. (1990). Estimation of biological nitrogen fixation and its contribution to nitrogen balance in wetland rice fields. In: Trans. Intern. Congr. Soil Sci. 14th Kyoto, Japan, Vol. **3** : 128-133.

Rout, B. (2001). Microbial activity and productivity of a soil (*vertic Haplaquept*) under long turm cropping, fertilization and manuring. M. Sc. (Micro.), Thesis,OUAT.

Rout, K. K. (1998). Nitrogen utilization pattern of hybrid rice and its parents in relation to nitrogen transformation in soil Ph.D. Thesis. Division of Soil Science and Agricultural Chemistry, IARI, New Delhi.

Sahrawat, K. L. (1980b). soil and fertilizer nitrogen transformation under alternate flooding and drying moisture regimes. *Plant Soil.* **55**: 225-233.

Sahrawat, K. L. (1981). Ammonification in air-dried tropical low land *Histosol. Soil Bio. Biochem.* **13**: 323-324

Sahrawat, K. L. (1982). Assay of nitrogen supplying capacity of tropical rice soils. *Plant Soil.* **65**: 111-121.

Sahrawat, K. L. (1983a). Nitrogen availability indices in submerged rice soils. *Adv. Agron.* **36**: 415-451.

Sahrawat, K. L. (1983b). Mineralisation of soil organic nitrogen under water logged conditions in relation to other properties of tropical rice soils. Aust. J. Soil Res. **21**: 133-138.

Sahu, B. N. and Nayak, B. C. (1971). Soil fertilizer investigation under continuous application of ammonium sulphate alone and in combination with organic manure in

long-term fertility trials. *Proc. Intern. Symp. Soil Fertil. Evaluation.* New Delhi, India : 873-879.

Santhy, T. ; Muthuvel, P. Selvi, D. and Dakshinamoorthy, M. (2000) status and impact of organic matter fractions on yield , uptake and available nutrients in LTFE. *J. Indian Soc. Soil Sci.* **87** (1-3) : 40-43.

Savant, N. K. and De Datta, S. K. (1982). Nitrogen transformation in wetland rice soils. *Adv. Agron.* **35**: 241-302.

Schnier, H. F. ; De Datta, S. K. and mengel ; K. (1987). Dynamics of ^{15}N labeled ammonium sulphate in various inorganic and organic soil fractions of wetland rice soils. *Biol. Fertil. Soils.* **4** : 171-177.

Shoji, S.; Ando, H. and Wada, G. (1986). Fate of nitrogen in paddy fields and nitrogen absorption by rice plants. *JARQ,* **20**(2): 92-105 .

Siddiq, E. A. (2000). Yawning Productivity gaps. In: *The Hindu*, Sec – 2. 39-44.

Singaram, P. and Kamalakumari, K. (1995). Effect of continuous application of different levels of fertilizers with farm yard manure on enzyme dynamics of soil. *J. Indian Soc. Soil Sci.* 364-365.

Singh, Y. and Beauchamp, E. G. (1986). N mineralisation and nitrification activity in limed and Urea treated soils. *Comm. Soil Sci. Plant Annal.* **17**(12): 1369-1381.

Singh, A. K.; Thakur, S. K. and Singh, S. S. (1996). Effect of nitrogen with and without FYM and zinc on yield, uptake and economics of rice. *J. Res.* **8**(2): 175-176.

Skujins, J. (1978). History of abiotic soil enzyme research. In: R. G. Burns (Ed.) Soil Enzymes. Academic Press, New York.: 1-50.

Smith, S. J.; Chichester, F. W. and Kissel, D. E. (1978). Residual forms of fertilizer N in field soils. *Soil Sci.* 125(3): 165-169.

Somani, L. L. and Saxena, S. N. (1976). Tropical Agriculturist. 132.p9.

Sprent, N. (1987). The ecology of the nitrogen cycle Cambridge press, Cambridge.

Sreedevi, B. and Thangamuthu, G. S. (1991). Studies on NPK uptake by rice under integrated nitrogen management. *Oryza.* **28**: 255-256.

Sriramachandrasekhran, M. V. and Ravichandran, M. (1999). Enzyme activities in flooded rice soil amended with organic manures. *Oryza* **36** (3) : 276-278.

Stanford, G. and Epstein, E. (1974). N mineralisation – water relations in soils. *Proc. Soil Sci. Soc. Am.* 38: 103-106.

Stanford, G. and Smith, S. J. (1972). Nitrogen mineralisation potential of soils. *Soil Sci. Soc. Am. J.* 36: 465-472.

Stanford, G. (1982). Assessment of soil N availability. In: Nitrogen in agricultural soils. Agronomy monograph. 22. ASA-CSSA-SSSA, Madison, Wisconsin, USA.

Subbaiah, G. and Mitra, B. N. (1997). Effect of foliar spray of micronutrient on growth and yield of rice. *Oryza.* **34**: 148-151.

Suzuki, M. (1990). Effect of continuous application of organic and inorganic fertilizers for sixty years on soil fertility and rice yield in paddy field. *Transactions 14th International Congress of soil.* **4** : 14-19.

Tabatabai, M. A. (1985). Effect of acid rains on soils. *Crit. Rev. Environ. Control.* **15**: 65-110.

Tabatabai, M. A.(1991). Soil enzymes. In : page, A. L. ; Miller, R. H. and Keeney, D. R. (ends) Methods of soil analysis. Part 2, chemical and microbiological perperties second editon : 903-948.

Tiwari, K. N. and Pathak, A. N. (1980). Green manuring in combination with fertilizer nitrogen on rice under double cropping system in an alluvial soil. *J. Indian Soc. Soil Sci.* **28** : 162-169.

Tsuboi, Y. (1975). Crop production and its improvement in Japan. *Proc. Crop. Sci. Soc.*, Japan. **44**: 488-491.

Uhlen, G. (1973). The effect of ploughed-in cereal straw in yields and soil properties. Scientific from the Agril. Univ. of Norway, **52**(10): 1-21.

Van Veen, J. A. ; Ladd, J. N. and Amato, M. (1985). Turnover of carbon and nitrogen through microbial biomass in a sandyloam and clay soil incubated with ^{14}C – glucose and $^{15}(NH_4)_2 SO_4$ under different moistuer regimes. *Soil Biol. Biochem.* **17** : 747-756.

Ventura, W. and Watanabe, I. (1978). Dry season soil conditions and soil nitrogen availability to wet season wetland rice. *Soil Sci. Plant Nutr.* **24**(4): 535-545.

Ventura and Watanabe, I. (1978). Dry season soil condition and soil nitrogen availability to wet season wet land rice. *Soil Sci. plant nutr.* **24** (4) : 535-545.

Wada, G.; Shoji, S. and Mai, T. (1986). Relationship between nitrogen absorption and growth and yield of rice plants. *JARQ.* **20**(2): 135-145.

Wada, G.; Aragones, D. V. and Aragones, R. C. (1989). Nitrogen absorption pattern of rice plants in the tropics. *Jpn. J. Crop Sci.* **58**(2): 225-231.

Wander, M. M. ; Traina, S. J. , Stinner, B. R. and Peters, S. E. (1994). The effects of organic and conventional management on biologically active soil organic matter pools. *Soil Sci. Soc. Am. J.* **58** : 1130-1139.

Watanabe, I. and Inubishi, K. (1986). Dynamics of available N in paddy soils. I. Changes in available N during rice cultivation and origin of nitrogen. *Soil Sci. Plant Nutr.* **32**(1): 37-50.

Weller, F. (1977). Stickstoffnachlieferung and Stickstoffbilanz obstbaulich genupzer Boden. Erwerbsbau, **19** : 132-135.

Weimer, S. and Scherer, H. W. (1992). Dynamics of non-exchangeable nitrogen after slurry application. *Proc. 2nd ESA Cong. Warwick,* England.: 312-313.

Williams, W. A.; Mikkelson, D. S.; Muller, K. E. and Ruckman, J. F. (1986). Nitrogen immobilization by rice straw incorporated in lowland rice production. *Plant Soil.* **28**: 49-60.

Woods, L. E.; Cole, C. V.; Porter, L. K. and Coleman, D. C. (1987). Transformation of added and indigenous nitrogen in gnotobiotic soil; A comment on the priming effect. *Soil Biol. Biochem.* **19**: 673-678.

Zhang, Fushen ; Shen, Alin ; Zhang, F. S. and Liu, C. Z. (1996). A preliminary study of the effect of silicon application to rice in the rice growing area along the Huanghe river. *J. Henan Agril. Sci.* **10** : 14-15.

APPENDIX

Table 1: Weekly weather parameters during cropping season at Bhubaneswar, Orissa.

Meteor. week No.	Period	Mean temp(°C)		RH(%)		Mean BSH (h/d)	Total rainfall (mm)	Total rainy days	Mean evap. (mm/d)
		Max.	Min.	0700h	1300h				
51	17-23 Dec.	28.4	13.7	81	40	9.0	0.0	0	3.5
52	24-31Dec	29.2	16.3	93	51	5.9	0.0	0	3.5
1	1-7 Jan.	27.4	12.4	85	36	8.6	0.0	0	3.5
2	8-14	30.1	12.6	95	36	9.5	0.0	0	4.0
3	15-21	30.8	15.7	92	37	8.8	0.0	0	4.2
4	22-28	30.0	17.0	93	43	8.5	0.0	0	4.1
5	29-4 Feb.	30.0	15.8	90	49	9.3	0.0	0	4.2
6	5-11	39.1	20.1	94	76	6.8	23.4	3	3.7
7	12-18	28.6	19.2	92	60	6.7	8.4	2	3.2
8	19-25	28.2	19.1	87	97	3.9	1.0	1	3.0
9	26-4 Mar.	32.0	18.1	92	40	8.5	0.0	0	4.4
10	5-11	34.2	21.8	95	45	9.1	0.0	0	5.1
11	12-18	33.8	22.9	94	74	8.8	0.0	0	5.6
12	19-25	33.3	22.8	94	91	8.6	0.0	0	6.1
13	26-1 April	34.7	21.6	92	44	8.9	0.0	0	6.2
14	2-8	36.2	25.6	92	60	9.1	0.0	0	7.8
15	9-15	35.9	25.1	94	62	8.9	1.0	1	7.7
16	16-22	35.9	24.5	93	64	9.0	38.8	2	7.1
17	23-29	35.8	25.3	90	66	7.5	14.0	2	7.5

Meteor. week No.	Period	Mean temp(^{0}C)		RH(%)		Mean BSH (h/d)	Total rainfall (mm)	Total rainy days	Mean evap. (mm/d)
		Max.	Min.	0700h	1300h				
25	23-29 June.	32.3	25.2	95	70	3.4	166.6	6	3.6
26	30-6 July	33.7	25.6	91	73	6.7	17.1	5	5.1
27	7-13	34.1	25.9	90	65	9.2	3.1	5	5.1
28	14-20	23.0	25.1	93	80	3.2	243.2	5	3.4
29	21-27	29.9	24.4	94	98	1.4	88.3	5	3.4
30	2-3 Aug.	32.0	24.6	90	74	3.2	24.8	3	3.5
31	4-10	33.0	25.3	92	75	6.8	17.8	4	3.8
32	11-17	32.2	28.3	93	79	4.2	22.1	4	3.5
33	18-24	32.3	24.8	90	78	4.5	87.7	5	3.5
34	25-31	32.6	25.6	94	74	9.4	20.7	5	3.6
35	1-7	31.7	25.1	90	67.6	5.7	32.5	4	3.7
36	8-14	32.4	24.7	91	73	4.4	11.4	4	3.7
37	15-21	32.5	24.6	93	71	5.2	25.3	3	3.6
38	22-28	31.3	25.1	96	79	5.8	97.3	4	4.0
39	29-5 Oct.	33.3	27.3	94	65	8.3	3.9	2	4.3
40	6-12	34.4	24.0	93	60	9.7	0.0	0	4.4
41	13-19	34.2	23.9	93	66	7.8	23.7	4	4.0
42	20-26	32.0	23.0	91	67	5.0	0.0	0	3.5
43	27-2 Nov.	34.0	21.3	93	50	8.4	0.0	0	3.6
44	3-9	31.2	20.7	93	60	9.1	0.0	0	
45	10-16	32.4	19.3	93	41	8.6	0.0	0	3.8