FRACTIONATION OF ORGANIC AND INORGANIC NITROGEN IN IMPORTANT SOIL TYPES OF KERALA

By

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THESIS

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DECLARATION

I hereby declare that this thesis **"Fractionation of organic and inorganic nitrogen in important soil types of Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any University or Society

Vellanikkara
15th April, 1992

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Certified that this thesis entitled **"Fractionation of organic and inorganic nitrogen in important soil types of Kerala"** is a record of research work done by **Smt.E.R. Mini**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her

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We, the undersigned members of the Advisory Committee of Smt.E.R. Mini, a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agricultural Chemistry, agree that the thesis "Fractionation of organic and inorganic nitrogen in important soil types of Kerala" may be submitted by Smt.E.R. Mini, in partial fulfilment of the requirement for the degree

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15th April, 1992

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C O N T E N T S

ABBREVIATIONS

NH_4-N	ammonia nitrogen
NO_3-N	nitrate nitrogen
FAN	fixed ammonia nitrogen
AaN	amino acid nitrogen
HaN	hexosamine nitrogen
HyAN	hydrolysable ammonia nitrogen
UHyN	unidentified hydrolysable forms of nitrogen
THyN	total hydrolysable nitrogen
NHyN	non-hydrolysable forms of unidentified nitrogen

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Introduction

INTRODUCTION

Nitrogen, the nutrient most often limiting crop yields continues to be the magic element of our agricultural abundance. More than 90 per cent of nitrogen in soil exist in the organic form which is not readily available for plant use. About 5 to 10 per cent of the organic nitrogen is mineralised annually and is absorbed by plants in the form of nitrate and ammonium ions.

Information on the fertility status of the soils of Kerala with respect to the total and available nutrients is available. A knowledge of the various fractions of total nutrients present in soil and the conditions under which these become available to plants is a pre-requisite in assessing the availability of nutrients to crops. A study on the distribution pattern of different fractions of soil nitrogen helps in tracing the contribution of organic nitrogen fractions to the mineralised nitrogen. An idea about the various fractions of nitrogen especially organic nitrogen the highest contributor of the total nitrogen is meagre. Such studies are also important from the view point of immobilisation and transformation of applied inorganic nitrogen.

It is well known that the level and rate of mineralisation of nitrogen influence the quantity of nitrogen immediately available for the plant growth. Although this is a continuous process, conventional estimates of soil available nitrogen take into account the status of inorganic nitrogen - exchangeable NH_4 and or NO_3-N and nitrogen liberated from oxidation/hydrolysis of organic nitrogen under laboratory conditions of incubation/digestion Recent studies have centred around identifying particular fractions and organic nitrogen, which are preferentially contributing to the nitrogen nutrition of crops The preference of certain forms of nutrients by the crop species is established. If the existing soil testing methods are made to tap in the same proportional amounts of nutrient from the different forms as the plant, their suitability for assessing the fertility status of soil can be improved Keeping these points in view, this investigation on fractionation of nitrogen in various soil types of Kerala was undertaken with the fc owing objectives

1. To study the distribution of various organic and inorganic fractions of soil nitrogen in different soil types of Kerala.
2. To assess the relative contribution of each fraction to the available nitrogen pool of the soil as assessed by chemical methods and plant uptake.

Review of Literature

REVIEW OF LITERATURE

Of the various essential elements, nitrogen probably has been subjected to the most study and still receives much attention. The amount of this element in available forms in the soil is small, while the quantity withdrawn annually by crops is comparatively large. The quantity of nitrogen in the surface soils ranges from 0 02 to 2.5 per cent and is closely related to the amount of soil organic matter, of which nitrogen makes up approximately 5 per cent

1. Forms of soil nitrogen

The chemical nature of soil organic nitrogen is not fully understood, but the available evidence based on hydrolysis with strong acid and subsequent fractionation of the hydrolyzate indicates the presence of considerable nitrogen in a form that is converted to ammonium during hydrolysis, a variety of amino acids, and a resistant fraction that is not hydrolysed (Stevenson, 1957).

Plants absorb nitrogen in the form of inorganic ionic forms as ammonia and nitrate, also in small quantities as urea. But more than 90 per cent of nitrogen is in the organic form. The inorganic form of nitrogen rarely exceeds 2 per cent in the cultivated soils (Bremner, 1967) Although nitrogen in the soil may come from dissimilar sources - plant residues, microbial cells, or inorganic fertilizers - after the process of humification has taken place, much of the nitrogen is incorporated into complexes of high molecular weight and comparative resistant to microbial degradation (Broadbent, 1968).

1.1 Inorganic nitrogen

a) Ammonia and Nitrate nitrogen

Generally inorganic forms of nitrogen are comparatively less in the soils compared to organic forms Cropping systems, cultivation practices and vegetation have their own effect on the inorganic forms of nitrogen. Grassland and forest soils differed much in the exchangeable ammonium nitrogen content (Jorgensen, 1967) Microbiological activity is equally responsible for the amount of ammonia and nitrate content in soils. Chemoautotrophs were responsible for the bulk of nitrification in cultivated soils (Campbell and Lees, 1967). Acidity in soil resulted in low population of nitrifers with more ammonium content in the soils (Brar and Giddens, 1968).

Swoden et al. (1977) found that soils from warmer climates yielded relatively less ammonia than did those from colder regions The ammoniacal and nitrate forms of nitrogen were found to be increased with increase in altitude and organic carbon (Singh and Datta, 1988).

Many of the soils of Kerala have pH values lower than the reported optimum for nitrification and often lower than the critical limit. There was significant negative correlation between pH and NH_4-N and positive correlation with NO_3-N (Zacharias, 1989)

b) Fixed ammonia nitrogen

Soil properties, especially clay and organic matter are responsible for ammonium fixation But Burge and Broadbent (1961) have reported a linear relationship between organic carbon and ammonium fixation. Krishnamoorthy (1966) has studied latosols of Tamil Nadu and concluded that ammonium fixation was more in Kodaikanal soils, which were low in pH and high in organic carbon.

Fixed ammonium was very much resistant to release as it was stabilised in the aromatic structure (Broadbent and Thenabadu, 1967) and high molecular weight fractions fixed more ammonium (Broadbent, 1968).

Prasad et al. (1970) have found that about 15 to 20 per cent of total nitrogen as fixed ammonium.

The ammonia fixing capacity of alluvial soils in Assam was correlated with the contents of clay and active iron oxide. In the absence of soil, fixation of ammonia by iron oxides increased with increasing additions of freshly precipitated hydrous oxides of iron (Saha and Mukhopadhyay, 1981).

The contents of FAN showed large variations among the soil series, but relatively smaller differences between horizons of the same profile (Sah and Pasricha, 1984) They also found that bulk of FAN is associated with finer textural fractions of the soil But they found a significant negative correlation between FAN and organic carbon and also with the coarser textural fractions of the soil.

1.2 Organic nitrogen

a) Total hydrolysable nitrogen

Hydrolysable nitrogen contains different forms like ammoniacal, amino acid, hexosamine and other forms. Hydrolysable nitrogen decreased gradually with the progress of humification (Kumada, 1956). Under the conditions of intensive farming the hydrolysable nitrogen may increase, with 50 to 60 per cent of nitrogen in the hydrolysable nitrogen as amino acid (Russell, 1966).

Sometimes lignin, a major constituent of organic matter immobilised the nitrogen and reduced the hydrolysable nitrogen to a considerable extent (Bradfield, 1968). Broadbent (1968) has indicated that hydrolysable nitrogen reduced as it entered into greater resistant molecules of humus particles.

Aomine (1972) has shown that the amount of hydrolysable nitrogen related to easily decomposable one which was closely dependent up on vegetation, climate, nature of soil and management Isirimah and Keeney (1973) concluded that the hydrolysable nitrogen content reduced as the time passed.

Singh et al. (1981) found that of the total nitrogen, 29 to 79 per cent was acid hydrolysable Moyano and Gallardo (1988) reported that the hydrolysable nitrogen contributed about 80 per cent of total nitrogen, ammonia and amino acid reached 20 per cent of hydrolysable nitrogen.

(i) Amino acid nitrogen

Considerable amount of nitrogen from hydrolysable nitrogen is in amino acid form. Gupta (1962) has indicated that the amino acid estimated by hydrolysis procedure was only minimum as it was destroyed during hydrolysis. However, Singh and Bhandari (1963) obtained a higher value as the duration of hydrolysis was increased to 72 hours.

Soil characters and conditions were found to influence amino acid fraction of the hydrolysable nitrogen Haider et al. (1965) confirmed the fixation of amino acids in the lattices of clay minerals. Alpha-amino nitrogen was 21 per cent of hydrolysable nitrogen as per Quinn and Solomon (1966)

Organic matter content and its nature are the other factors which affect the amino acid distribution in soils. Maximum number of amino acids was noted in the soils which are high in organic matter and nitrogen (Malival and Khangarot, 1966 and Krishnamoorthy and Durairaj, 1968)

Broadbent (1968) has shown that recently immobilised nitrogen would have more of amino acid than ammoniacal nitrogen. Isirimah and Keeney (1973) concluded that most of the mineralised nitrogen came from amino acid nitrogen.

Ramamoorthy and Velayutham (1976) found that about 18 to 30 per cent of the total nitrogen in most surface soils occurred as bound amino acids. Soils from warmer climates yielded relatively more amino acids than those from colder regions (Sowden et al., 1977). But they found that climate doesn't influence the amino acid composition of soils

The contents of sodium and sulphate ions in irrigation water were significantly correlated with soil AaN fraction (Aggarwal et al., 1977).

Mohapatra and Khan (1982) reported that AaN ranged from 51 8 per cent in alluvial soils to 57 per cent in acid sulphate soils. But according to earlier reports (Kojima, 1947; Bremner, 1949; Stevenson, 1954; Sowden, 1956; Cheng and Kurtz, 1963, Keeney and Bremner, 1964) bound amino acid fractions account for only 20 to 40 per cent of the total nitrogen.

Mohapatra and Khan (1983) found that AaN made substantial contribution to the potentially mineralisable nitrogen in waterlogged rice soils.

(ii) Hydrolysed ammonia nitrogen

Ramamoorthy and Velayutham (1976) indicated that hydrolysable ammonium accounted for 18 to 30 per cent of total organic nitrogen. Hydrolysable ammonium was highest in alluvial soils and lowest in the acid sulphate soils. Hydrolysable ammonium was the second dominant fraction of soil nitrogen in alluvial and laterite soils and third dominant fraction in acid sulphate soils (Mohapatra and Khan, 1982). Mohapatra and Khan (1983) indicated that the mineralisable nitrogen is significantly correlated to hydrolysable ammonium.

(iii) Hexosamine nitrogen

Khan (1969) found that increased application of manures and fertilizers have considerably enhanced the organic carbon in the form of hexose and hexosamine (8 7 to 11.2 per cent). The contents of sodium and sulphate ions in irrigation water were significantly correlated with soil HaN fractions (Aggarwal and Dhir, 1977). The HaN accounted for 4.8 to 9.2 per cent of total nitrogen in cultivated soil profiles in Tanzania (Singh _et al_., 1981).

(iv) Unidentified fractions of hydrolysable nitrogen

Cultivation led to a decrease in the content of UHyN (Keeney and Bremner, 1964). Singh _et al_. (1981) reported that unidentified nitrogen in the surface horizons were in the range 0.3 to 41.5 per cent of total soil nitrogen in cultivated soil profiles in Tanzania. The content of unidentified nitrogen, though quantitatively important was not directly related to immediately available nitrogen (Perumal _et al_., 1986).

b) Nonhydrolysable nitrogen

The nature and origin of NHyN are not well understood Cultivation leads to a marked decrease in the content of NHyN (Keeney and Bremner, 1964; Meints and Peterson, 1977). Bremner (1965) has shown that unhydrolysable nitrogen may be mainly from humic nitrogen, clay bound nitrogen and heterocyclic nitrogen.

Flaig (1966) has reported that oxidation and condensation increased the proportion of unhyrdolysable nitrogen. Sowden (1977) reported that about 13.5 per cent of total nitrogen as NHyN in representative Canadian soils. The content of NHyN, though quantitatively important was not directly related to the available nitrogen (Perumal et al., 1986).

2. Particle size distribution and nitrogen fractions

The most important fraction which is influenced by particle size distribution is FAN. Bulk of FAN is associated with finer textural fractions of the soil (Sah and Pasricha, 1984). They obtained a positive correlation between clay and FAN, also between silt and FAN and a negative one with the coarse fraction.

3. Forms of nitrogen with yield and uptake

Relationship of soil nitrogen fractions with crop response reveal that amino acid fraction to be important for crops like maize (Cornforth, 1968), wheat (Aggarwal, 1971) and Pearl millet (Singh, 1972). Availability of native FAN to crops was reported by several scientists (Black and Waring, 1972; Kowalenko and Cameron, 1978; Mengel and Seherer, 1981, Keerthisinghe et al., 1984).

The influence of different forms of nitrogen on yield and nitrogen uptake in rice, as revealed by simple correlation coefficient indicates that AaN, HyAN and FAN are important fractions of nitrogen supply with r values of 0.70**, 0.71** and 0.76** respectively for yield and 0.86**, 0.89** and 0.81** for nitrogen uptake (Perumal and Velayutham, 1977). Availability of residual FAN to the crop is stated by Saha and Mukhopadyay (1986).

Swarajyalakshmi (1987) concluded that the AaN, HaN and UHyN are the principal fractions of organic nitrogen contributing to the available pool. Non-exchangeable NH_4^+-N was a significant contributor to the plant N supply to wheat in Virginia (Baethgen and Alley, 1987). Mohapatra (1988) stated the negative relation of NHyN to grain yield and nitrogen uptake in rice.

4. Nitrogen forms in relation to soil test methods

Greenhouse and laboratory studies were conducted on soils collected from 37 Wisconsin tobacco fields to evaluate their capacity to supply nitrogen for two successive tobacco crops. Correlation analyses were made between the nitrogen content of each crop and the nitrogen determined by the various soil tests on the samples taken before the first crop. Highly significant correlation coefficients of 0.97 and 0.90 were obtained for soil NO_3-N and Aspergilles niger test, respectively (Peterson et al., 1960)

Singh and Tripathi (1970) reported that nitrogen extracted by alkaline permanganate method was found to be best correlated with the nitrogen content of the plant. The alkaline $KMno_4$-N was found to be highly correlated with amino sugar nitrogen, HyAN and AaN (Srivastava, 1975)

All forms of nitrogen were significantly correlated with organic carbon and variations in these constitutents in relation to environmental factors followed a similar trend (Palaniappan, 1975). Despite noticeable difference in carbon and nitrogen content of soil, the C:N ratios remained practically unaffected signifying that both carbon and nitrogen were simultaneously and similarly affected. He also found a high degree of relationship with hydrolysable nitrogen and organic carbon (0.919**). In linear correlation alkaline $KMnO_4$ extracted available nitrogen was found to be highly correlated with amino sugar N, HyAN and AaN (Srivastava, 1975).

Thakur et al. (1976) found that the percentage of organic carbon content can be used as an index of available nitrogen in soil for making fertilizer recommendations. The relative contributor of different fractions of nitrogen to the available nitrogen was 75 per cent as estimated by organic carbon method and 64 per cent as estimated by alkaline $KMnO_4$ (Perumal and Velayutham, 1977).

Balasundaram (1978) based on his studies on the red soils (Typic Ustorthent) of Bhavanisagar, Tamil Nadu, reported a positive and significant relationship with exchangeable NH_4-N and alkaline $KMnO_4$-N. A significant negative correlation between FAN and organic carbon was observed in all the profiles studied in Punjab by Sah and Pasricha (1984). Sharma et al. (1984) found out a positive and significant correlation coefficient of 0.468*, on relating the hydrolysable NH_4 fraction to organic carbon of Ustoebrept. Perumal and Velayutham (1986) showed that this method of determination of available nitrogen could be improved by modifying in such a way that it will extract to less extent from UHyN and NHyN forms and to a greater extent from AaN and HyAN fractions.

Materials and Methods

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Materials and Methods

MATERIALS AND METHODS

To study the distribution of various organic and inorganic fractions of soil nitrogen in different soil types of Kerala, 100 surface soil samples belonging to five types were selected from various districts of the state. The five soil types were laterite, brown hydromorphic, coastal alluvium, Kuttanad alluvium and forest soil. The details of soils collected are given in Table 1.

Surface soils of 0-15 cm depth were collected during summer. The samples were air dried in shade, gently powdered, passed through a 2 mm sieve and stored in properly labelled bags.

The important features of the soils collected, are given below.

1. Laterite

Laterites of Kerala are typical kaolinitic weathering products of gneissic and granitic rocks, developed under humid tropical conditions. The surface soil, which is reddish brown to yellowish red, is mostly gravelly loam to gravelly clay loam in texture. The plinthite is characterised by a compact vesicular mass below the B horizon, composed essentially of a mixture of hydrated oxides of iron and aluminium. Laterites are in general poor in available nitrogen, phosphorus and potassium and are low in bases. They are generally oxidic and low in organic matter content. These soils respond well

Table 1(a) Location of the soil samples
Laterite soil

Sl.No.	Sample No	Place of collection	District
1	L_1	Ollur	Thrissur
2	L_2	Pudukkad	,,
3	L [illegible]	Kodakara	,,
4	L_4	Kadukutty	,,
5	L_5	Unnikulam	Kozhikode
6	L_6	Naduvannur	,,
7	L_7	Kakkodi	,,
8	L_8	Nadakavu	Malappuram
9	L_9	Kuttipuram	,,
10	L_{10}	Valanchery	,,
11	L_{11}	Vattamkulam	,,
12	L_{12}	Kottakal	,,
13	L_{13}	Pulamenthol	,,
14	L_{14}	Kooriyadu	,,
15	L_{15}	Panampra	,,
16	L_{16}	Chelampra	,,
17	L_{17}	Cheruvannur	Kozhikode
18	L_{18}	Ulleri	,,
19	L_{19}	Okkal	Ernakulam
20	L_{20}	Patiparambu	Malappuram

Table 1(b). Location of the soil samples
Forest soil

Sl.No.	Sample No.	Place of collection	District
1	F_1	Silentvalley	Palakkad
2	F_2	Arippa	Thiruvananthapuram
3	F_3	Kulamavu	Idukki
4	F_4	Muthanga	Wayanad
5	F_5	Nilambur	Malappuram
6	F_6	Konni	Pathanamthitta
7	F_7	Ranni	Pathanamthitta
8	F_8	Iravikulam	Idukki
9	F_9	Peerumedu	Idukki
10	F_{10}	Peechi	Thrissur
11	F_{11}	Malayattoor	Ernakulam
12	F_{12}	Karulai	Malappuram
13	F_{13}	Agali	Palakkad
14	F_{14}	Cheruvannur	Kozhikode
15	F_{15}	Sholayar	Thrissur
16	F_{16}	Mavoor	Kozhikode
17	F_{17}	Thattekkad	Ernakulam
18	F_{18}	Punalur	Kollam
19	F_{19}	Kumarakom	Kottayam
20	F_{20}	Rajagiri	Kasaragod

Table 1(c). Location of the soil samples
Brown hydromorphic soil

Sl.No.	Sample No.	Place of collection	District
1	B_1	Nenmanikkara	Thrissur
2	B_2	Karoor	,,
3	B_3	Kolazhi	,,
4	B_4	Nelluvai	,,
5	B_5	Chovvannur	,,
6	B_6	Choondal	,,
7	B_7	Pattikad	,,
8	B_8	Vadakenchery	Palakad
9	B_9	Chillenchery	,,
10	B_{10}	Kollenkode	,,
11	B_{11}	Vadavannur	,,
12	B_{12}	Puthiyanagar	,,
13	B_{13}	Nanmanda	Kozhikode
14	B_{14}	Kollumpuram	,,
15	B_{15}	Edavakod	Malappuram
16	B_{16}	Vellanikkara	Thrissur
17	B_{17}	Mulakulam	Kottayam
18	B_{18}	Piravam	Ernakulam
19	B_{19}	Koothattukulam	,,
20	B_{20}	Atholi	Kozhikode

Table 1(d). Location of the soil samples
Coastal alluvium

Sl.No.	Sample No.	Place of collection	District
1	C_1	Guruvayoor	Thrissur
2	C_2	Chattukulam	,,
3	C_3	Karuvatta	Alappuzha
4	C_4	Haripad	,,
5	C_5	Chepad	,,
6	C_6	Chengoli	,,
7	C_7	Pathiyoor	,,
8	C_8	Kayamkulam	,,
9	C_9	Krishnapuram	,,
10	C_{10}	Ochira	,,
11	C_{11}	Kulasekharapuram	,,
12	C_{12}	Karunagappilly	Kollam
13	C_{13}	Nattika	Thrissur
14	C_{14}	Ezhumuna	Alappuzha
15	C_{15}	Maraikulam	,,
16	C_{16}	Cherthala	,,
17	C_{17}	Athyad	,,
18	C_{18}	Charamangalam	,,
19	C_{19}	Mannar	,,
20	C_{20}	Pattanakad	Thrissur

Table 1(e). Location of the soil samples
Kuttanad alluvium

Sl.No.	Sample No.	Place of collection	District
1	K_1	Ramankari	Alappuzha
2	K_2	Nedumudi	,,
3	K_3	Thakazhi	,,
4	K_4	Veliyanadu	,,
5	K_5	Kainakari	,,
6	K_6	Vezhapuram	,,
7	K_7	Moncombu	,,
8	K_8	Pulinkunnu	,,
9	K_9	Thalavady	,,
10	K_{10}	Neelamperur	,,
11	K_{11}	Thottappally	,,
12	K_{12}	Ambalapuzha	,,
13	K_{13}	Vaikom	Kottayam
14	K_{14}	Vechoo	,,
15	K_{15}	Thannirmukkam	Alappuzha
16	K_{16}	Udayanapuram	,,
17	K_{17}	Changanachery	Kottayam
18	K_{18}	Kavalam	Alappuzha
19	K_{19}	Kumarakom	Kottayam
20	K_{20}	Thottakam	Alappuzha

to management practices. They cover about 65 per cent of the total area of the State and are the most extensive of the soil groups found in Kerala.

2. Coastal alluvium

These soils are seen in the coastal tracts along with west as a narrow belt with an average width of about 10 km and have been developed from recent marine deposits The texture is dominated by sand fraction. The 'A' horizon is usually thin and the surface textures observed are loamy and sandy loam. The water table is high in low-lying areas These soils are acidic and of low fertility level. The low content of organic matter and clay has resulted in low cation exchange capacity of the soil

3. Brown hydromorphic

These soils are mostly confined to valley bottoms of undulating topography in the midland and in low-lying areas of coastal strip. They have been formed as a result of transportion and sedimentation of material from adjacent hill slopes and also through deposition by rivers. They exhibit wide variation in physico-chemical properties and morphological features The development of soil profiles has occurred under impeded drainage conditions. They are moderately supplied with organic matter, nitrogen and potassium and are deficient in lime and phosphate

4. Kuttanad alluvium

The Kuttanad region covering about 875 sq km is an unique agricultural area in the world. A good portion of this area lies 1-2 m below the sea level and is submerged for major part of the year. The area is susceptible to seasonal ingress of saline water as a result of tidal inflow from the sea. Soils of Kuttanad form the typical waterlogged soils and are entirely different from normal well drained soils in their morphological, chemical and physical characteristics. They can be grouped into three categories viz., kayal, karappadam and kari soils.

(i) Kayal soils

The kayal soils are found in the reclaimed lake beds in Kottayam and Alappuzha districts. These soils are slightly acidic, medium in organic matter and poor in total and available nutrients; but are fairly rich in calcium. They are seriously affected by salinity.

(ii) Karappadam soils

The karappadam soils occur along the inland waterways and rivers, and are distributed over a large part of upper Kuttanad. These soils are characterised by high acidity, high salt content and fair amount of decaying organic matter. They are generally poor in available nutrients, particularly phosphorus.

(iii) Kari soils

The kari soils resemble peat soils. They occur in patches in the districts of Alappuzha, Kottayam and Ernakulam. These are black, poorly drained, heavy textured soils distributed in flat areas lying 1 or 2 m below the sea level The profiles exhibits typical aquic characteristics. Decomposed organic matter is often observed in the lower layers. These soils are highly acidic and accumulation of salts to toxic level often affects the crop growth and yield in this region.

5. Forest loam

As the name indicates, these soils are the products of weathering of crystalline rocks under forest cover. They have immature profiles with shallow soils. In areas with lesser canopy cover, signs of laterisation have been observed in the profiles. These soils are generally acidic with the pH ranging from 5.5 to 6.3. They are rich in nitrogen but poor in bases because of heavy leaching.

The following analysis were undertaken using these selected soils

1) pH
2) Electrical conductivity
3) Particle size analysis
4) Organic carbon

5) Cation exchange capacity

6) Total nitrogen

7) Available nitrogen

8) Plant available nitrogen

9) Fractionation of nitrogen

10) Total phosphorus and total potassium

11) Exchangeable Ca and Mg

1. pH

The pH of 1:2.5 soil water suspension was measured using a pH meter.

2. Electrical conductivity

Electrical conductivity of the soil solution (1:2 5) was determined using a digital conductivity bridge

3. Particle size analysis

Particle size distribution was determined by the hydrometer method as described by Piper (1942). Here, the density of the suspension at a given depth as a function of time was calculated. Forty gram of air dried soil was thoroughly dispersed in 10 ml of 1.5 per cent sodium hexametaphosphate solution by stirring in a mechanical shaker for 30 min. The dispersion mixture was transferred to a 1000 ml stoppered cylinder and hydrometer readings were taken after 4 min and 2 h. The first reading accounted for silt and clay and second for clay alone.

4. Organic carbon

Organic carbon was determined by the method of Walkley and Black (1934) in which the soil was digested with standard potassium dichromate and sulphuric acid and the excess chromic acid was back titrated against standard ferrous sulphate using ferroin as indicator

5. Cation exchange capacity

In a weighed sample of soil, cations were displaced by ammonium by leaching the soil with neutral normal ammonium acetate solution. The excess of ammonium acetate was removed by washing with alcohol. The soil was then distilled with magnesium oxide, the ammonia liberated being absorbed in a known excess of standard acid. The excess acid was titrated with standard alkali and the cation exchange capacity was calculated.

6. Total nitrogen

Total nitrogen was determine by microkjeldhal method (Jackson, 1958). In this method, all forms of nitrogen were converted into sulphate of ammonia by digestion with sulphuric acid and catalyst mixture. A water extract of the sulphate of ammonia was distilled with excess alkali and distillate was collected in a 2 per cent solution of boric acid.

7. Available nitrogen

Available nitrogen was determined by alkaline permanganate method suggested by Subbiah and Asija (1956). Here, the amount of soil nitrogen released by alkaline permanganate solution (100 ml 0.32 per cent potassium permanganate and 100 ml of 2.5 per cent sodium hydroxide) from 20 g soil was estimated by distillation procedure Care was taken to see that a fixed volume of distillate was collected in standard acid each time The excess acid was then back titrated against standard alkali using methylred indicator.

8. Determination of plant available nitrogen

For the determination of plant available nitrogen, a laboratory experiment by modified Neubauer seedling method was done. In this technique 100 rice seedlings were made to feed exhaustively on 100 g of soil mixed with 50 g of sand for 17 days in dishes of 11 cm diameter and 7 cm depth. Nitrogen uptake was calculated from the dry weight and total nitrogen percentage.

9. Fractionation of soil nitrogen

The fractionation of soil nitrogen was carried out by an adapted version of the flow sheets given by Cheng and Kurtz (1963) and Keeney and Bremner (1964) The individual fractions were estimated as described by Bremner (1965)

a) Exchangeable NH_4^+ - nitrogen (NH_4-N) The soil samples (0 5 mm sieved) were extracted with 2N KCl in a 1 10 soil to KCl ratio by shaking for 1 h and filtered off using Whatman No 1 filter paper. Leachate was collected and an aliquot of this was distilled with magnesium oxide in Bremner apparatus as described by Bremner (1965).

b) Nitrate nitrogen (NO_3-N). Further distillation of the above with Devarda's alloy in the Bremner set (Bremner, 1965).

c) Total hydrolyzable nitrogen (THyN) The soil residue left after leaching with 2N KCl was transferred to 500 ml conical flask and 6N HCl was added (soil : HCl ratio 1 : 4). The suspension was digested for 12 h in a water bath at 100°C under reflux. The hydrolysate mixture was filtered through Whatman No.50 filter paper. The residue was washed with 3 or 4 washings of distilled water to make the volume approximately 150 ml. The pH of the extract was adjusted to 5.0 by dropwise addition and constant stirring with 5N NaOH and finally the pH was adjusted to 6.5 ± 0.1 with 0.5N NaOH using Beckman pH meter. The neutralised extract was transferred to a 250 ml volumetric flask and made to volume with distilled water The soil residue left on the filter paper was preserved for estimation of fixed ammonium in soil.

Ten ml of the above neutralised extract was digested with 1 g of K_2SO_4 - $CaSO_4$ - Se catalyst mixture and 2 ml of concentrated

H_2SO_4 in a 100 ml Kjeldahl digestion flask continuously for one hour. The digested material was cooled and distilled in the Bremner apparatus under alkaline conditions using 20 ml of 10N NaOH. The distillate was absorbed in 100 ml of 2 per cent boric acid and titrated with 0 005N H_2SO_4.

d) Hydrolyzable ammoniacal nitrogen (HyAN): An aliquot (25 ml) of neutralised hydrolysate was distilled with about 0.15 g of MgO as mentioned in Part (a) above

e) Hexosamine and hyddrolyzable ammoniacal nitrogen: Twenty five ml of the neutralised hydrolyzate was taken in Bremner distillation flask. Twenty five ml of phosphate borate buffer (pH 11.2) was added. The distillation was then carried out with MgO as described in Part (a) above.

f) Hexosamine nitrogen (HaN): It was found out by taking the difference of the values obtained in (e) and (d) mentioned above.

g) Amino acid nitrogen (AaN): Five ml of hydrolyzate was taken in a 50 ml conical flask. One ml of 0.5N NaOH was added and the content of the flask was heated in water bath (100°C) until the volume of the same get reduced to 3 ml. After cooling, 500 mg of citric acid and 100 mg of ninhydrin were added to the flask and kept immersed in a water bath (100°C). After 1 min, the flask was swirled for a few seconds, without removing it from the water bath and then allowed to remain in the water bath for additional 9 min The flask along with the content was then cooled and the content was transferred to Bremner distillation flask by giving washings with distilled water. Ten ml of phosphate borate buffer (pH 11.2) and 1 ml of 5N NaOH were added and distillation was carried out as described in Part (a)

h) Unidentified hydrolyzable forms of nitrogen (UHyN): This was got by substracting the sum of HyAn, HaN and AaN from THyN

i) Non-hydrolyzable forms of unidentified nitrogen (NHyN): This was also found out by difference, by substracting the THyN and inorganic nitrogen from total nitrogen.

j) Fixed ammoniacal nitrogen (FAN): The residue left after acid hydrolysis in Part (c) was transferred to a 500 ml polythene flask. One hundred ml of a mixture of 5N HF and 1N HCl was added (soil . mixture ratio 1 : 5) mixed well and allowed to remain covered for 24 h at room temperature The suspension was filtered through Whatman filter paper No.42 in polyethylene flask. The entire leachate was transferred to Bremner distillation flask and distilled with 125 ml 10N NaOH as in Part (a).

10. Total phosphorus and potassium

Hydrochloric acid extract of the soil was used for estimating this (Jackson, 1958). Total phosphorus was determined by the vanado-molybdo phosphoric yellow colour method and total potassium was determined using a flame photometer. Both these were carried out using one composite sample belonging to each type.

11. Exchangeable calcium and magnesium

The ammonium acetate leachate obtained at the time of determination of CEC was made use for the determination of exchangeable cations (Piper, 1942). Exchangeable Ca and Mg were determined by the versenate titration method (Hesse, 1972).

12. Statistical analysis

The data were examined statistically making use of the principles of correlation and regression as described by Panse and Sukhatme (1967).

Results and Discussion

RESULTS AND DISCUSSION

The present study was undertaken to find out the various fractions of nitrogen in the important soil types of Kerala, and to assess the relative contribution of each fraction to the available nitrogen pool of the soil Fractionation of nitrogen was done in five important soil types viz., laterite, forest, brown hydromorphic, coastal alluvium and Kuttanad alluvium

1. Laterite soil

1.1. General characteristics (Table 2)

The soils belonging to this type were only slightly acidic and the pH values were mostly in the range of 5.4 to 7.00 Particle size distribution studies showed the predominance of sand 50 to 81 per cent) followed by clay (10 to 34 per cent) and silt (8 to 19 per cent) Cation exchange capacity was rather high and ranged between 8.8 and 29.3 cmol(p^+) kg^{-1}. Organic carbon content was appreciable in some samples while it was rather low in a few. The values ranged from 0 50 to 2 65 per cent with a mean of 1.12 per cent. The mean values for total phosphorus and potassium were 48.8 ppm and 5200 ppm respectively.

The content of exchangeable calcium was 4.65 cmol(p^+) kg^{-1} and that of magnesium was 1.074 cmol(p^+) kg^{-1}.

Table 2. General characteristics of the soils

Soil type	pH	EC dSm^{-1}	CEC $cmol(p^+)kg^{-1}$	Mechanical analysis Sand (%)	Mechanical analysis Silt (%)	Mechanical analysis Clay (%)	Textural class	Total N	Total P_2O_5	Total K_2O	Exchangeable Ca $cmol(p^+)kg^{-1}$	Exchangeable Mg $cmol(p^+)kg^{-1}$	OC (%)
Laterite	6.10	0.18	18.89	67.06	12.40	20.89	Sandy clay loam	0.17	48.80	5200	4.65	1.074	2.12
Forest	5.50	0.17	27.83	67.01	8.15	24.34	"	0.27	87.50	6200	8.95	3.580	1.12
Brown hydromorphic	5.60	0.07	20.25	64.91	13.70	21.84	"	0.30	32.30	3200	1.79	2.240	0.91
Coastal alluvium	6.60	0.15	8.48	80.60	4.20	12.30	Loamy sand	0.18	10.20	2400	2.84	0.900	0.34
Kuttanad alluvium	4.70	2.65	19.38	61.39	16.45	22.29	Sandy clay loam	0.16	20.80	3800	4.30	3.400	1.56

1.2. Total and available nitrogen and fractionation of nitrogen

The total nitrogen content of the laterite soils selected for the present study varied from 0.105 to 0 294 per cent with a mean value of 0.174 per cent (1740 ppm). Fractionation of soil nitrogen into inorganic and organic components has shown that the content of these fractions vary widely and present mean values of 473 and 1264 ppm respectively for the inorganic and organic fractions The data on various fractions of nitrogen in laterite soils are given in Tables 3a and 3b The inorganic nitrogen fractions (including ammoniacal, nitrate and fixed ammonium) account for 27 per cent of the total nitrogen and the remaining 73 per cent is constituted by various organic nitrogenous compounds.

From the data presented in Tables 3a and 3b, it may be seen that among the various fractions the maximum content is recorded for AaN followed by FAN, NHyN, HaN, UHyN, NH_4-N, NO_3-N and HyAN in the descending order. Amino acid nitrogen is reported to be very important fraction contributing to the release of nitrogen as mineral nitrogen (Srivastava, 1975). Stewart et al. (1963) found that change in AaN was closely related to inverse changes in inorganic nitrogen of the soil

Percentage contribution of various nitrogen fractions to total nitrogen is given in Fig 1 Of the total nitrogen 27.59 per cent was AaN, 20 69 per cent FAN, 16 67 per cent NHyN, 14 94 per cent

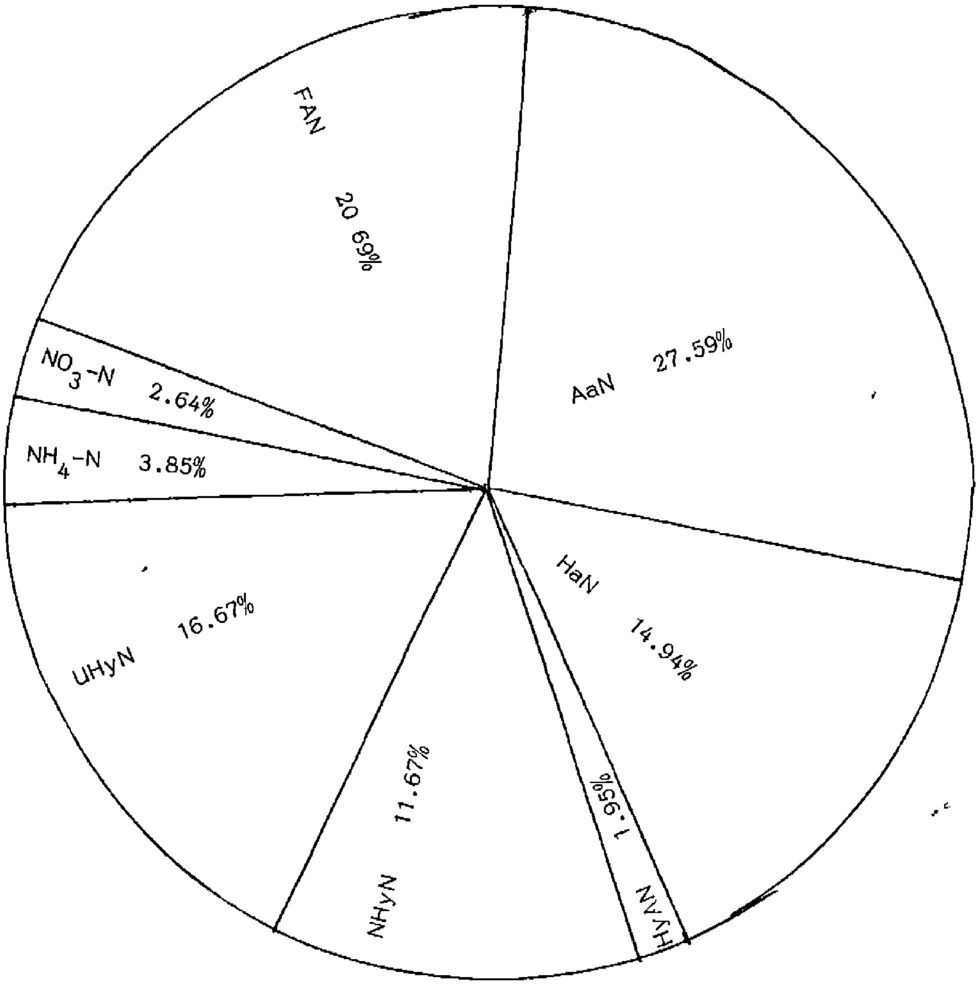


Fig. 1. Nitrogen fractions in laterite soil (expressed as percentage to total N)

Table 3a. Total N, alkaline $KMnO_4$-N and inorganic fractions of N in laterite soil, ppm

Sample No.	Total N	Alkaline $KMnO_4$-N	NH_4-N	NO_3-N	FAN
L_1	1750	121	46(2 9)	54(3.1)	380(21.7)
L_2	1050	127	40(3.8)	29(2.8)	270(25 7)
L_3	1680	181	37(2 2)	38(2.3)	390(23.2)
L_4	1400	174	67(4.8)	54(3.9)	250(17.9)
L_5	2300	300	62(2.7)	9(0 4)	270(11 7)
L_6	1750	128	96(5.5)	71(4.1)	320(18.3)
L_7	1330	194	50(3.8)	31(2 3)	310(23.3)
L_8	2170	154	86(4.0)	67(3.1)	500(23.0)
L_9	1400	228	84(6.0)	46(3.3)	260(18.6)
L_{10}	2940	241	115(3.9)	86(2.9)	710(24.2)
L_{11}	1120	121	94(8.4)	54(4.8)	230(20.5)
L_{12}	2030	301	36(1.8)	30(1.5)	280(13 8)
L_{13}	1680	140	88(5.2)	70(4.2)	380(22.6)
L_{14}	1540	327	106(6 9)	57(3.7)	210(13.6)
L_{15}	1960	294	79(4 0)	53(2.7)	500(25.5)
L_{16}	1610	77	40(2.5)	-	320(19.9)
L_{17}	1540	221	25(1 6)	64(4.2).	390(25.3)
L_{18}	1680	127	34(2.0)	32(1 9)	460(27.4)
L_{19}	1540	77	39(2.5)	25(1.6)	240(15.6)
L_{20}	2380	307	107(4.5)	49(2.1)	540(19.8)
Mean	1740	192	67	46	360

Values in parantheses are percentage to total nitrogen

Table 3b Organic fractions of nitrogen in laterite soil, ppm

Sample No.	Aan	HaN	HyAN	UHyN	THyN	NHyN
L_1	270(15.4)	330(18.9)	-	400(22.9)	1000(57 2)	270(15.4)
L_2	470(44.8)	180(17.1)	50(4.8)	10(1.0)	710(67.6)	1(0.1)
L_3	430(25 6)	200(11 9)	-	420(25.0)	1050(62 5)	165(9 8)
L_4	550(39.3)	130(9.3)	50(3.6)	220(15.7)	950(67.9)	79(5.6)
L_5	420(18 3)	300(13.0)	50(2.2)	650(28.3)	1420(61.7)	539(23 4)
L_6	510(29.1)	170(9.7)	60(3.4)	510(29.1)	1250(71.4)	13(0.7)
L_7	390(29 3)	330(24.8)	50(3.8)	20(1.5)	790(59 4)	149(11 2)
L_8	460(21.2)	270(12.4)	60(2.8)	590(7.4)	1380(63.6)	137(26.1)
L_9	460(32 9)	210(15 0)	-	310(22.1)	980(70.0)	30(2 1)
L_{10}	490(16 7)	300(10.2)	30(1.0)	300(10.2)	1120(38.1)	909(30.9)
L_{11}	390(34 8)	170(15.2)	80(7.1)	90(8.0)	730(65.2)	42(3.8)
L_{12}	840(41.4)	380(18.7)	50(2.5)	310(15.3)	1580(77.8)	164(8.1)
L_{13}	470(28.0)	300(17.9)	-	350(20.8)	1120(66.7)	22(1 3)
L_{14}	630(40.9)	200(12.6)	80(5.2)	220(14.3)	1130(73.4)	200(13.0)
L_{15}	700(35 7)	220(11 2)	80(5.1)	80(4.1)	1080(55.1)	248(12 7)
L_{16}	560(34.8)	210(13.0)	80(5.0)	50(3.1)	900(55.9)	350(21.7)
L_{17}	300(19.5)	230(14.9)	-	220(14 3)	750(48 7)	311(20.2)
L_{18}	530(31.6)	280(16.7)	-	220(13.1)	1030(61 3)	124(7.4)
L_{19}	290(18 8)	350(22.8)	-	480(31.2)	1120(72.7)	116(7.5)
L_{20}	470(19.8)	500(21.0)	-	530(22.3)	1500(63.0)	184(7.7)
Mean	480	260	34	200	1002	290

* Values in parantheses are percentage to total nitrogen

HyAN, 11 67 per cent UHyN, 3.85 per cent NH_4-N, 2.64 per cent NO_3-N and 1.95 per cent HyAN

In the organic fractions, the hydrolysable nitrogen constituted 79 27 per cent which under favourable soil conditions can undergo mineralisation and become available to the plants. Total hydrolysable nitrogen contributed 58 per cent of total nitrogen. Total hydrolysable nitrogen upto 61.0 per cent of total nitrogen was reported by Perumal (1975) in the Adanur Series and Varghese (1988) in the Somayannur Series of Tamil Nadu.

Among the different fractions of nitrogen AaN forms the major part with a per cent contribution of 27.6 per cent This is in confirmity with the findings of Aggarwal et al. (1977), Swarajyalakshmi (1987) and Varghese (1988).

The native fixed ammonium content of the laterite soil comes to 20.69 per cent of total nitrogen. Most of the soil samples of the laterite type were collected from non-cropped area. In the fallow soil the release of non-exchangeable NH_4^+ was virtually nil (Mengel et al., 1990). So the highest fixed ammonium content may be due to the inclusion of fallow soil samples in the study.

Mengel and Seherer (1981) have shown that NH_4^+ release followed root growth, and Seherer (1984) demonstrated that a substantial release of non-exchangeable NH_4^+ was obtained only if the soil was cropped

2. Forest soil

2 1. General characteristics (Table 2)

The pH of these soils ranged from 5 2 to 7.2. As in the case of laterite soil, here also sand fraction showed the predominance (52 to 78 per cent) followed by clay (17 to 40 per cent) and silt (2 to 20 per cent). CEC was rather high and ranged between 8.38 to 37.4 cmol(p^+) kg^{-1}. Among the five types, organic carbon content was maximum for this type (0.64 to 5 04 per cent) The mean values of total phosphorus and potassium were 87.50 ppm and 6200 ppm. The content of exchangeable calcium was 8.95 cmol(p^+) kg^{-1} and that of magnesium was 3.58 cmol(p^+) kg^{-1}.

2.2 Total and available nitrogen and fractionation of nitrogen

The data on various fractions of nitrogen in forest soils are given in Tables 4a and 4b.

The mean value of total nitrogen content of the forest soil was 0.304 per cent (3040 ppm), which was quite high compared to the nitrogen status of the other soil types selected for the study (0.105 to 0.490 per cent). Out of this, the inorganic nitrogen content was 475 ppm i.e., only 16 per cent of the total nitrogen. Eighty four per cent of the total nitrogen thus resides in the organic fraction.

Among the organic fractions, the THyN recorded a mean value of 1302 ppm (620 to 1950) i.e., 51 per cent of the total organic

Table 4a. Total N, alkaline $KMnO_4$-N and inorganic fractions of nitrogen in forest soil, ppm

Sample No.	Total N	Alkaline $KMnO_4$-N	NH_4-N	NO_3-N	FAN
F_1	4900	699	369(7 5)	94(1.9)	530(10 8)
F_2	3010	194	96(3.2)	57(1.9)	200(6.7)
F_3	3990	261	94(2.3))	58(1.5)	150(3.8)
F_4	3380	154	67(2.0)	47(1.4)	400(11.8)
F_5	1820	148	72(3 9)	49(2.7)	60(3.3)
F_6	2520	274	83(3.2)	53(2.1)	300(11.9)
F_7	3710	267	152(4 0)	66(1.8)	760(20.5)
F_8	3290	294	136(4.1)	69(2.1)	190(5.8)
F_9	3100	208	90(2.9)	54(1.7)	320(1.3)
F_{10}	3290	241	62(1 8)	42(1 3)	190(5 8)
F_{11}	2800	307	58(2.1)	49(1.8)	560(20.0)
F_{12}	2730	241	66(2.4)	54(2.0)	550(20.2)
F_{13}	3640	208	103(2 8)	62(1.7)	420(11.5)
F_{14}	1050	88	75(7.1)	51(4.9)	270(25.7)
F_{15}	2450	247	67(2.7)	43(1.8)	290(11.8)
F_{16}	3010	427	80(2.7)	59(2.0)	290(9 6)
F_{17}	2240	154	88(3.9)	62(2.6)	230(10.3)
F_{18}	2030	234	93(4.6)	49(3.1)	90(4.4)
F_{19}	3920	208	61(1 5)	31(1.3)	350(8.9)
F_{20}	1820	254	119(6.5)	53(1.7)	310(17.0)
Mean	3040	255	102	53	320

Values in paranthe\u0073es are percentage to total nitrogen

Table 4b. Organic fractions of nitrogen in forest soil, ppm

Sample No.	AaN	HaN	HyAN	UHyN	THyN	NHyN
F_1	280(5.7)	490(1 6)	100(2.0)	640(13.1)	1510(30.8)	3397(69.3)
F_2	350(11.6)	380(12 0)	50(1.7)	920(30.6)	1700(56.5)	957(31.8)
F_3	530(13.3)	480(12.0)	-	120(30 1)	1130(28.3)	2558(64.1)
F_4	390(11.5)	380(11.2)	50(15 0)	180(53.3)	1000(29.6)	1866(55.2)
F_5	630(34.6)	230(12.6)	50(27.5)	40(2.2)	950(52.2)	689(37.9)
F_6	700(27 8)	330(13 1)	-	190(7 5)	1220(48.4)	934(37.1)
F_7	1120(30 2)	700(18.9)	50(1.4)	80(2.2)	1950(52.6)	782(21.1)
F_8	300(9.1)	500(15.2)	80(2 4)	720(21 9)	1600(48.6)	1295(39.4)
F_9	630(45.0)	280(9 3)	150(4.8)	890(28.7)	1950(62.9)	686(22 1)
F_{10}	370(11.3)	280(8.5)	30(0 9)	170(5 2)	850(25.8)	2146(65.2)
F_{11}	700(25.00)	290(8 8)	300(10.7)	10(0 4)	1300(46.4)	833(29.8)
F_{12}	630(23.1)	540(19.8)	40(1 5)	60(2.2)	1270(46.5)	790(28.9)
F_{13}	540(14.8)	250(6 9)	80(2 2)	1110(30 5)	1980(54 4)	1075(29.5)
F_{14}	350(33.3)	150(14.3)	100(9 5)	20(1.9)	620(59.0)	34(3 2)
F_{15}	710(29.0)	250(10 2)	80(3.3)	50(2.0)	1090(44 5)	960(39.2)
F_{16}	940(31.2)	420(14.0)	130(4.3)	10(0 3)	1500(49.8)	1081(35.9)
F_{17}	540(24.1)	300(13.4)	30(1.3)	80(2.7)	950(42.4)	913(40.8)
F_{18}	490(24.1)	400(19.7)	-	440(21.7)	1330(65.5)	455(22.4)
F_{19}	240(6.1)	550(14.0)	80(2 0)	510(13.0)	1380(35 2)	3129(79.8)
F_{20}	410(22.5)	230(12 6)	50(2.8)	60(3.3)	750(41.2)	610(33 5)
Mean	540	370	70	315	1302	1260

Values in parantheses are percentage to total nitrogen

fractions. Compared to the laterite soil, the hydrolysable nitrogen fractions recorded only a lesser value. Unlike in the case of laterite soil, here the major fraction of nitrogen was in the nonhydrolysable form. The hydrolysis of soil was carried out with 6N HCl for a period of 12 hours As suggested by Stevenson (1957), this time might not be enough for liberating the hydrolysable nitrogen fractions viz , AaN, HaN etc. in the forest soil. He has suggested that optimum analytical conditions must be established for each type of soil when investigating the aminopolysaccharides in soils and also found that the time of maximum liberation of hexosamine with 6N HCl varied with the soil type. On examining the relationship between total nitrogen and available nitrogen of forest soil, it was seen that only 8 per cent of the total nitrogen was in the available form.

Percentage contribution of various nitrogen fractions to total nitrogen is given in Fig. 2. The total nitrogen content is very high and comes to 0.304 per cent. The higher litter production and deposition which has contributed to the highest content of organic matter in the forest soil is responsible for the high content of total N. Of this 41 45 per cent is accounted by NHyN, 17.86 per cent AaN, 12.24 per cent HaN, 10.36 per cent UHyN, 10.63 per cent FAN, 3.36 per cent NH_4-N, 2.37 per cent HyAN and 1.74 per cent NO_3-N.

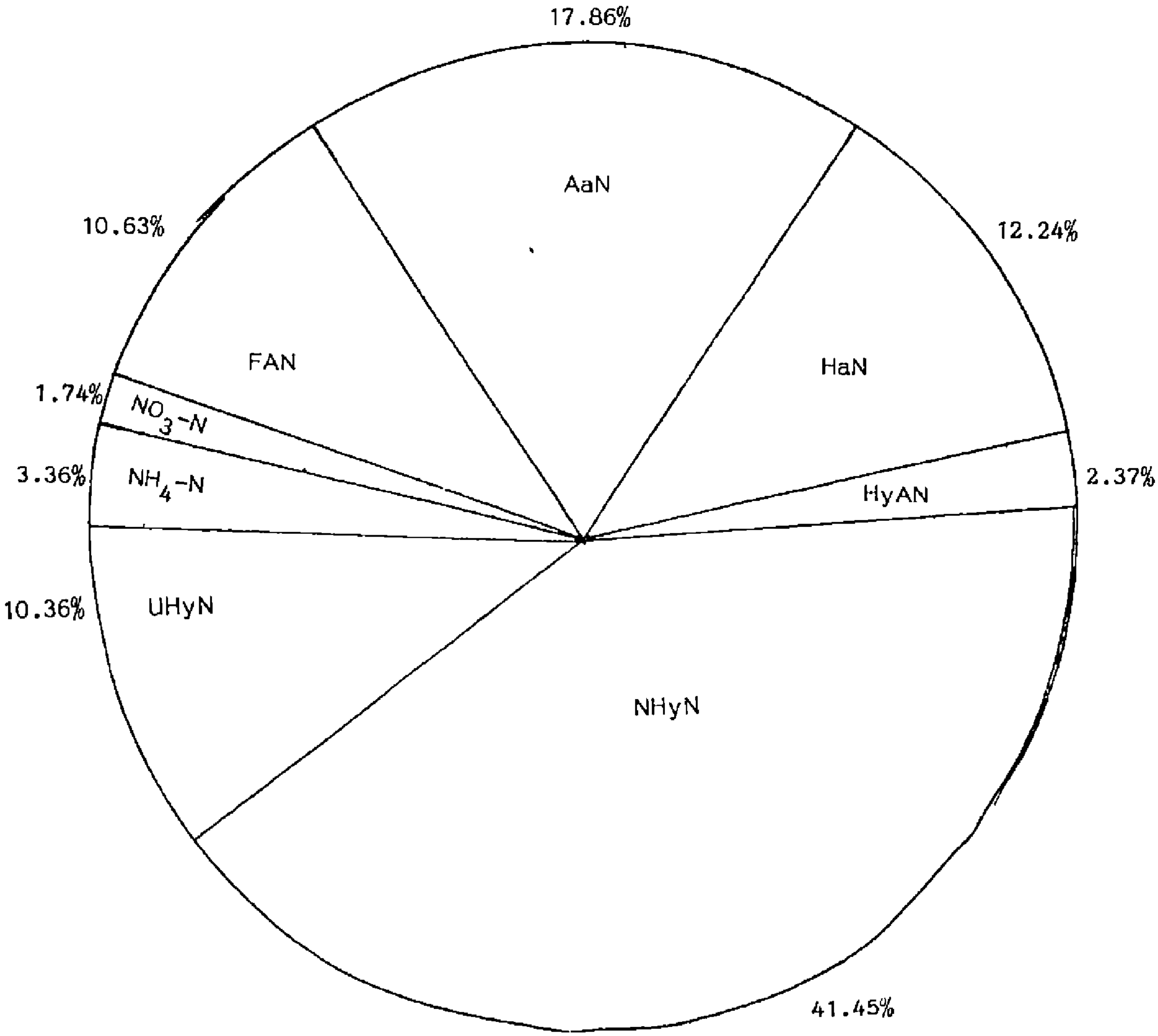


Fig.2. Nitrogen fractions in forest soil (expressed as percentage to total N)

3. Brown hydromorphic soil

3.1. General characteristics (Table 2)

Soils belonging to this type also were acidic in reaction. pH ranged from 4.9 to 6.8. Particle size distribution showed predominance of sand fraction (52 to 78 per cent), followed by clay (13 to 32 per cent) and silt (7 to 27 per cent) Cation exchange capacity ranged between 10 4 to 32.9 cmol(p^+) kg^{-1}. Organic carbon content ranged between 0.39 to 1.91 per cent The average amount of total phosphorus and potassium were 32 30 ppm and 3200 ppm. The content of exchangeable calcium was 1 79 cmol(p^+) kg^{-1} and that of magnesium was 2.24 cmol(p^+) kg^{-1}

3.2. Total and available nitrogen and fractionation of nitrogen

The data on various fractions of nitrogen in brown hydromorphic soils are given in Tables 5a and 5b.

The total nitrogen content of this type of soil was 0.180 per cent (range 0.112 to 0.287 per cent). Out of this the inorganic nitrogen fractions comes to 399 ppm i.e., 22 per cent of total nitrogen and the remaining 78 per cent was organic nitrogen. In classifying the organic nitrogen fractions to the hydrolyzable and non-hydrolyzable fractions, the THyN fractions recorded a mean value of 1208 ppm i.e., 79 per cent of the organic fractions Here, the THyN is found to be equal to the THyN of laterite soil

Table 5a. Total N, alkaline $KMnO_4$-N and inorganic fractions of nitrogen in brown hydromorphic soil, ppm

Sample No.	Total N	Alkaline $KMnO_4$-N	NH_4-N	NO_3-N	FAN
B_1	1680	150	20(1.2)	30(1.8)	290(17.3)
B_2	1190	13	60(5.0)	96(8.1)	190(16.0)
B_3	1610	1260	22(1.4)	11(0.7)	290(18.0)
B_4	1540	147	74(4.8)	54(3.5)	270(17.5)
B_5	1610	187	69(4.3)	22(1.4)	180(11.2)
B_6	1540	49	27(1 8)	27(1.8)	410(26.6)
B_7	1820	315	45(2.5)	17(0.9)	270(14 8)
B_8	1380	945	86(6.2)	58(4.2)	290(21.0)
B_9	1540	134	60(3.9)	61(4 0)	240(15.6)
B_{10}	1890	101	74(3 9)	24(1.3)	250(13.2)
B_{11}	1120	14	54(4.8)	34(3.0)	300(26.8)
B_{12}	1260	150	37(2.9)	20(1.6)	310(24.6)
B_{13}	1610	1197	33(2.1)	20(1.2)	130(8.1)
B_{14}	2590	1229	64(2.5)	-	520(20 1)
B_{15}	2870	260	46(1.6)	-	310(10.8)
B_{16}	1680	186	53(3.2)	21(1 3)	250(14.9)
B_{17}	2380	32	48(2 0)	230(9 7)	570(24.0)
B_{18}	2520	241	70(2.8)	50(2.0)	210(8.3)
B_{19}	2580	[illegible]7	59(2.3)	18(0.7)	540(20.9)
B_{20}	1540	120	64(4 2)	23(1 5)	450(29.2)
Mean	1800	345	56	33	310

Values in parantheses are percentage to total nitrogen

Table 5b. Organic fractions of nitrogen in brown hydromorphic soil, ppm

Sample No.	Aan	HaN	Hy AN	UHyN	THyN	NHyN
B_1	380(22.6)	150(8.9)	50(3.0)	200(11.9)	780(46 4)	560(33.3)
B_2	590(49 6)	50(4 2)	150(12 6)	10(0.8)	800(67 2)	44(3.7)
B_3	460(28.6)	170(10.6)	110(6 8)	210(13 0)	950(59.0)	337(20.9)
B_4	390(25 3)	280(18.18)	-	390(25.3)	1060(68.8)	82(5.3)
B_5	420(26.1)	200(12 4)	80(5 0)	150(9.3)	850(52.8)	489(30.4)
B_6	350(22.7)	260(16 9)	90(5 9)	550(35 7)	1250(81.2)	226(1 5)
B_7	510(28.0)	280(15.4)	-	310(17 0)	1100(60.4)	388(21.3)
B_8	130(9.4)	200(14.5)	-	420(30.4)	750(54.3)	196(14.2)
B_9	810(52 6)	250(16.2)	180(11.7)	160(10.4)	1400(90.9)	79(5.1)
B_{10}	420(22 2)	300(6.9)	130(6.9)	540(28 6)	1390(73 5)	152(8.0)
B_{11}	210(18 8)	230(20.5)	-	60(5.4)	500(44.6)	232(20.7)
B_{12}	390(31.0)	230(18.3)	50(4 0)	190(15.1)	860(68.3)	33(2.6)
B_{13}	210(13.0)	100(6.2)	100(6.2)	540(33.5)	950(59.0)	477(29.6)
B_{14}	230(8.9)	330(12.7)	-	840(32.4)	1400(54.1)	606(23.4)
B_{15}	560(19.5)	380(17 4)	70(2.4)	660(23.0)	1670(58.2)	354(12.3)
B_{16}	500(29.8)	150(8 9)	50(3 0)	370(22.0)	1070(63.7)	392(23 3)
B_{17}	470(19.8)	430(18.1)	-	800(33.6)	1700(71.4)	390(16 4)
B_{18}	280(11.1)	200(7 9)	120(4.8)	590(23.4)	1190(47.2)	940(37 3)
B_{19}	280(10 9)	420(16 3)	30(1 2)	200(7 6)	930(36.1)	933(36.2)
B_{20}	180(11.7)	239(14 9)	50(3.3)	290(18.8)	750(48.7)	253(16.4)
Mean	390	250	[illegible]	380	1208	330

Values in parantheses are percentage to total nitrogen

The available nitrogen recorded an average value of 345 ppm (13 to 1260 ppm). The contribution from the NH_4-N and NO_3-N comes to only 89 ppm. So contribution from the organic fractions to the available N-pool is established here. Unlike in the case of laterite and forest soil types, 19 per cent of the total nitrogen is in the available form. As in the case of laterite soil here also the maximum content is reported for the AaN. Being the important fraction contributing to the release of mineral nitrogen (Srivastava, 1975) the potential of the soil type to release nitrogen is established.

Percentage contribution of various nitrogen fractions to total nitrogen is given in Fig. 3. The mean content of total nitrogen is found to be 0.180 per cent of this 21.6 per cent accounted for AaN, 21.2 per cent UHyN, 18.2 per cent NHyN, 17.2 per cent FAN, 13.76 per cent HaN, 3.16 per cent HyAN, 3 11 per cent NH_4-N and 1.67 per cent NO_3-N. The reported maximum content AaN confirmed the results reported by Aggarwal et al. (1977), Swarajyalakshmi (1987) and Varghese (1988).

4. Coastal alluvium

4.1. General characteristics (Table 2)

Most of the soils of this type were near neutral in reaction, pH ranging from 5.8 to 7.4. In texture they were loamy sand and sand was the major fraction (75 to 93 per cent) followed by clay (3 to 24 per cent) and silt (2 to 8 per cent). Organic carbon content

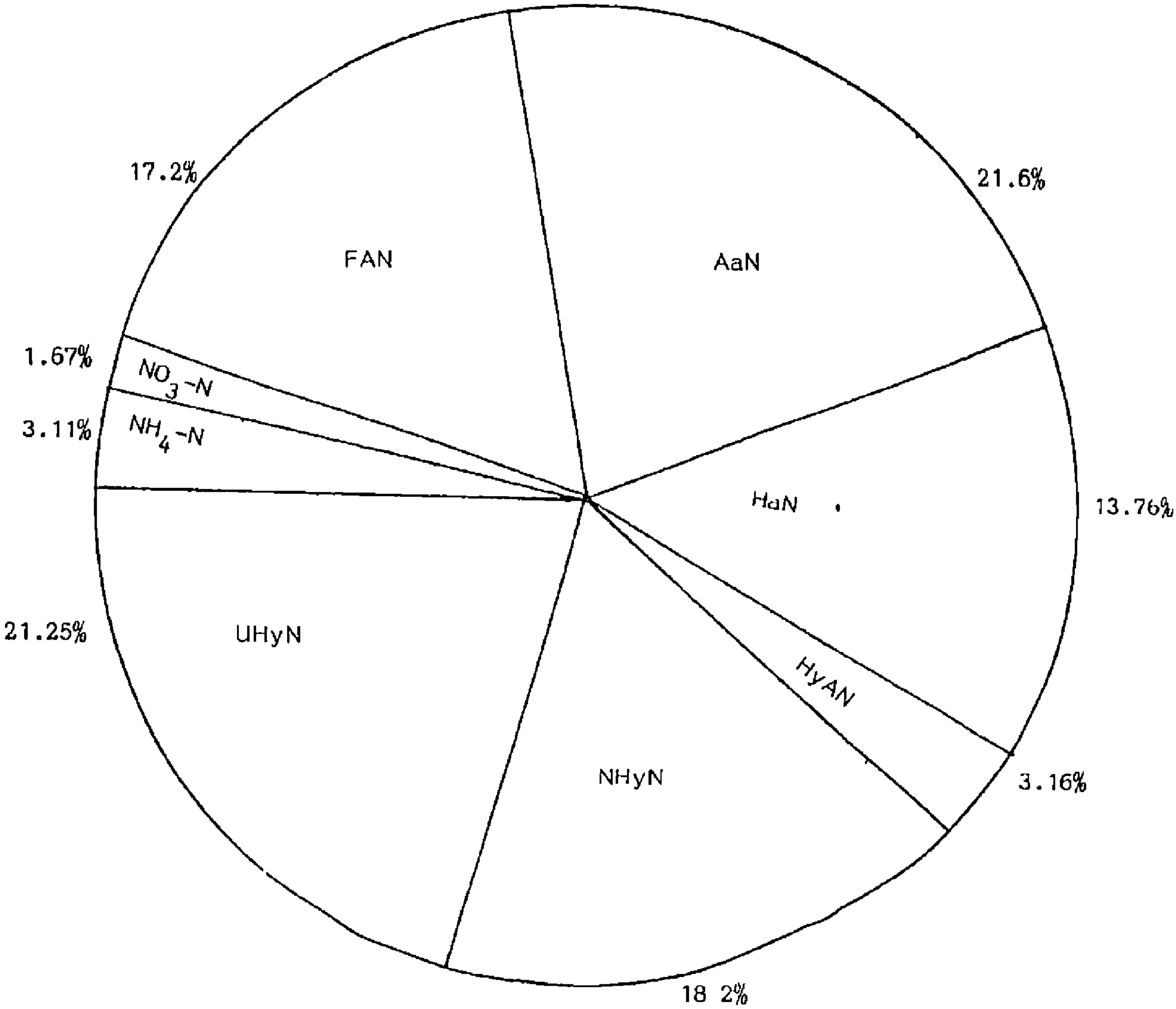


Fig.3. Nitrogen fractions in brown hydromorphic soil pressed as percentage to total N)

was very low (0.14 to 0.80 per cent). The average amount of total phosphorus and potassium were 10.20 ppm and 2400 ppm. The content of exchangeable calcium was 2.64 cmol(p^+) kg^{-1} and that of magnesium was 0.90 cmol(p^+) kg^{-1}.

4.2. Total and available nitrogen and fractionation of nitrogen

The total nitrogen content of the coastal alluvium comes to an average value of 0.161 per cent (range 0.840 to 0.329 per cent). The data on various fractions of nitrogen is given in Tables 6a and 6b. Out of this the inorganic nitrogen contribution is 278 ppm i.e., 17 per cent of total nitrogen and the organic nitrogen constitutes the remaining 83 per cent. Among the organic nitrogen fractions, the THyN recorded an average value of 850 ppm i.e., 73 per cent of the organic nitrogen fraction. For the laterite and brown hydromorphic also, THyN contributed almost the same percentage as that of organic nitrogen.

The available nitrogen recorded an average value of 66 ppm (14 to 154 ppm). The inorganic fractions viz., NH_4-N and NO_3-N together comes to a mean value of 78 ppm So unlike in other soil types, coastal alluvium, the entire available nitrogen might have come from these two inorganic fractions. The available nitrogen comes to only 4 per cent of the total nitrogen. Among the different soil types studied the coastal alluvium recorded the least available nitrogen content.

Table 6a. Total N, alkaline $KMnO_4$-N and inorganic fractions of nitrogen in coastal alluvial soil, ppm

Sample No.	Total N	Alkaline $KMnO_4$-N	NH_4-N	NO_3-N	FAN
C_1	1220	21	30(2.5)	-	160(13.1)
C_2	1760	54	27(1 5)	-	220(12 5)
C_3	2310	154	27(1.2)	-	270(11.7)
C_4	1540	88	50(3.6)	40(2.6)	170(11.0)
C_5	2380	88	22(0 9)	30(1.3)	260(10.9)
C_6	2100	21	109(5.2)	54(2 6)	180(8.6)
C_7	840	54	83(9.9)	48(5.7)	90(10.7)
C_8	900	88	45(5.0)	-	280(31.1)
C_9	1610	54	66(4.1)	43(2.7)	150(9.3)
C_{10}	1470	88	88(6.0)	64(4.4)	190(12.9)
C_{11}	2100	21	51(2.4)	8(0.4)	370(17.6)
C_{12}	1330	32	44(3.3)	58(4.4)	330(24.8)
C_{13}	1260	21	152(12.1)	56(4.4)	110(8.7)
C_{14}	1050	154	63(6.0)	39(3.7)	120(11.4)
C_{15}	1400	88	51(3.6)	41(2.9)	110(7.9)
C_{16}	2380	54	35(1.5)	5(0.2)	170(7.1)
C_{17}	3290	88	18(0.6)	22(0 7)	150(4.6)
C_{18}	1550	14	26(1.7)	-	220(14.2)
C_{19}	1400	21	5(0.4)	-	200(14.3)
C_{20}	1890	121	36(1.9)	56(3.0)	180(9.5)
Mean	1610	66	50	28	200

Values in parantheses are percentages to total nitrogen

Table 6b. Organic fractions of nitrogen in coastal alluvial soil, ppm

Sample No.	AaN	HaN	HyAN	UHyN	THyN	NHyN
C_1	320(26 2)	20(1.6)	80(6.6)	280(23.0)	700(57.4)	320(27.1)
C_2	150(8.5)	100(5.7)	50(2.8)	480(27.3)	780(44.3)	733(41.7)
C_3	670(29.0)	70(3.0)	23(1.0)	1010(43.7)	1773(76.8)	33(1.4)
C_4	380(24.7)	130(8.4)	200(13.0)	20(1.3)	730(47.4)	544(35.3)
C_5	320(13.5)	200(8.4)	-	600(25.2)	1120(47.1)	975(41.0)
C_6	280(13.3)	120(5.7)	90(4.3)	70(3.3)	560(26.7)	1207(57.5)
C_7	230(27.4)	100(11.9)	80(9.5)	190(22.6)	600(28.6)	19(2.3)
C_8	210(23.3)	180(20.0)	50(5.6)	60(6.7)	500(55.6)	75(8.3)
C_9	270(16.8)	50(3.1)	130(8.1)	230(14.3)	680(42.2)	671(41.7)
C_{10}	300(20.4)	150(16 2)	-	280(19.1)	730(49.7)	398(27.1)
C_{11}	510(24.3)	180(8.6)	-	400(19.1)	1090(51 9)	581(27.7)
C_{12}	380(28.6)	170(12.8)	130(9.8)	50(3.8)	730(54.9)	168(12.6)
C_{13}	340(27.0)	30(2.4)	50(11.9)	190(15.1)	610(48.4)	232(18.4)
C_{14}	350(33.3)	80(7.6)	200(19.1)	70(6.7)	700(66.7)	128(12.2)
C_{15}	230(16.4)	70(5.0)	80(5.7)	70(33.6)	450(32.1)	348(24.9)
C_{16}	510(21.4)	70(2.9)	130(5.5)	500(21.0)	1210(50.8)	960(40.3)
C_{17}	600(18.2)	100(3.0)	100(3 0)	150(4.6)	950(28.9)	590(17.9)
C_{18}	420(27.1)	150(9.7)	80(5.2)	430(27.7)	1080(69.7)	124(8.0)
C_{19}	290(20.7)	50(3.6)	100(7.1)	80(6.4)	530(37.9)	665(47.5)
C_{20}	420(22.2)	70(3.7)	130(6.9)	860(45.5)	1480(78.3)	138(7.3)
Mean	260	110	100	450	850	322

Values in parantheses are percentage to total nitrogen

Percentage contribution of various fractions to total nitrogen is given in Fig 4 Among the different soil types selected for the study, the coastal alluvium reported the least content of total nitrogen The mean total nitrogen content of this soil type comes to 0 1813 per cent. Of this 27 65 per cent is NHyN, 22.26 per cent AaN, 19.96 per cent UHyN, 12 4 per cent FAN, 6.51 per cent HaN, 6.26 per cent HyAN, 3.1 per cent NH_4-N andd 1.74 per cent NO_3-N.

5. Kuttanad alluvium

5 1. General characteristics (Table 2)

These soils were highly acidic in nature and average pH value was 4.7. Particle size distribution showed predominance of sand (32 to 75 per cent) followed by clay (7 to 40 per cent) and silt (8 to 26 per cent). CEC ranged from 10.4 to 36.95 cmol(p^+) kg^{-1}. Organic carbon content was appreciable in most of samples and ranged from 0.19 to 4.63 per cent. The average amounts of total phosphorus and potassium were 20.8 ppm and 3800 ppm. The content of exchangeable calcium was 4.30 cmol(p^+) kg^{-1} and that of magnesium was 3.40 cmol(p^+) kg^{-1}.

5.2. Total and available nitrogen and fractionation of nitrogen

The data on various fractions of nitrogen is given in Tables 7a and 7b.

The total nitrogen content of the Kuttanad alluvium is 0.2705 per cent. The inorganic nitrogen fractions contributed 609 ppm i e ,

Table 7a Total N, Alkaline $KMnO_4$-N and inorganic fractions of nitrogen in Kuttanad alluvial soil, ppm

Sample No.	Total N	Alkaline $KMnO_4$-N	NH_4-N	NO_3-N	FAN
K_1	2940	389	114(3.7)	202(6.9)	540(18.4)
K_2	2940	197	74(2 4)	59(2.0)	280(9.5)
K_3	3010	325	95(3.2)	71(2.4)	390(13 [illegible])
K_4	3640	261	92(2.5)	203(5.6)	550(15.1)
K_5	2310	197	91(3.9)	117(5.1)	420(18.2)
K_6	3220	197	154(4.7)	95(3.0)	390(12.1)
K_7	2660	166	146(5 5)	438(16.5)	410(15 4)
K_8	1960	32	56(2.9)	38(19.4)	190(19.7)
K_9	2240	261	132(5.8)	170(7 6)	280(12.5)
K_{10}	3180	38	128(4 0)	20(0.7)	390(12.3)
K_{11}	1400	325	54(3 6)	31(2.2)	290(20.7)
K_{12}	1820	77	214(11.5)	147(8.1)	360(19 8)
K_{13}	2940	197	64(2.0)	65(2.2)	300(10.2)
K_{14}	2590	70	124(4.8)	61(2.2)	340(13.1)
K_{15}	2380	38	58(2.4)	28(2.6)	640(26.9)
K_{16}	2100	134	49(2.3)	62(1.3)	500(23 8)
K_{13}	3360	197	72(2.1)	170(1.9)	200(6.0)
K_{18}	2450	197	114(4.7)	70(6.9)	690(28.2)
K_{19}	2590	261	138(5.3)	50(2.7)	730(28.2)
K_{20}	3430	203	53(1 5)	108(1 5)	190(5.5)
Mean	2705	188	101	108	400

Values in parantheses are percentages to total nitrogen

Table 7b. Organic fraction of nitrogen in Kuttanad alluvial soil, ppm

Sample No	AaN	HaN	HyAN	UHyN	THyN	NHyN
K_1	320(10.9)	270(9 2)	80(2.7)	730(24.8)	1400(47.6)	684(23.3)
K_2	320(10 9)	580(2.4)	230(7 8)	80(2.7)	1210(41.2)	1820(61.9)
K_3	560(19.6)	240(8.0)	90(3.0)	100(3.3)	990(32.9)	1464(48.6)
K_4	810(22.3)	270(7.4)	130(3.6)	290(8.0)	1500(41.2)	1295(35.4)
K_5	580(25.1)	300(13 0)	30(1.3)	20(0.9)	930(40.3)	752(32 6)
K_6	230(7.1)	380(11.8)	-	20(0 6)	630(19.6)	1321(41.0)
K_7	270(10.2)	400(15 0)	130(4.9)	410(15.4)	1210(45.5)	456(17.1)
K_8	350(17.9)	150(7 7)	130(6.6)	170(8.7)	800(40.8)	876(44.7)
K_9	420(18.9)	430(19.2)	-	230(10 3)	1080(48.2)	578(25.8)
K_{10}	620(19.5)	310(9.8)	90(2.8)	160(5.0)	1180(37.1)	1461(45.9)
K_{11}	590(42 1)	50(3.8)	100(7.1)	170(12.1)	910(65.0)	146(10 4)
K_{12}	390(21.4)	220(12.1)	80(4.4)	360(19.8)	1050(57.7)	490(26.9)
K_{13}	310(10.5)	380(12.9)	-	90(3.1)	780(26.5)	1731(58.9)
K_{14}	600(23.2)	250(9.7)	200(7 7)	220(8 5)	1270(49.0)	798(30 8)
K_{15}	350(14.7)	140(2.1)	100(4.2)	300(12.6)	890(37 4)	921(38.7)
K_{16}	430(20.5)	310(14.8)	70(3.3)	140(6.7)	950(45.2)	573(27.3)
K_{17}	120(33.6)	400(11 9)	-	810(24 1)	1330(39.6)	1691(50 3)
K_{18}	360(15.0)	380(15.5)	-	360(14.7)	1100(44.9)	376(15.4)
K_{19}	330(12.7)	330(12.7)	-	490(18.9)	1150(44.4)	501(19 3)
K_{20}	230(6.7)	380(5.3)	130(3 8)	60(1.8)	800(23.3)	2537(74.0)
Mean	410	310	80	290	1050	1002

Values in parantheses are percentage to total nitrogen

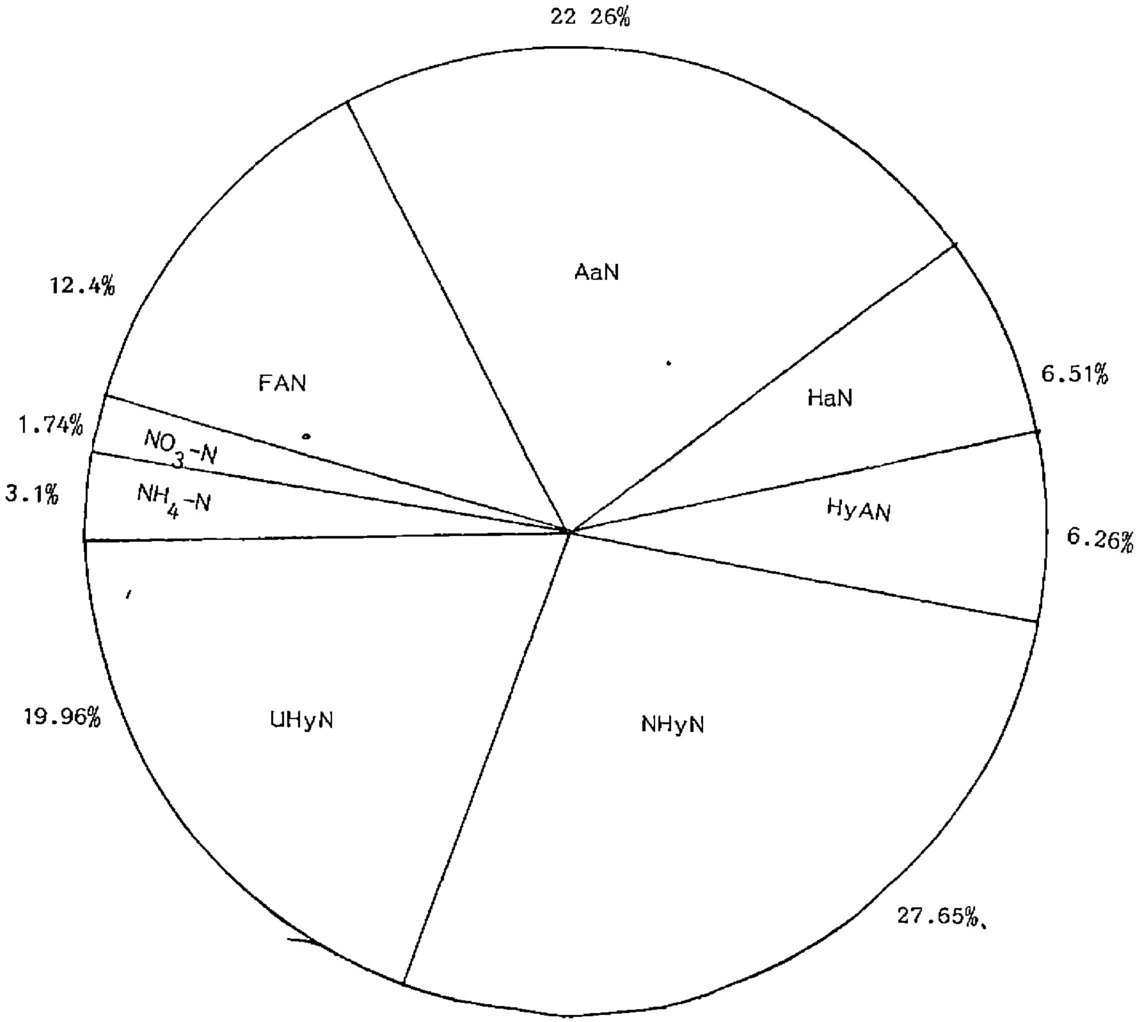


Fig.4. Nitrogen fractions in coastal alluvial soil (expressed as percentage to total N)

23 per cent of total nitrogen and the remaining 77 per cent is organic nitrogen. Among the organic nitrogen fractions, THyN comes to 51 per cent of the organic N. For the forest soil and Kuttanad alluvium soil types, the same trend is observed in the contribution of THyN to total organic N. The non-hydrolyzable fraction is the highest for both the soil types

Mean available N content is 188 ppm (32 to 389 ppm) i.e , 7 per cent of the total N content of the soil. In the case of forest soil too, the contribution rate is similar to that of the Kuttanad alluvium.

The data revealed that among the fractions studying the NHyN contributed the maximum content followed by AaN. In the case of forest soil and coastal alluvium too, the same trend is obtained.

Percentage contribution of various fractions to nitrogen is given in Fig. 5. The mean total nitrogen is found to be 0.2705 per cent. Of this, 37.04 per cent is NHyN, 15.16 per cent AaN, 14.94 per cent FAN, 11.42 per cent HaN, 10 76 per cent UHyN, 3.99 per cent NO_3-N, 3.7 per cent NH_4-N and 2 96 per cent HyAN

Among the five soil types taken for the study, the forest soil and Kuttanad alluvium recorded the maximum content of NHyN fractions of 41 45 per cent and 37 04 per cent of total nitrogen, respectively. This may be due to the hydrolysis procedure used for the study. In the present study, the soils were hydrolysed with

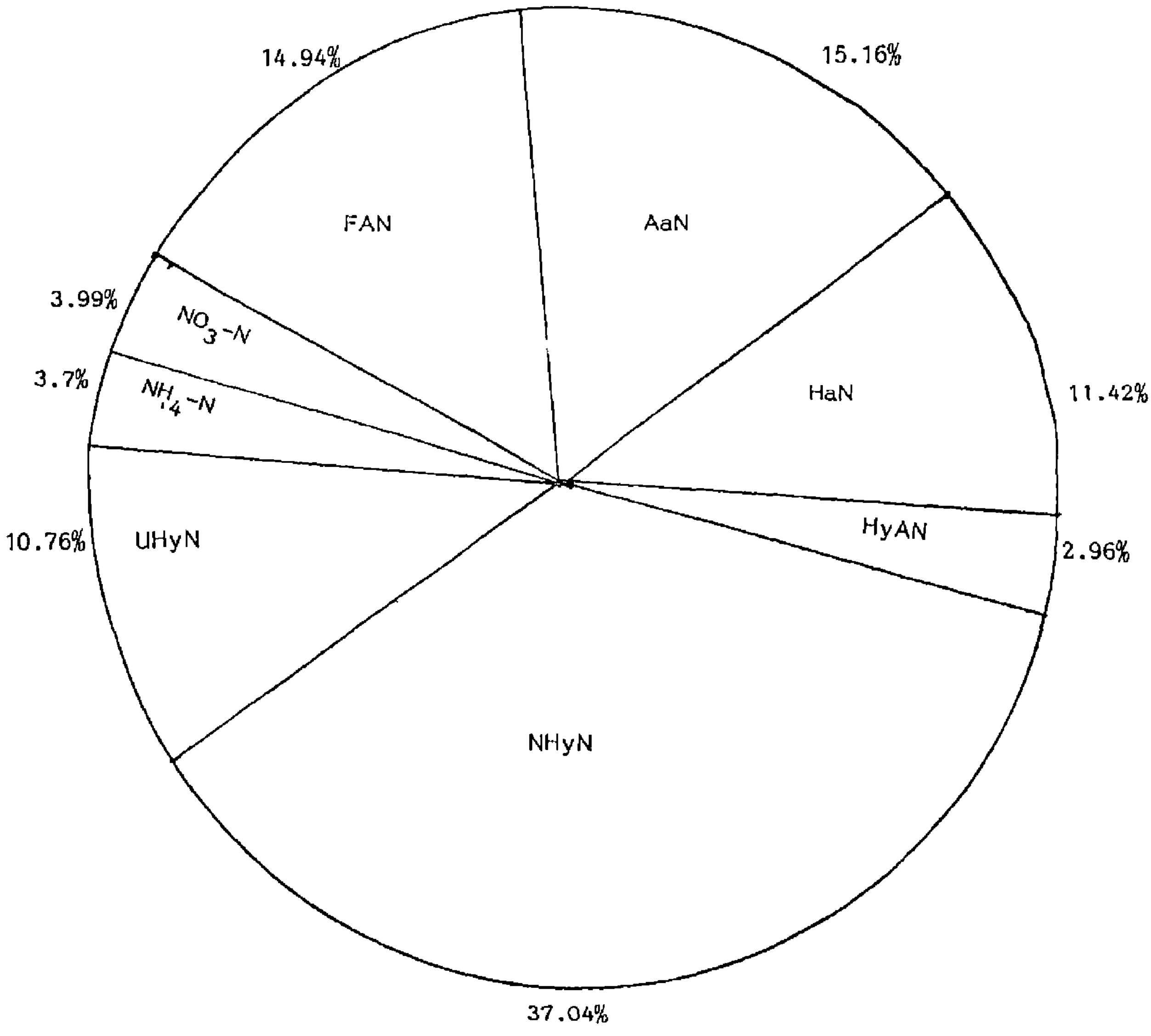


Fig.5 Nitrogen fractions in Kuttanad alluvial soil (expressed as percentage to total N)

6N HCl for 12 hours. This may not be enough for the liberation of hydrolyzable nitrogen fractions. Stevenson (1957) also reported of the establishment of optimum analytical conditions and organic fractions for each type of soil

6. Influence of soil properties on fractions of nitrogen

6.1. pH

The data on pH of various soils is given in Table 8. Simple linear regression analysis showed that pH is significantly but negatively correlated to total nitrogen in brown hydromorphic soil ($r = -0.46^{*}$) But various fractions of nitrogen do not show any significant relationship to pH in any of the soil type

6 2 Cation exchange capacity

The data on CEC is given in Table 9. Among the five soil types studied the maximum cation exchange capacity is reported for forest soil (27.83 cmol(p^{+}) kg^{-1}) and the least for coastal alluvium (8.48 cmol(p^{+}) kg^{-1}). A high cation exchange capacity due to high organic matter content is reported by several workers (Larson and Clapp, 1984; Gangopadyay et al , 1990). The low content of clay and organic matter may be responsible for the low cation exchange capacity in coastal alluvium.

6 2.1. Laterite soil

Simple regression analysis showed that cation exchange capacity

Table 8. pH of soils

Sample No.	pH	Sample No	pH	Sample No.	pH	Sample No.	pH	Sample No.	pH
L_1	6.70	F_1	5.30	B_1	5.30	C_1	7.00	K_1	4.10
L_2	6.50	F_2	5.30	B_2	5.40	C_2	6.70	K_2	3.95
L_3	6.90	F_3	5.20	B_3	6.00	C_3	5.15	K_3	4.10
L_4	6.80	F_4	5.40	B_4	5.10	C_4	7.20	K_4	4.10
L_5	6.20	F_5	5.50	B_5	5.65	C_5	6.10	K_5	4.40
L_6	6.35	F_6	5.65	B_6	5.30	C_6	6.20	K_6	4.00
L_7	7.00	F_7	5.45	B_7	5.80	C_7	6.70	K_7	4.60
L_8	6.60	F_8	5.20	B_8	5.55	C_8	6.50	K_8	3.40
L_9	5.60	F_9	7.20	B_9	5.15	C_9	6.10	K_9	4.30
L_{10}	5.90	F_{10}	5.80	B_{10}	5.85	C_{10}	6.30	K_{10}	5.30
L_{11}	6.75	F_{11}	5.30	B_{11}	6.20	C_{11}	6.90	K_{11}	5.90
L_{12}	6.25	F_{12}	5.75	B_{12}	6.80	C_{12}	7.00	K_{12}	3.10
L_{13}	6.10	F_{13}	6.30	B_{13}	5.10	C_{13}	7.40	K_{13}	7.00
L_{14}	5.90	F_{14}	5.40	B_{14}	5.50	C_{14}	6.50	K_{14}	6.50
L_{15}	5.95	F_{15}	5.85	B_{15}	5.20	C_{15}	6.60	K_{15}	6.20
L_{16}	6.00	F_{16}	5.80	B_{16}	5.30	C_{16}	7.00	K_{16}	5.10
L_{17}	6.20	F_{17}	5.80	B_{17}	5.20	C_{17}	6.75	K_{17}	5.45
L_{18}	6.40	F_{18}	5.50	B_{18}	4.90	C_{18}	6.65	K_{18}	4.20
L_{19}	5.40	F_{19}	5.55	B_{19}	5.15	C_{19}	5.80	K_{19}	3.50
L_{20}	6.00	F_{20}	5.40	B_{20}	5.05	C_{20}	7.20	K_{20}	2.55
Mean	6.10		5.50		5.50		6.6		4.70

Table 9. Cation exchange capacity of soils [cmol (p^+) kg^{-1}]

Sample No.	CEC	Sample No.	CEC	Sample No.	CEC	Sample No.	CEC	Sample No.	CEC
L_1	10.27	F_1	37.40	B_1	18.50	C_1	5.45	K_1	28.19
L_2	9.60	F_2	25.70	B_2	10.40	C_2	10.85	K_2	20.46
L_3	19.63	F_3	15.13	B_3	20.25	C_3	8.83	K_3	22.18
L_4	8.83	F_4	28.40	B_4	16.03	C_4	5.50	K_4	32.18
L_5	10.15	F_5	8.38	B_5	10.88	C_5	7.25	K_5	25.18
L_6	20.47	F_6	25.03	B_6	32 90	C_6	5.00	K_6	20 80
L_7	10.48	F_7	54.10	B_7	14.90	C_7	4.55	K_7	20.68
L_8	27.91	F_8	35.15	B_8	20.18	C_8	8.60	K_8	10.40
L_9	10.28	F_9	22.10	B_9	19.08	C_9	5.71	K_9	20.95
L_{10}	29.30	F_{10}	31.10	B_{10}	20.15	C_{10}	5.68	K_{10}	20.33
L_{11}	8.98	F_{11}	26.83	B_{11}	22.10	C_{11}	6.80	K_{11}	20.99
L_{12}	10.28	F_{12}	33.13	B_{12}	20.28	C_{12}	17.38	K_{12}	23.75
L_{13}	20.15	F_{13}	23.00	B_{13}	10.75	C_{13}	6.35	K_{13}	27.95
L_{14}	8.95	F_{14}	10.85	B_{14}	26.18	C_{14}	7.70	K_{14}	29.20
L_{15}	27.91	F_{15}	27.50	B_{15}	20.27	C_{15}	4.80	K_{15}	32.20
L_{16}	20.19	F_{16}	36.05	B_{16}	16.03	C_{16}	9.50	K_{16}	31 99
L_{17}	22.27	F_{17}	17.15	B_{17}	27.15	C_{17}	5.00	K_{17}	18.50
L_{18}	25.18	F_{18}	15.01	B_{18}	12.98	C_{18}	8.60	K_{18}	36.95
L_{19}	10.15	F_{19}	24.10	B_{19}	27.29	C_{19}	4.78	K_{19}	31.38
L_{20}	22.15	F_{20}	22.10	B_{20}	20.18	C_{20}	9.05	K_{20}	19.38
Mean	18.89		27.83		20.25		8.48		19.48

significantly influences the content of FAN and the same is graphically presented in Fig. 6 (r = 0.87**). Multiple regression model was also worked out between the cation exchange capacity and the various fractions of nitrogen The corresponding regression equation is CEC = −1.033 − 315.68 NH_4-N − 437.26 NO_3-N + 696.48 FAN + 30.24 AaN − 253.17 HaN + 322.31 HyAN − 79.78 NHyN − 181.60 UHyN (R^2 = 0.87**).

Among the various nitrogen fractions FAN alone showed significant correlation with CEC Partial r^2 showed that the only significant fraction is FAN. From the equation it is clear that, 87 per cent variation in nitrogen fractions can be explained by the variation of the CEC for the soil Fixation of ammonium in soils is mostly influenced by the type of the predominating clay mineral. Illite and related 2:1 minerals which have an interlayer spacing of 1.33 A° are known to trap ammonium ions in between the lattics and its availability and refixation is facilitated by alternate wetting and drying of soils. Among the different soil types studied brown hydromorphic soils record the lowest values for fixed ammonium. These soils which are cultivated to rice, are subjected to alternate wetting and drying conditions which lead to the release of fixed ammonium ions, which may be a reason for the low content of fixed ammonium present in these soils.

6.2 2. Forest soil

The cation exchange capacity values were highest for this type of soils. The fractions which are significantly and positively

Fig.6 Relationship between FAN and CEC in laterite soil

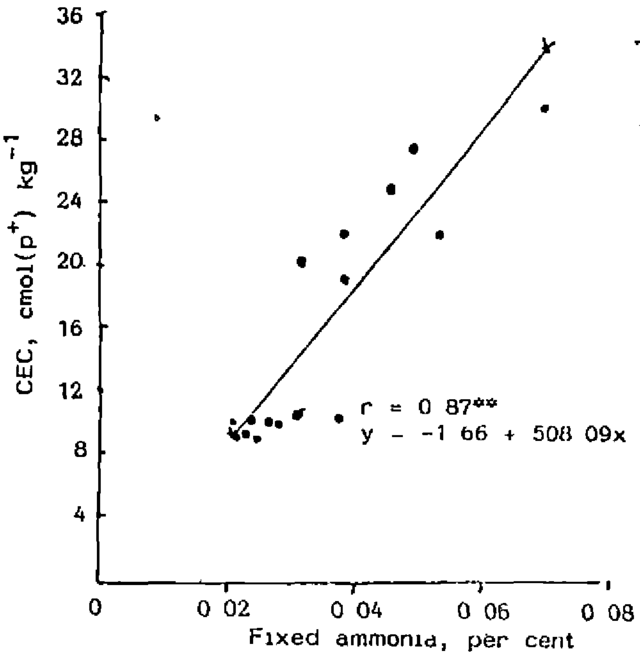


Fig.7 Relationship between FAN and CEC in forest soil

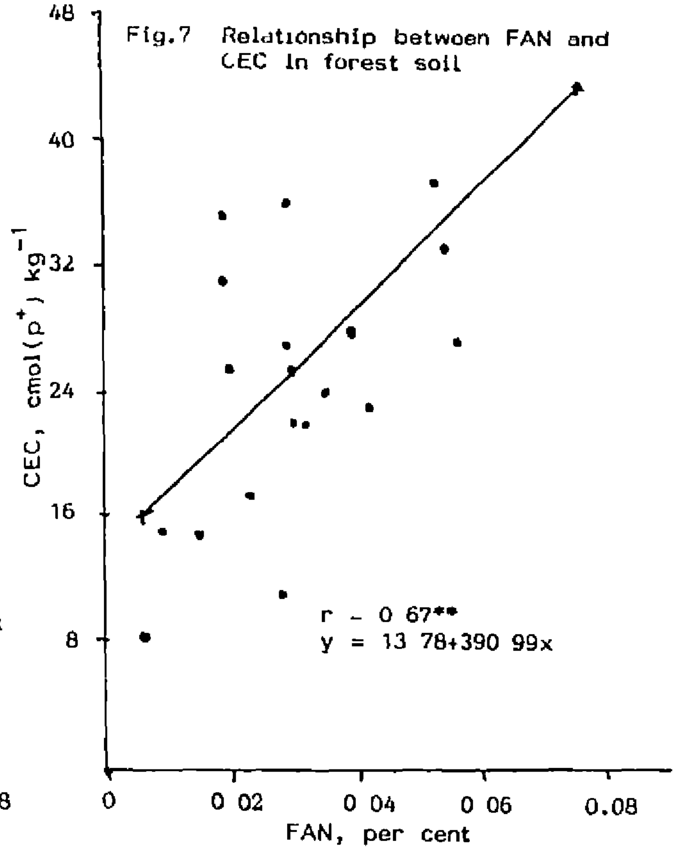


Fig.8 Relationship between FAN and CEC in brown hydromorphic soil

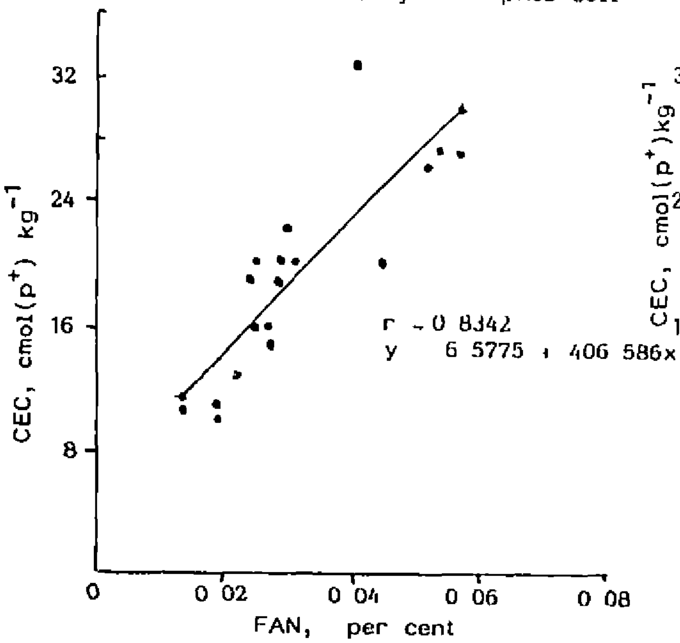
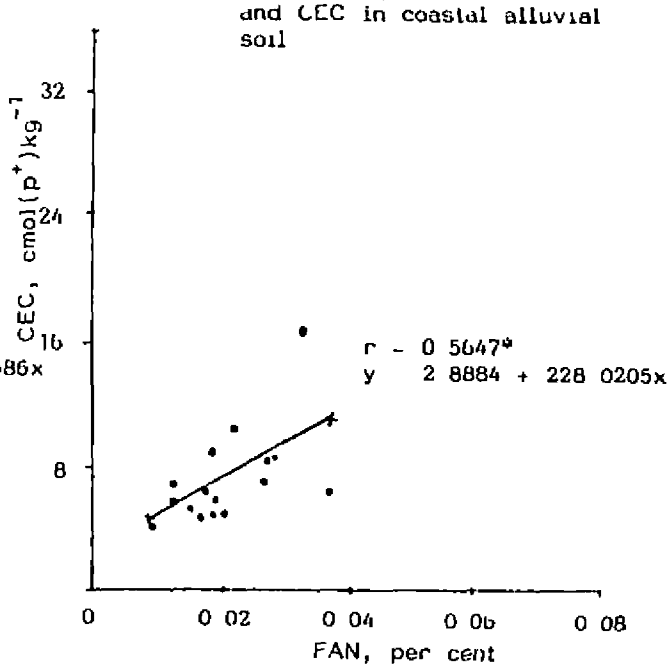


Fig 9 Relationship between FAN and CEC in coastal alluvial soil



correlated with cation exchange capacity are FAN (0.67** Fig. 7), HaN (0.69**) and total hydrolysable nitrogen (0.53**) Fixation of nitrogen by high organic matter soils has been reported by many workers (Burge and Broadbent, 1961, Krishnamoorthy, 1966). The hydroxyl group present in the organic matter may be the site of the reaction with the added ammonia.

Multiple regression analysis showed that, cation exchange capacity is significantly influenced by the various fractions in the case of forest soil (R^2 = 0 72**). Partial r^2 showed that the only significant fraction affecting cation exchange capacity is HaN Multiple regression equation is, CEC = 8 06 + 307.76 NH_4-N − 2560.99 NO_3-N + 117.18 FAN + 119 56 AaN + 502 59 HaN* + 69 58 HyAN − 16.08 NHyN + 48.51 UHyN (R^2 = 0.72**).

6.2.3. Brown hydromorphic soil

For this type of soil also, there is significant positive correlation between cation exchange capacity and FAN (0 83**) and it is graphically presented in Fig. 8. Another fraction which showed significant positive correlation with cation exchange capacity is HaN (0.66**). Multiple regression analysis showed that the cation exchange capacity is significantly influenced by the various fractions of nitrogen (R^2 = 0.80). The corresponding regression equation is, CEC = 12.33 − 1026.80 NH_4-N + 417.77 NO_3-N + 277.60 FAN* − 123.63 AaN + 321.03 HaN + 237.93 HyAN − 44 35 NHyN + 6.34 UHyN (R^2 = 0.80**).

Partial r^2 showed that, the only fraction which is significant is FAN

6 2.4. Coastal alluvium

Simple linear regression showed that, cation exchange capacity is significantly correlated to FAN ($r = 0.57^{**}$) The relationship between the cation exchange capacity and fixed NH_4-N is graphically presented in Fig. 9. The multiple regression equation between the cation exchange capacity and nitrogen fractions is given below.

$$CEC = 0.445 - 188\ 76\ NH_4\text{-}N + 538\ 75\ NO_3\text{-}N + 315.87\ FAN^{*} - 53.63\ AaN - 46.10\ HaN + 202.35\ HyAN + 2\ 49\ NHyN + 12.86\ UHyN$$

$(R^2 = 0.48)$

In the coastal alluvium, none of the fractions ~~are~~ is found to be significantly affecting the cation exchange capacity But 48 per cent variation in cation exchange capacity of these type of soils can be explained by nitrogen fractions

6.2.5. Kuttanad alluvium

Simple linear regression analysis showed that cation exchange capacity is significantly correlated with FAN ($r = 0.83^{**}$). The graphical representation of the same is given in Fig. 10. Multiple regression analysis showed that cation exchange capacity is significantly influenced by the various fractions of nitrogen ($R^2 = 0\ 74$).

Fig 10. Relationship between FAN and CEC in Kuttanad alluvial soil

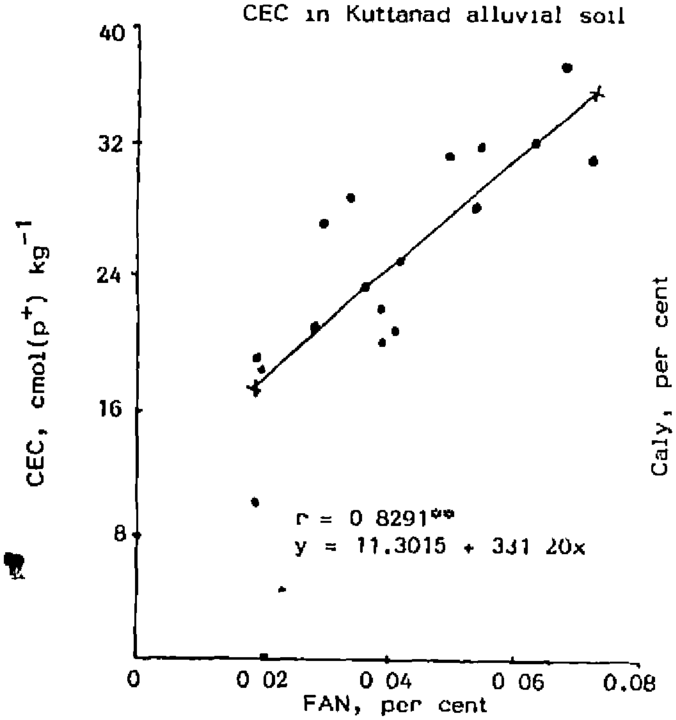


Fig 11 Relationship between clay and FAN in laterite soil

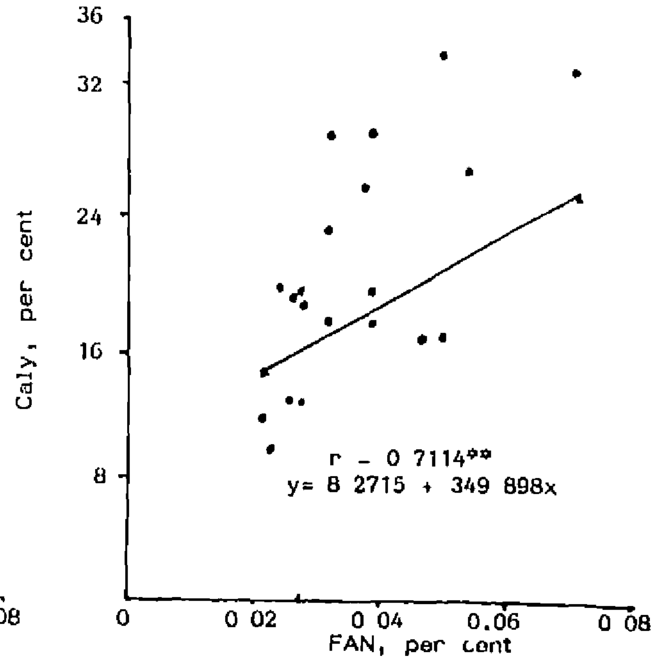


Fig.12. Relationship between FAN and total N in laterite soil

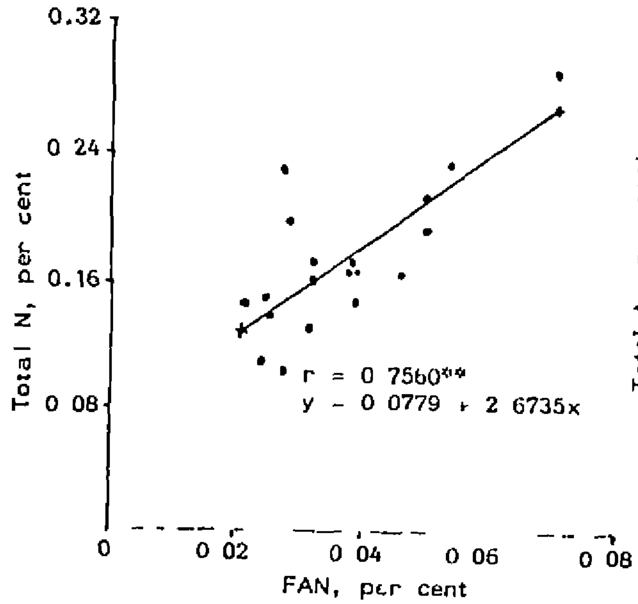
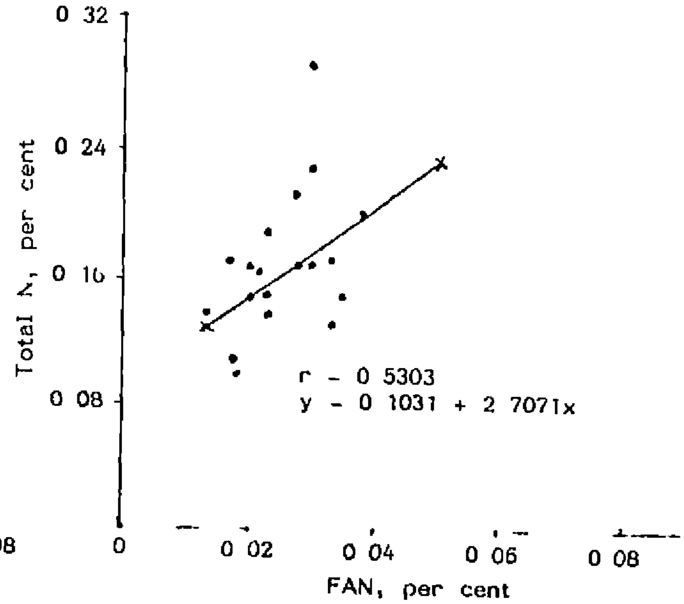


Fig 13 Relationship between HaN and total N in laterite soil



Partial r^2 showed that, the only significant fraction affecting cation exchange capacity in the case of Kuttanad alluvium is FAN. The regression equation is

$$CEC = 8.89 - 216.21\ NH_4\text{-}N - 45.22\ NO_3\text{-}N + 331.89\ FAN^{*} + 66.65\ AaN + 111.02\ HaN - 37.62\ HyAN - 6.99\ NHyN - 3.19\ UHyN \quad (R^2 = 0.74^{**}).$$

In all the five soil types a significant positive correlation between cation exchange capacity and FAN is reported. Retention of NH_4^+ in the clay and organic matter fraction may be responsible for this relationship.

7. Relationship between particle size distribution and nitrogen fractions

The data on sand, silt and clay per cent of various soils are given in Table 10. The mean content of sand percentage in the selected soil types were 67.06 (50.01 to 81.01), 67.01 (52.01 to 78.01), 64.91 (52.01 to 78.01), 87.60 (68.99 to 92 98) and 61.39 (31.99 to 74.99) in the laterite, forest, brown hydromorphic, coastal alluvium and Kuttanad alluvium respectively.

In laterite soil 72 per cent variation in the sand content can be explained by the nitrogen fractions. The HyAN significantly influenced the sand. Importance of this HyAN in laterite soil was reported by Mohapatra and Khan (1982).

Table 10a. Percentage of sand

Sample No.	Laterite	Sample No.	Forest soil	Sample No.	Brown hydromorphic	Sample No.	Coastal alluvium	Sample No	Kuttanad alluvium
L_1	72.09	F_1	52.01	B_1	62 99	C_1	92.99	K_1	58.99
L_2	70.99	F_2	71.01	B_2	72 99	C_2	87.99	K_2	67.99
L_3	62.99	f_3	72.01	B_3	67.99	C_3	89.99	K_3	50.99
L_4	70.99	F_4	68.01	B_4	61.99	C_4	92.99	K_4	71.99
L_5	72.99	F_5	78.01	B_5	72.99	C_5	81.99	K_5	71.99
L_6	61.99	F_6	71.01	B_6	52.98	C_6	92 99	K_6	58.99
L_7	68.99	F_7	53.01	B_7	61.99	C_7	92.98	K_7	50 99
L_8	71.99	F_8	54.01	B_8	67 99	C_8	89.98	K_8	68.99
L_9	61.99	F_9	71.01	B_9	62.99	C_9	92.99	K_9	62.99
L_{10}	50.99	F_{10}	68.01	B_{10}	67.99	C_{10}	92.99	K_{10}	71.99
L_{11}	81.99	F_{11}	71.01	B_{11}	69.99	C_{11}	89.99	K_{11}	68.99
L_{12}	72.99	F_{12}	54.01	B_{12}	67 99	C_{12}	68.99	K_{12}	71.99
L_{13}	61.98	F_{13}	71.01	B_{13}	72.99	C_{13}	82.99	K_{13}	62.99
L_{14}	60.99	F_{14}	72.01	B_{14}	67.99	C_{14}	92 99	K_{14}	31.80
L_{15}	58.99	F_{15}	68.01	B_{15}	67.99	C_{15}	92.98	K_{15}	52.98
L_{16}	70.99	F_{16}	61.01	B_{16}	61.99	C_{16}	79.99	K_{16}	51.98
L_{17}	70.99	F_{17}	72.01	B_{17}	67.99	C_{17}	92.98	K_{17}	71.89
L_{18}	68.99	F_{18}	71.01	B_{18}	78.99	C_{18}	81.99	K_{18}	52.99
L_{19}	72.99	F_{19}	71.01	B_{19}	61 99	C_{19}	92.99	K_{19}	74.99
L_{20}	61.99	F_{20}	71.01	B_{20}	71 99	C_{20}	74.99	K_{20}	50.99
Mean	67.06		67.01		67.14		87.60		61.39

Table 10b. Percentage of silt

Sample No.	Laterite	Sample No.	Forest soil	Sample No.	Brown hydromorphic	Sample No.	Coastal alluvium	Sample No.	Kuttanad alluvium
L_1	8.00	F_1	8.0	B_1	12 00	C_1	3.00	K_1	18.00
L_2	17 00	F_2	12.00	B_2	9.00	C_2	4 00	K_2	17.00
L_3	9.00	F_3	4.99	B_3	14 00	C_3	2.00	K_3	22.01
L_4	17.00	F_4	12.00	B_4	8 00	C_4	3 00	K_4	12.00
L_5	8.00	F_5	3.99	B_5	17.00	C_5	4.00	K_5	20.01
L_6	10.00	F_6	3.99	B_6	27.00	C_6	3.00	K_6	22.99
L_7	9.00	F_7	12 00	B_7	7 00	C_7	2.00	K_7	26.00
L_8	12.00	F_8	12.00	B_8	14.00	C_8	2 00	K_8	17.01
L_9	19.00	F_9	4.00	B_9	12.00	C_9	3 00	K_9	12.00
L_{10}	17 00	F_{10}	2 00	B_{10}	14 00	C_{10}	5 00	K_{10}	17.00
L_{11}	9 00	F_{11}	3.00	B_{11}	15 00	C_{11}	3.00	K_{11}	20 99
L_{12}	9.00	F_{12}	14 99	B_{12}	14 00	C_{12}	8 00	K_{12}	22.00
L_{13}	12 00	F_{13}	8 00	B_{13}	8.00	C_{13}	3.00	K_{13}	19 00
L_{14}	18.00	F_{14}	20.00	B_{14}	22.00	C_{14}	4.00	K_{14}	15.00
L_{15}	15.00	F_{15}	12.00	B_{15}	15.00	C_{15}	2.00	K_{15}	12.00
L_{16}	12.00	F_{16}	12.00	B_{16}	8.00	C_{16}	2.00	K_{16}	8.00
L_{17}	12.00	F_{17}	4.00	B_{17}	12.00	C_{17}	2.00	K_{17}	17.00
L_{18}	15 00	F_{18}	4 00	B_{18}	9.00	C_{18}	3.00	K_{18}	10.00
L_{19}	8.00	F_{19}	8.00	B_{19}	22.00	C_{19}	2.00	K_{19}	9.00
L_{20}	12.00	F_{20}	12.00	B_{20}	15.00	C_{20}	4.00	K_{20}	12.01
Mean	12.4		8 15		13.7		3.2		16 45

Table 10c. Percentage of clay

Sample No.	Laterite	Sample No.	Forest soil	Sample No.	Brown hydromorphic	Sample No.	Coastal alluvium	Sample No.	Kuttanad alluvium
L_1	19.99	F_1	39.99	B_1	25.99	C_1	4.99	K_1	23 99
L_2	12 99	F_2	16.99	B_2	18.99	C_2	8.99	K_2	15.99
L_3	28.99	F_3	23 00	B_3	18.99	C_3	8.99	K_3	27 98
L_4	12.99	F_4	19.99	B_4	30.99	C_4	4.99	K_4	16.99
L_5	19.99	F_5	18.00	B_5	10.99	C_5	14.99	K_5	8.98
L_6	28 99	F_6	25.00	B_6	29.99	C_6	4.99	K_6	19.00
L_7	22.99	F_7	34.99	B_7	31.99	C_7	5.02	K_7	23.99
L_8	16.99	F_8	33.99	B_8	18.99	C_8	8.99	K_8	14 98
L_9	19.99	F_9	24.99	B_9	25.99	C_9	4.99	K_9	25.99
L_{10}	32.99	F_{10}	29.99	B_{10}	23.99	C_{10}	2.99	K_{10}	11 99
L_{11}	9.99	F_{11}	25 99	B_{11}	25.99	C_{11}	7 99	K_{11}	11.00
L_{12}	18 99	F_{12}	21.00	B_{12}	18.99	C_{12}	23.99	K_{12}	6.99
L_{13}	26.02	F_{13}	20.99	B_{13}	19.99	C_{13}	14.99	K_{13}	18.99
L_{14}	11.99	F_{14}	17.99	B_{14}	20.99	C_{14}	3.99	K_{14}	38.99
L_{15}	33.99	F_{15}	19 99	B_{15}	17.99	C_{15}	5.99	K_{15}	35.99
L_{16}	17.99	F_{16}	26.99	B_{16}	30.99	C_{16}	18.99	K_{16}	40 02
L_{17}	17.99	F_{17}	23.99	B_{17}	20.99	C_{17}	5.99	K_{17}	11.01
L_{18}	16.99	F_{18}	24.99	B_{18}	12.99	C_{18}	15.99	K_{18}	37.99
L_{19}	19.99	F_{19}	20.99	B_{19}	16.99	C_{19}	5.99	K_{19}	16.99
L_{20}	26.99	F_{20}	16.99	B_{20}	13.99	C_{20}	21.99	K_{20}	37 98
Mean	20.89		24.34		21.84		9.20		22.29

The mean content of silt percentage in the selected soil types were 12.4 (8 to 19), 8.15 (2 to 12), 13.7 (7 to 27), 3.2 (2 to 8) and 16 45 (9 to 26) in the laterite, forest, brown hydromorphic, coastal alluvium and Kuttanad alluvium respectively.

The mean content of clay percentage in the selected soil types were 20.89 (9 99 to 33.99), 24.34 (16.99 to 39.99), 21.84 (12.99 to 31.99), 8 85 (2 99 to 23.99) and 22.29 (6.99 to 38 99) respectively

In the laterite soil, a significant relationship between FAN and clay content was obtained from simple regression equation (r = 0.60**) The graphical representation of the same is given in Fig. 11. Coarse clay was found to be quantitatively the most important fraction in fixing added NH_4^+ as well as being the fraction containing the largest portion of native fixed NH_4^+.

8. Relationship between total nitrogen and nitrogen fractions

8.1 Laterite soil

Simple linear regression analysis showed that FAN (r = 0.76**), HaN (r = 0 53*), NHyN (r = 0 74**) and THyN (r = 0.71**) are significantly correlated to total nitrogen The graphical representations of these are given in Fig. 12, 13, 14 and 15. Multiple regression analysis showed that various fractions significantly influence total nitrogen content in soil. Regression equation is, Fig 14 Relationship between NHyN and total N in laterite soil

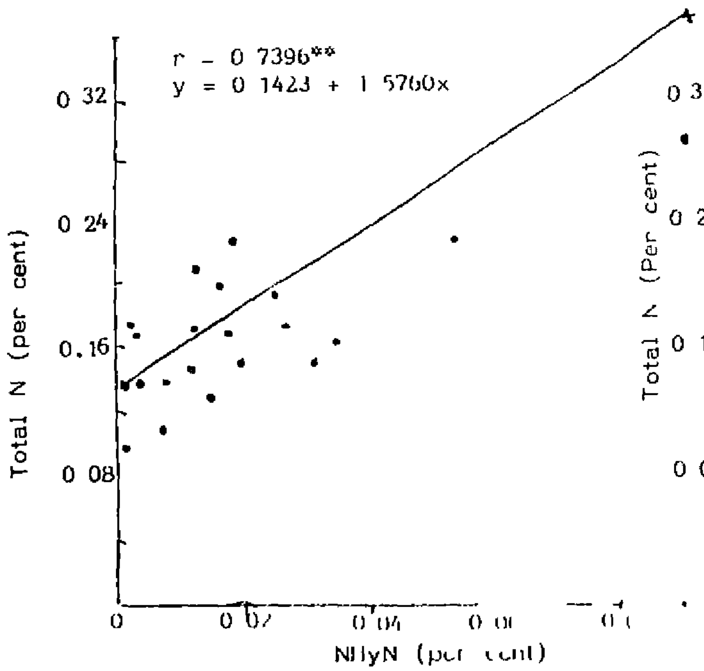


Fig 15 Relationship between THyN and total N in laterite soil

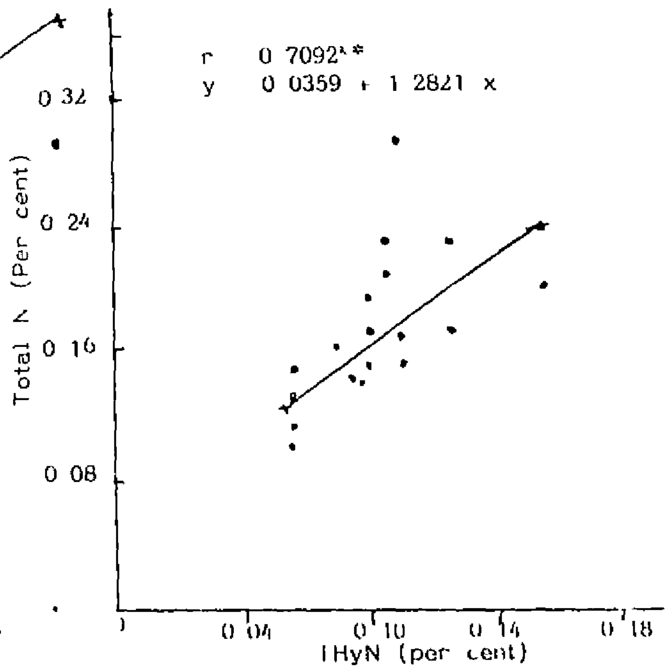


Fig 16 Relationship between NH_4 N and total N in forest soil

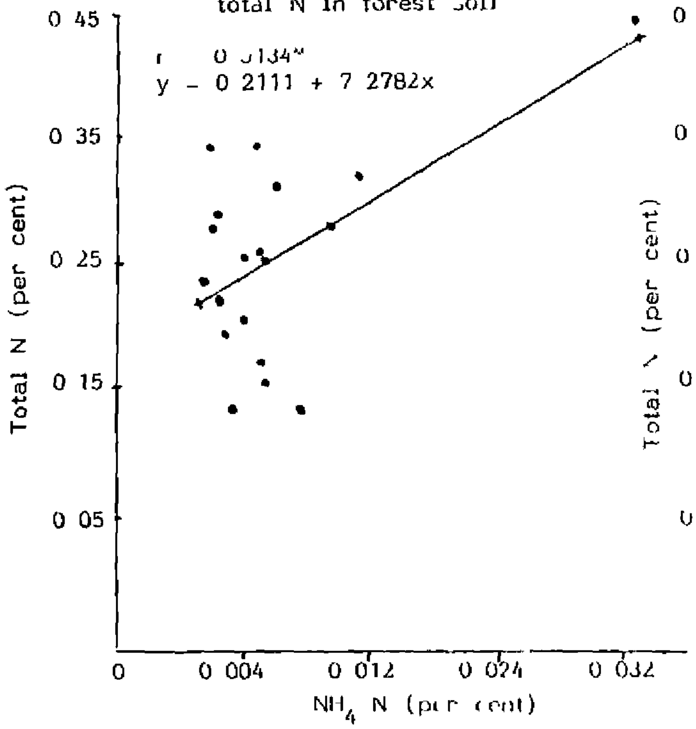
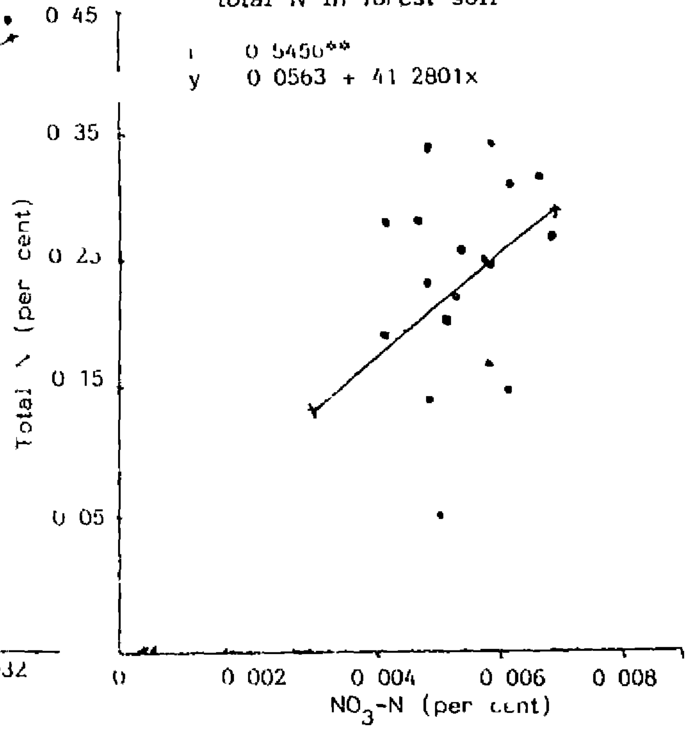


Fig 17 Relationship between NO_3-N and total N in forest soil



$$\text{Total N} = 0.0108 + 1.2329\ NH_4\text{-N} - 1.118\ NO_3\text{-N} + 1.1388\ \text{FAN}^{**} + 0.0347\ \text{AaN}^{**} + 0.0073\ \text{HaN}^{**} + 0.0098\ \text{HyAN} + 1.0724\ \text{NHyN}^{**} + 1.1232\ \text{UHyN}^{**}\ (R^2 = 0.99^{**}).$$

From the equation it is understood that 99 per cent variation in total nitrogen can be explained by the nitrogen fractions. Being the significant contributing fractions, a unit increase in FAN, AaN, HaN, NHyN and UHyN <u>cetaris paribus</u> will increase the total nitrogen by 1.139, 0.035, 0.007, 1.072 and 1.123 units respectively.

8.2. Forest soil

Simple linear regression analysis showed that in forest soil NH_4-N (0.51**), NO_3-N (0.55**), HaN (0.66**) and NHyN (0.82**) are significantly correlated to total nitrogen. The graphical representations of these are given in Fig Nos.16, 17, 18 and 19.

The multiple regression model between the total nitrogen and nitrogen fractions is given below

$$\text{Total N} = -0.0394 - 0.055\ NH_4\text{-N} + 25.51\ NO_3\text{-N} + 1.555\ \text{FAN} - 0.527\ \text{AaN} - 0.0064\ \text{HaN} - 1.308\ \text{HyAN} + 0.903\ \text{NHyN}^{**} + 0.185\ \text{UHyN}\ (R^2 = 0.87^{**}).$$

In the forest soil, 87 per cent variation in total nitrogen can be explained by nitrogen fractions. Being the significant contributing fraction, a unit increase in NHyN will increase the total nitrogen by 0.903 units.

Fig 18 Relationship between HaN and total N in forest soil

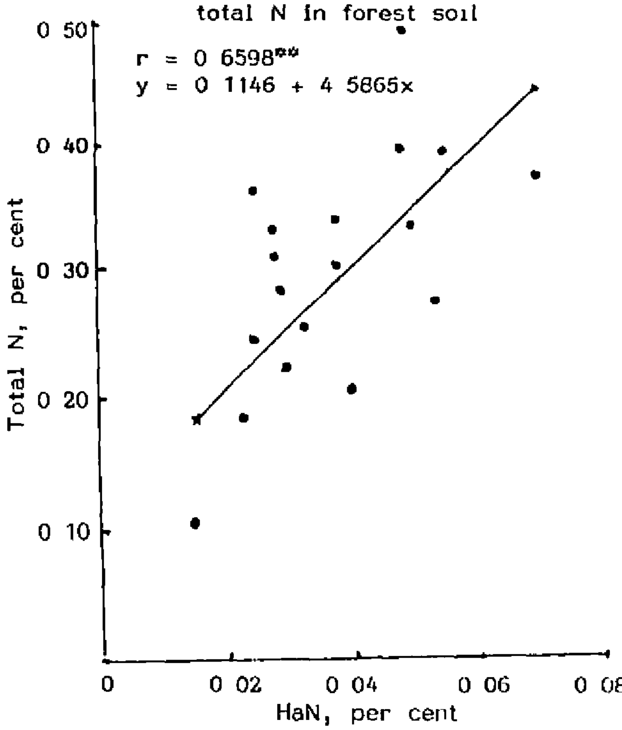


Fig 19 Relationship between NHyN and total N in forest soil

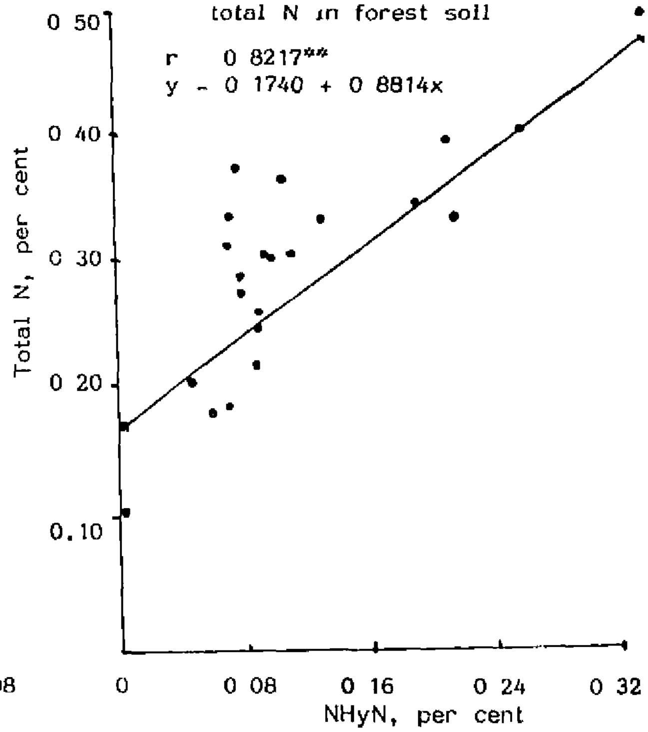


Fig 20 Relationship between NO_3-N and total N in brown hydromorphic soil

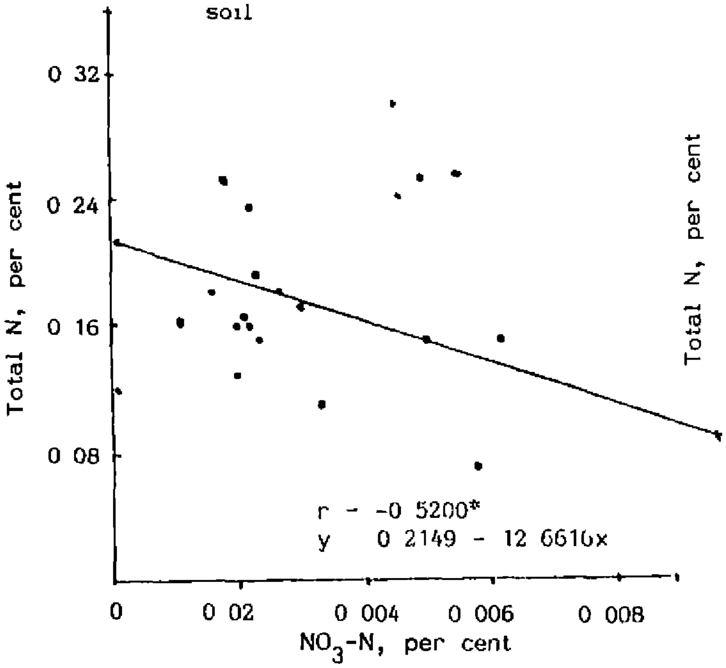
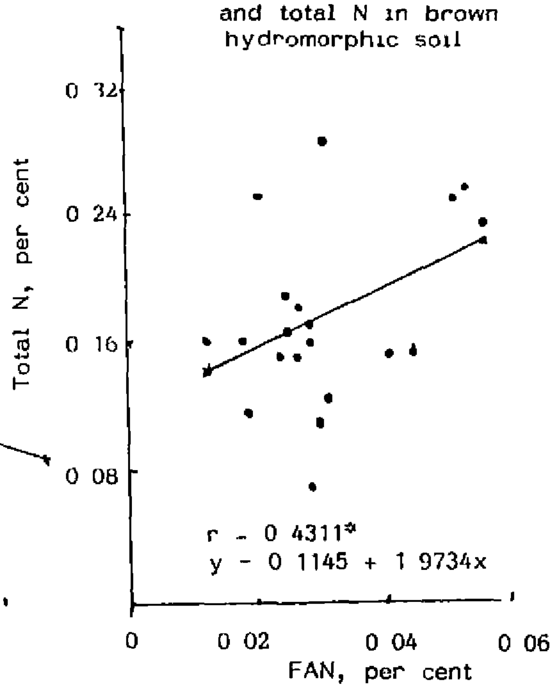


Fig 21 Relationship between FAN and total N in brown hydromorphic soil



8.3. Brown hydromorphic

Simple linear regression analysis showed that FAN (0.43*), NO_3-N (-0.52**), HaN (0.64**), THyN (0.73**) and NHyN (0.56**) are significantly correlated to total nitrogen. The graphical representations of these are given in Fig. Nos.20, 21, 22, 23 and 24.

The multiple regression model between the total nitrogen and nitrogen fractions is given below:

Total N = 0.0011 + 0.255 NH_4-N - 1.806 NO_3-N + 0.259 FAN + 1.318 AaN* + 1.777 HaN + 0.635 HyAN + 1.139 NHyN** + 0.996 UHyN** (R^2 = 0 89**).

Being the significant contributing fractions, a unit increase in AaN, NHyN and UHyN cetaris paribus will increase the total nitrogen by 1.318, 1.139 and 0.996 units respectively.

8 4. Coastal alluvium

Simple linear regression analysis showed that AaN (0.66**), NHyN (0 53*) and THyN (0.55**) are significantly correlated to total nitrogen. The graphical representations of these are given in Fig. Nos.25, 26 and 27.

The multiple regression model between the total nitrogen and nitrogen fractions is given below:

Total N = 0.1009 - 3.302 NH_4-N + 1.98 NO_3-N - 4.03 FAN + 3.35 AaN** + 2.80 HaN - 2.53 HyAN + 0.59 NHyN + 0.403 UHyN (R^2 = 0.77 **).

Fig 22 Relationship between HaN and totan N in brown hydromorphic soil

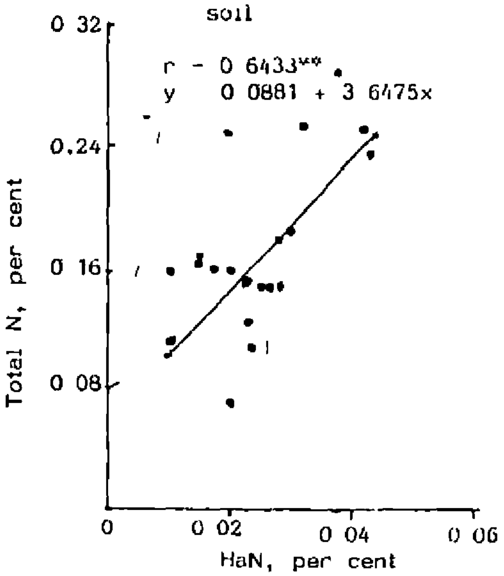


Fig 23 Relationship between THyN and total N in brown hydromorphic soil

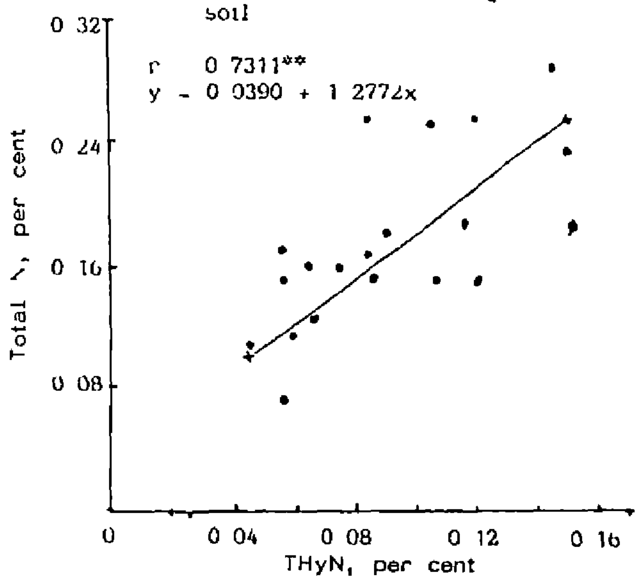


Fig 24 Relationship between NHyN and total N in brown hydromorphic soil

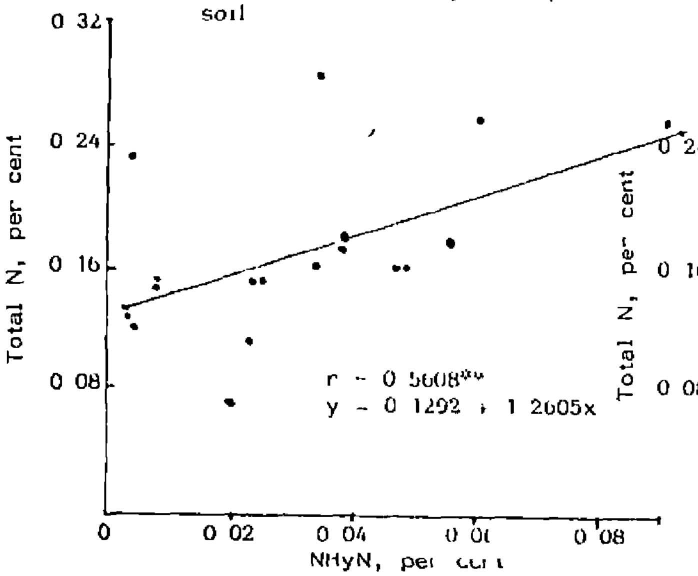


Fig 25 Relationship between AaN and total N in coastal alluvial soil

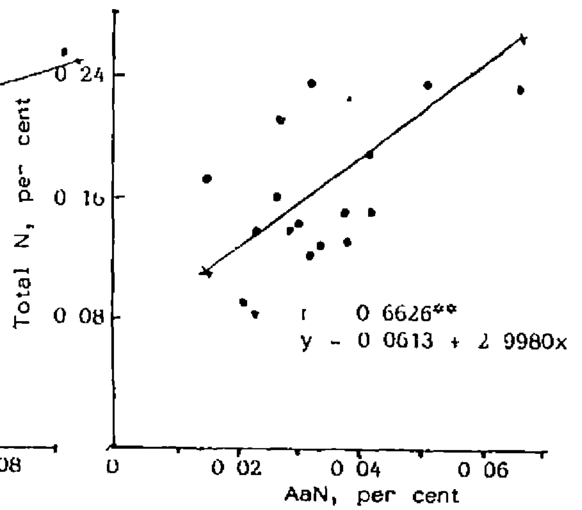


Fig 26 Relationship between NHyN and total N in coastal alluvial soil

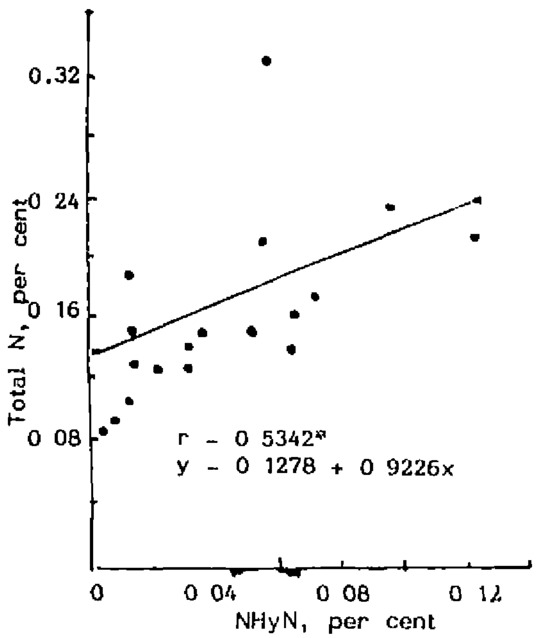


Fig 27 Relationship between THyN and total N in coastal alluvial soil

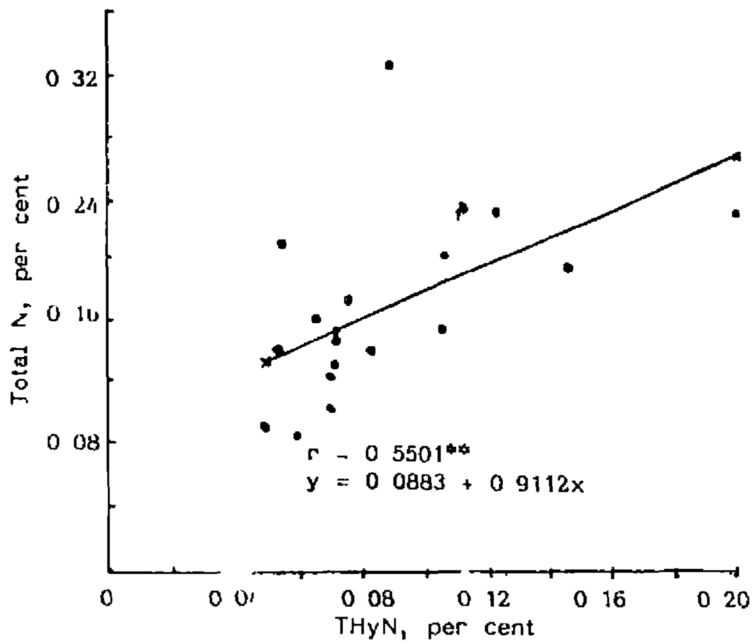


Fig 28 Relationship between THyN and total N in Kuttanad alluvium

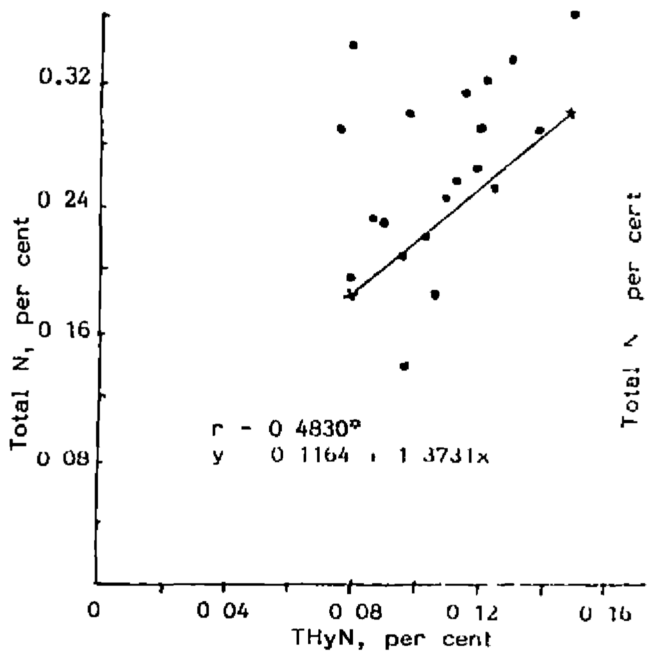
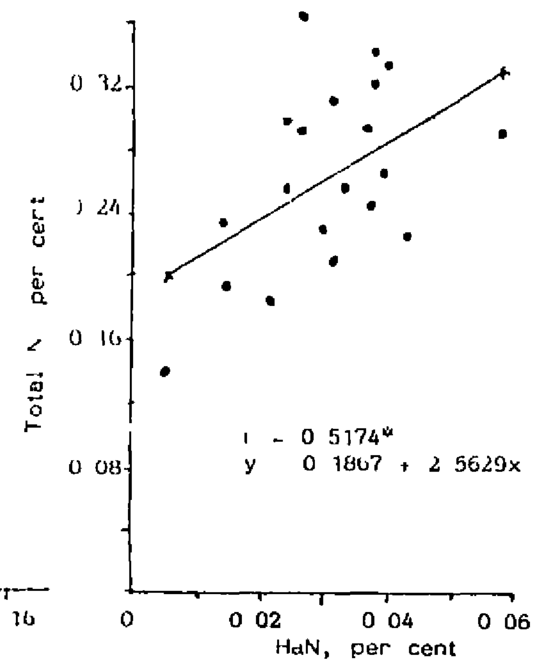


Fig 29 Relationship between HaN and total N in Kuttanad alluvium



Being the significant contributing fraction, a unit increase on AaN *cetaris paribus* will increase the total nitrogen by 3.35 times respectively.

8.5. Kuttanad alluvium

Simple linear regression analysis showed that HaN (0.52**) and THyN (0.48*) are significantly correlated to total nitrogen. The graphical representations of these are given in Fig. Nos. 28 and 29

The multiple regression model between the total nitrogen and nitrogen fractions is given below

$$\text{Total N} = 0.0039 + 1.362\ NH_4\text{-}N^{*} + 1\ 335\ NO_3\text{-}N^{**} + 0.798\ \text{FAN}^{**} + 1.293\ \text{AaN}^{**} - 10.573\ \text{HaN}^{*} - 0.252\ \text{HyAN} + 1.003\ \text{NHyN}^{**} + 1.117\ \text{UHyN}^{**}\ (R^2 = 0.99^{**}).$$

Being the significant contributing fractions, unit increase in NH_4-N, NO_3-N, FAN, AaN, HaN, NHyN and UHyN *cetaris paribus* will increase the total nitrogen by 1.362, 1.335, 0.798, 1.293, 0.573, 1.033 and 1.117 units respectively.

9. Relationship between organic carbon and nitrogen fractions

The organic carbon contents of the selected soil types is given in Table 11.

Table 11. Organic carbon of soils (per cent)

Sample No.	O C.	Sample No.	O.C.	Sample No.	O.C	Sample No	O.C.	Sample No.	O C.
L_1	0.70	F_1	5.04	B_1	0 72	C_1	0.24	K_1	1 52
L_2	0.51	F_2	2.36	B_2	0.46	C_2	0.33	K_2	1 52
L_3	0.62	F_3	1.97	B_3	0.75	C_3	0.36	K_3	1.17
L_4	0 39	F_4	1.63	B_4	0.72	C_4	0.18	K_4	2.65
L_5	1 17	F_5	1.38	B_5	0 67	C_5	0 26	K_5	2.12
L_6	1 30	F_6	2 39	B_6	0 71	C_6	0.28	K_6	1.46
L_7	0 86	F_7	4.03	B_7	0.54	C_7	0.14	K_7	1.85
L_8	1 15	F_8	3.01	B_8	0.39	C_8	0 27	K_8	0 44
L_9	1 47	F_9	1.32	B_9	1 09	C_9	0 35	K_9	1.69
L_{10}	1 19	F_{10}	1.50	B_{10}	1.30	C_{10}	0.40	K_{10}	2 84
L_{11}	0 56	F_{11}	2.70	B_{11}	0.53	C_{11}	0 30	K_{11}	0.19
L_{12}	2.06	F_{12}	2.05	B_{12}	0.56	C_{12}	0 36	K_{12}	1.83
L_{13}	0 97	F_{13}	1.21	B_{13}	1.08	C_{13}	0.33	K_{13}	1.04
L_{14}	1 47	F_{14}	0.64	B_{14}	1.32	C_{14}	0.77	K_{14}	0 32
L_{15}	1 91	F_{15}	2 05	B_{15}	1.85	C_{15}	0.26	K_{15}	0.53
L_{16}	1 09	F_{16}	2.00	B_{16}	1.16	C_{16}	0.18	K_{16}	0 39
L_{17}	0.86	F_{17}	1 49	B_{17}	0 44	C_{17}	0.29	K_{17}	1.65
L_{18}	0 92	F_{18}	1.49	B_{18}	1.16	C_{18}	0.80	K_{18}	1.74
L_{19}	0.50	F_{19}	2.05	B_{19}	1.91	C_{19}	0 33	K_{19}	1.62
L_{20}	2.65	F_{20}	2.00	B_{20}	0.77	C_{20}	0.45	K_{20}	4.63
Mean	1.12		2 12		0.91		0 34		1.56

9.1. Laterite soil

The mean content of organic carbon in this type is 1.12 per cent (range, 0.50 to 2.65 per cent). Simple linear regression analysis showed that THyN (0 68**), AaN (0.56**) and HaN (0.53**) are significantly correlated to organic carbon. The graphical representation of the relationship of organic carbon with THyN, AaN and HaN is presented in Fig. Nos.30, 31 and 32 respectively. Multiple regression analysis showed that various fractions significantly influenced organic carbon content in soil. Partial r^2 showed that AaN and HaN significantly influenced the organic carbon content. The regression equation is

$$O.C. = -1.340 + 76.89\ NH_4\text{-}N - 41.11\ NO_3\text{-}N + 6.07\ FAN + 23.40\ AaN^{*} + 30.71\ HaN^{*} + 7\ 73\ HyAN - 2.22\ NHyN - 1.83\ UHyN\ (R^2 = 0.75^{**}).$$

From the above multiple regression model it is understood that 75 per cent variation in organic carbon content can be explained by the nitrogen fractions Being the significant contributing fractions, a unit increase in AaN and HaN cetaris paribus will increase the organic carbon by 23.4 and 30.7 units respectively.

9.2. Forest soil

Among the five selected soil types, the maximum organic carbon is reported for forest soil. The mean content of organic carbon is 2.12 per cent (0.64 to 5.04 per cent). Simple linear regression analysis showed that in forest soil, NH_4-N (0.78**), NO_3-N

Fig.30 Relationship between THyN and organic carbon in forest soil

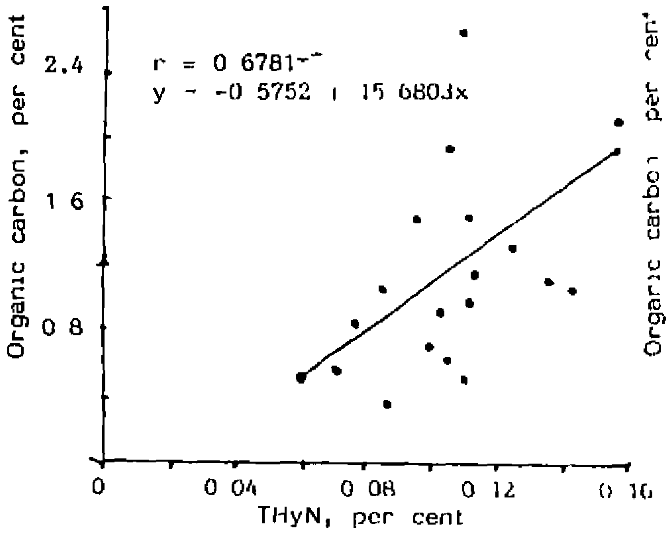
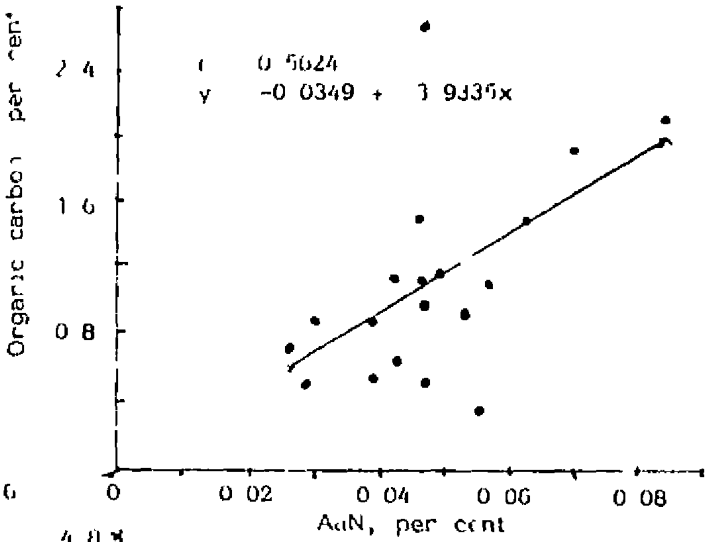


Fig 31 Relationship between AaN and organic carbon in laterite soil



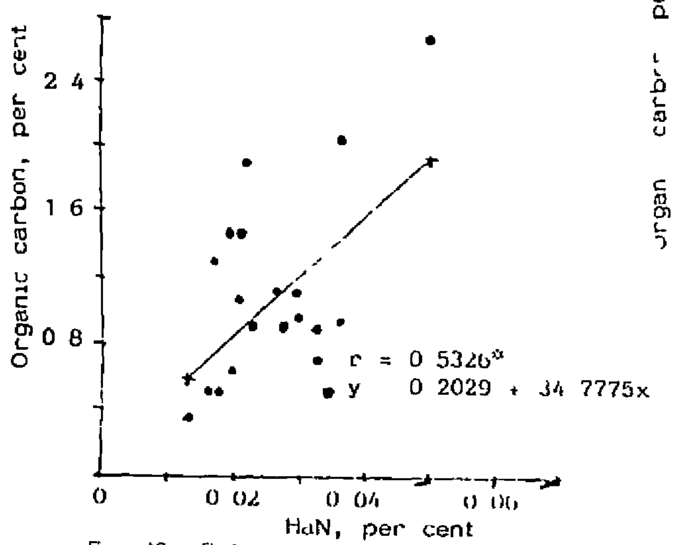


Fig 32 Relationship between HaN and organic carbon in laterite soil

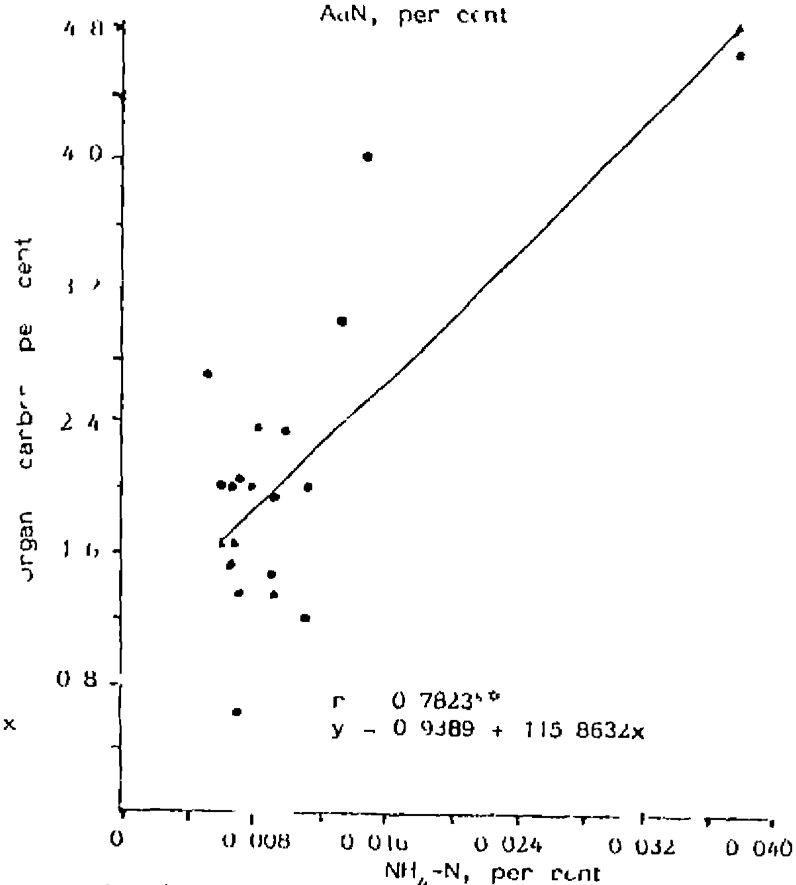


Fig 33 Relationship between NH_4 N and organic carbon in forest soil

(0.65**), FAN (0.57**), HaN (0 65 **) and NHyN (0.44*) are significantly correlated to organic carbon and these are graphically presented in Fig. Nos. 33, 34, 35, 36 and 37 respectively. The multiple regression model between the organic carbon and nitrogen fractions is given below.

O.C = 0.328 + 103.80 NH_4-N** - 229.35 NO_3-N - 2.87 FAN + 6.40 AaN + 41.88 HaN* + 32.47 HyAN - 0.514 NHyN - 0.723 UHyN (R^2 = 0.87**).

From the equation it is revealed that a unit increase in the content of NH_4-N and HaN cataris paribus will increase the organic carbon content by 103.80 units and 41.88 units respectively.

9.3. Brown hydromorphic soil

The mean content of organic carbon for this type is 0.91 per cent (range, 0.39 to 1.85 per cent). Simple linear regression analysis showed that only HaN is significantly correlated to organic carbon content (0.43*) and this is graphically presented in Fig. 38. Multiple regression analysis showed that various fractions of nitrogen significantly correlated to organic carbon content (R^2 = 0.70**). Partial r^2 showed that only NHyN is significant. Regression equation is

O.C = -0.1054 + 48.65 NH_4-N - 67 29 NO_3-N - 2.36 FAN + 4.32 AaN + 16.30 HaN + 31.68 HyAN + 7.64 NHyN* + 0.743 UHyN (R^2 = 0.70*).

Fig 34 Relationship between NO_3-N and organic carbon in forest soil

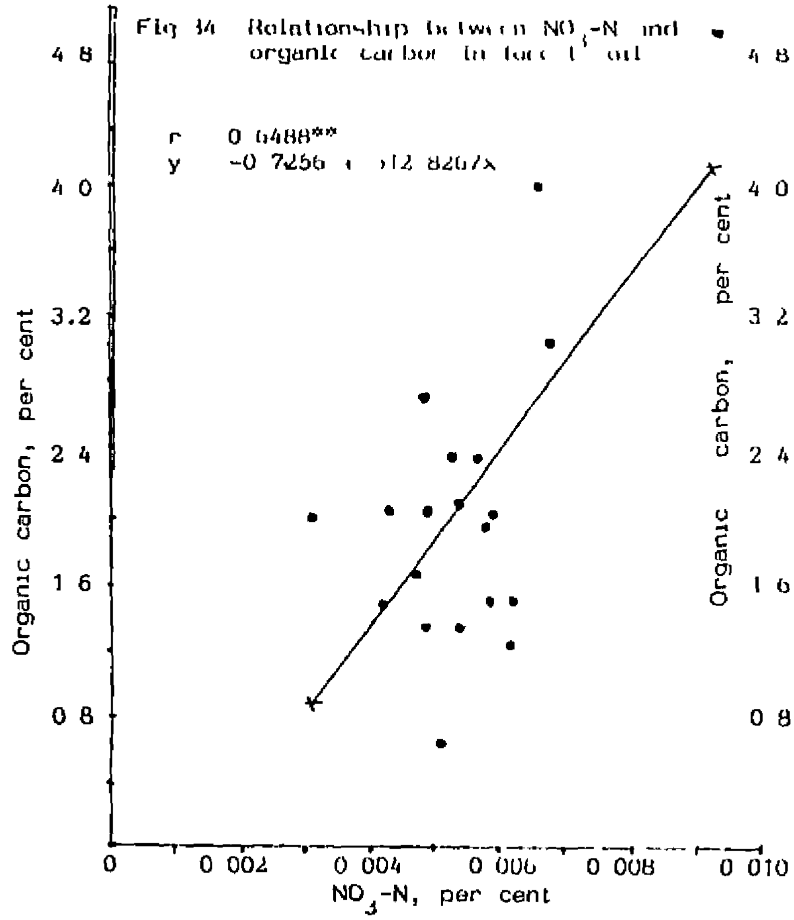


Fig 35 Relationship between FAN and organic carbon in forest soil

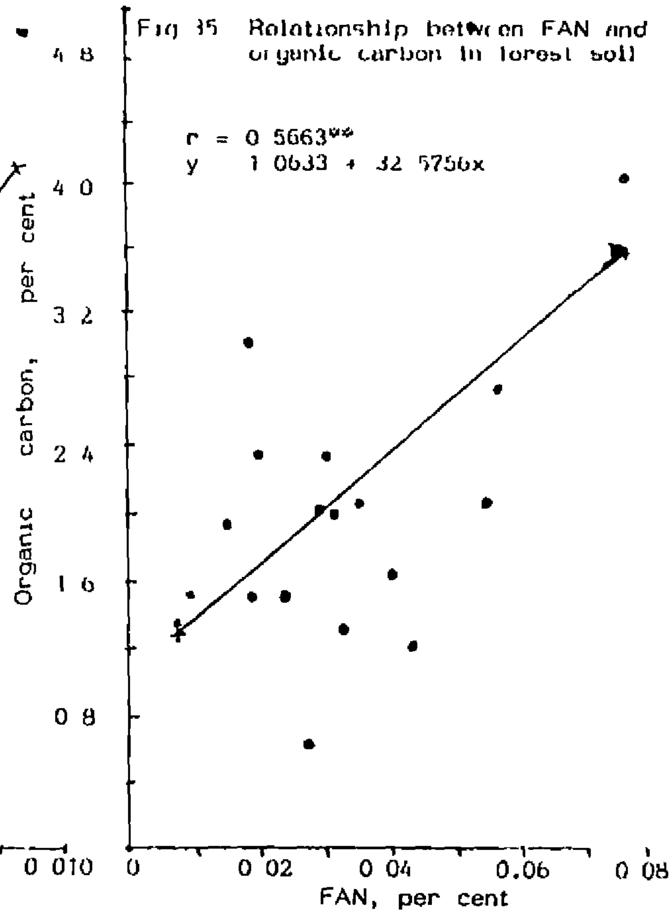


Fig 36 Relationship between HaN and organic carbon in laterite soil

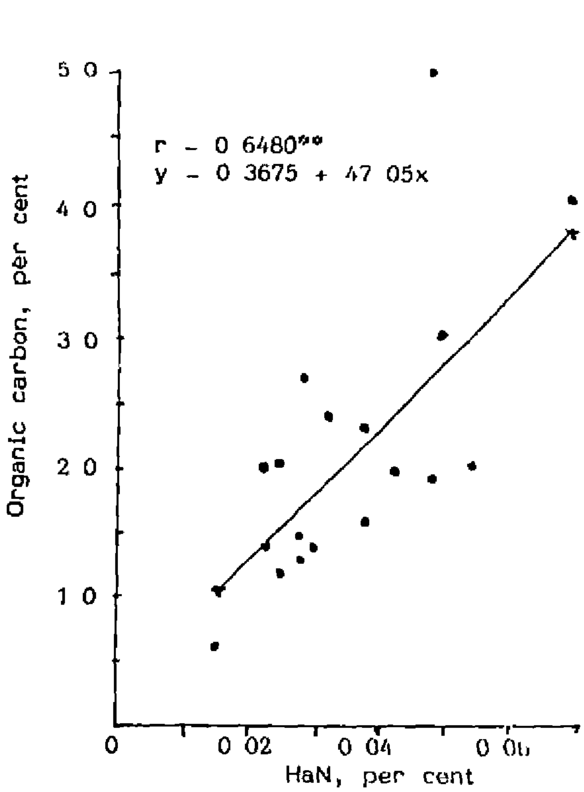
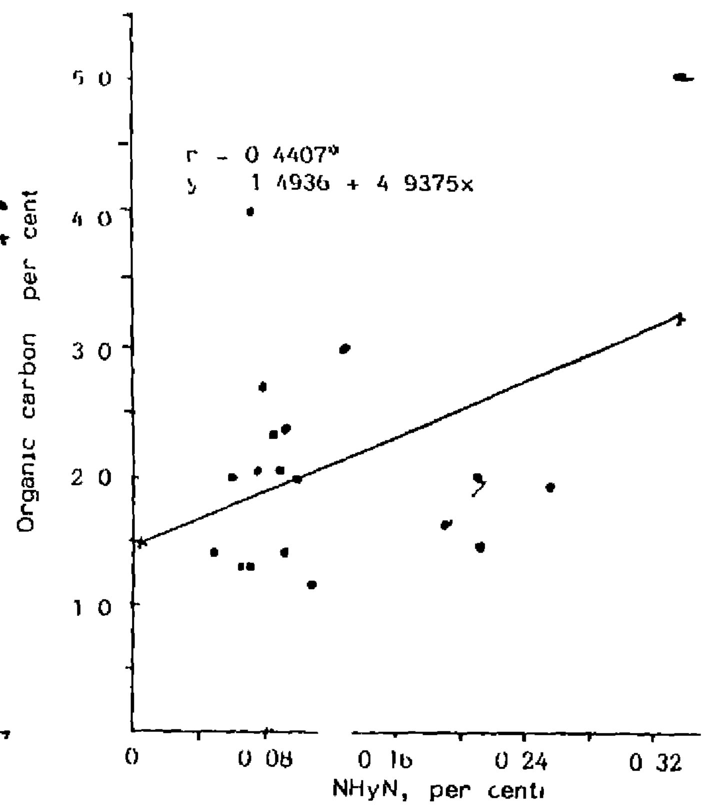


Fig 37 Relationship between NHyN and organic carbon in forest soil



Since NHyN is the significant fraction, it can be explained that keeping all other fractions constant a unit increase in NHyN will increase the organic carbon by 7.64 times.

9.4. Coastal alluvium

Among the selected soil types, the minimum organic carbon is reported for this type. The mean content of organic carbon is 0.34 per cent (0.14 to 0.80 per cent). In this type, simple regression analysis and multiple regression analysis showed that none of the various fractions of nitrogen significantly influence organic carbon. Multiple regression equation is

$$O.C. = 0.382 - 8.02\ NH_4\text{-}N + 5.66\ NO_3\text{-}N - 6.74\ FAN + 1.30\ AaN + 8.17\ HaN + 3.20\ HyAN - 1.72\ NHyN - 10.679\ UHyN\ (R^2 = 0.18).$$

9.5. Kuttanad alluvium

The mean content of organic carbon is 1.56 per cent (0.19 to 4.63 per cent). Simple linear regression analysis showed that only NHyN is significantly correlated to organic carbon (r = 0.48*) and this is graphically presented in Fig 39. Multiple regression analysis showed that various fractions of nitrogen doesn't significantly influence the organic carbon of soil.

$$O.C. = 0.958 - 194.82\ NH_4\text{-}N + 40.11\ NO_3\text{-}N + 7.01\ FAN + 3.30\ AaN - 6.98\ HaN - 28.71\ HyAN - 28.47\ NHyN^{*} + 14.47\ UHyN\ (R^2 = 0.56).$$

Fig 38 Relationship between HaN and organic carbon in brown hydromorphic soil

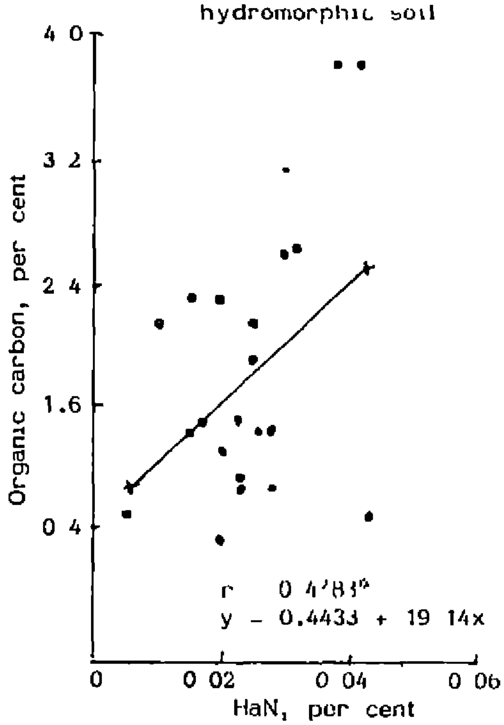


Fig 39 Relationship between NHyN and organic carbon in Kuttanad alluvial soil

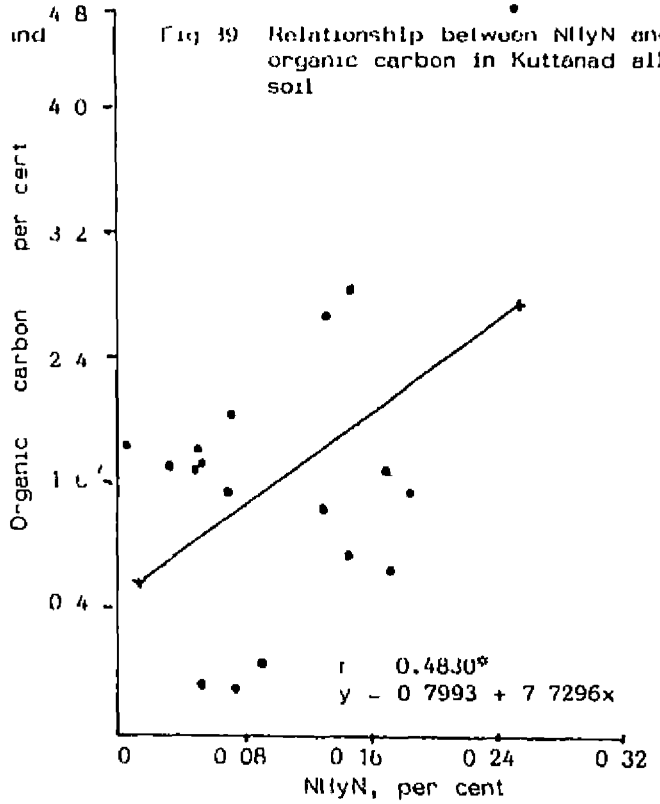


Fig 40 Relationship between THyN and alkaline $KMnO_4$-N in laterite soil

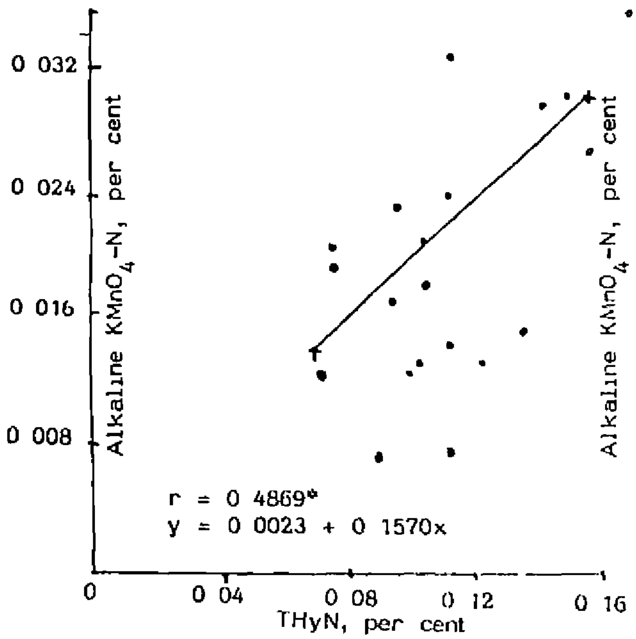
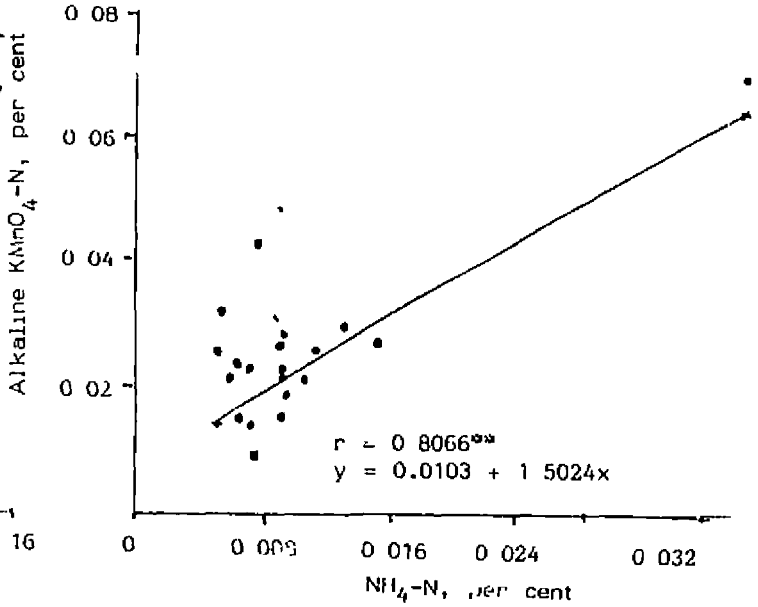


Fig 41 Relationship between NH_4-N and alkaline $KMnO_4$-N in forest soil



On studying the relationship of various nitrogen fractions to organic carbon in the selected soil types of Kerala it is revealed that, 75 per cent variation of organic carbon in laterite soil, 87 per cent variation of organic carbon in forest soil and 70 per cent variation of organic carbon in brown hydromorphic soils can be explained by the nitrogen fractions of the soils. But in the case of coastal alluvium and Kuttanad alluvium a significant relationship between the nitrogen fractions and organic carbon could not be established The relative importance of different fractions of nitrogen to organic carbon is reported as 75 per cent (Perumal and Velayudham, 1977).

10. Relationship between alkaline $KMnO_4$-N and nitrogen fractions

The data on alkaline $KMnO_4$ nitrogen of the selected soil types is given in Table 12.

10.1. Laterite

The mean content of alkaline $KMnO_4$-N for this type is 0.0192 per cent (0.0121 to 0.0327 per cent). Simple linear regression analysis showed that only THyN (0 49) is significantly correlated with alkaline $KMnO_4$-N The graphical representation of this is given in Fig. 40. Srivastava (1975) also established a highly significant correlation between THyN and alkaline $KMnO_4$-N

Table 12. Alkaline $KMnO_4$ nitrogen of soils (per cent)

Sample No.	Alkaline $KMnO_4$-N	Sample No.	Alkaline $KMnO_4$-N	Sample No	Alkaline $KMnO_4$-N	Sample No	Alkaline $KMnO_4$-N	Sample No.	Alkaline $KMnO_4$-N
L_1	0.0121	F_1	0.0699	B_1	0.0150	C_1	0 0021	K_1	0.0389
L_2	0.0127	F_2	0 0194	B_2	0 0013	C_2	0.0054	K_2	0.0197
L_3	0.0181	F_3	0.0261	B_3	0 1260	C_3	0 0154	K_3	0.0325
L_4	0.0174	F_4	0 0154	B_4	0 0147	C_4	0 0088	K_4	0.0261
L_5	0 0300	F_5	0 0148	B_5	0 0187	C_5	0 0088	K_5	0.0197
L_6	0.0128	F_6	0.0274	B_6	0 0049	C_6	0 0021	K_6	0 0197
L_7	0 0194	F_7	0.0267	B_7	0 0315	C_7	0 0054	K_7	0.0166
L_8	0 0154	F_8	0 0294	B_8	0 0945	C_8	0.0088	K_8	0 0032
L_9	0.0228	F_9	0.0208	B_9	0 0134	C_9	0.0054	K_9	0.0261
L_{10}	0.0241	F_{10}	0.0241	B_{10}	0 0101	C_{10}	0.0088	K_{10}	0.0038
L_{11}	0.0121	F_{11}	0 0307	B_{11}	0 0014	C_{11}	0 0021	K_{11}	0.0325
L_{12}	0.0301	F_{12}	0 0241	B_{12}	0 0150	C_{12}	0 0032	K_{12}	0.0077
L_{13}	0.0140	F_{13}	0 0208	B_{13}	0 1197	C_{13}	0.0021	K_{13}	0 0197
L_{14}	0.0327	F_{14}	0.0088	B_{14}	0.1229	C_{14}	0.0154	K_{14}	0.0070
L_{15}	0.0294	F_{15}	0 0247	B_{15}	0 0260	C_{15}	0.0088	K_{15}	0.0038
L_{16}	0 0077	F_{16}	0 0427	B_{16}	0 0186	C_{16}	0 0054	K_{16}	0.0134
L_{17}	0.0221	F_{17}	0.0154	B_{17}	0 0032	C_{17}	0.0088	K_{17}	0 0197
L_{18}	0.0127	F_{18}	0.0234	B_{18}	0 0241	C_{18}	0 0014	K_{18}	0.0197
L_{10}	0.0077	F_{19}	0 0208	B_{19}	0 0167	C_{19}	0.0021	K_{19}	0 0261
L_{20}	0.0307	F_{20}	0 0254	B_{20}	0.0120	C_{20}	0 0121	K_{20}	0.0203
Mean	0.0192		0.0255		0 0345		0.0066		0.0188

The multiple regression model is given below

$$\text{Alkaline } KMnO_4\text{-N} = 0.004 + 0\ 22\ NH_4\text{-N} + 0.75\ NO_3\text{-N} - 0\ 28\ FAN + 0.34\ AaN + 0.30\ HaN - 0\ 54\ HyAN + 0\ 18\ NHyN - 0.03\ UHyN\ (R^2 = 0\ 54)$$

Partial r^2 showed that AaN, a contributent of THyN significantly and positively influence the alkaline $KMnO_4$-N.

Relationship of soil nitrogen fractions with crop response revealed that AaN is important for crops like maize (Cornforth, 1965), wheat (Aggarwal, 1971), pearl millet (Singh, 1972). Perumal and Velayutham (1977) stated the importance of amino acid nitrogen in the nutrition of rice.

So, the significant relationship established between the AaN and alkaline $KMnO_4$-N shows that the alkaline $KMnO_4$-N in the laterite soils of Kerala can be considered as a reliable method of available nitrogen estimation. Swarajyalakshmi (1987) established the contribution of AaN in the available pool of nitrogen.

10.2. Forest soil

The mean content of alkaline $KMnO_4$-N for this type is 0.0255 per ent (0.0088 to 0 0699 per cent)

Simple linear regression analysis showed that NH_4-N (0.81**), NO_3-N (0.66 *) and NHyN (0.52**) are significantly and positively correlated with alkaline $KMnO_4$-N and these are graphically presented in Fig. Nos. 41 to 43. Multiple regression analysis showed that various fractions of nitrogen significantly influence the alkaline $KMnO_4$-N (R^2 = 0.84). Partial r^2 value showed that, among the various fractions NH_4-N and HyAN is significant Regression equation is,

$$\text{Alkaline } KMnO_4\text{-N} = 0.003 + 1.53\ NH_4\text{-N}^{**} - 2.50\ NO_3\text{-N} - 0.23\ \text{FAN} + 21.0\ \text{AaN} + 0.20\ \text{HaN} + 0.63\ \text{HyAN} + 0.04\ \text{NHyN} - 0.005\ \text{UHyN}\ (R^2 = 0.84^{**}).$$

The equation revealed that 84 per cent variation in alkaline $KMnO_4$-N can be explained by nitrogen fractions. A unit increase in NH_4-N and HyAN cetaria paribus will increase the alkaline $KMnO_4$-N by 1.53 and 0.63 units respectively.

In forest soils the dominant end product of mineralization is NH_4-N which agrees with the data reported by several workers (Nommik, 1976; Geist, 1977; Federer, 1983).

10.3. Brown hydromorphic soil

The mean content of alkaline $KMnO_4$-N for this type is 0.0345 per cent (0 0013 t0 0.1229 per cent).

Simp.. linear regression and multiple regression analysis showed that various fractions of nitrogen does not significantly influence the alkaline $KMnO_4$-N. Multiple regression equation is

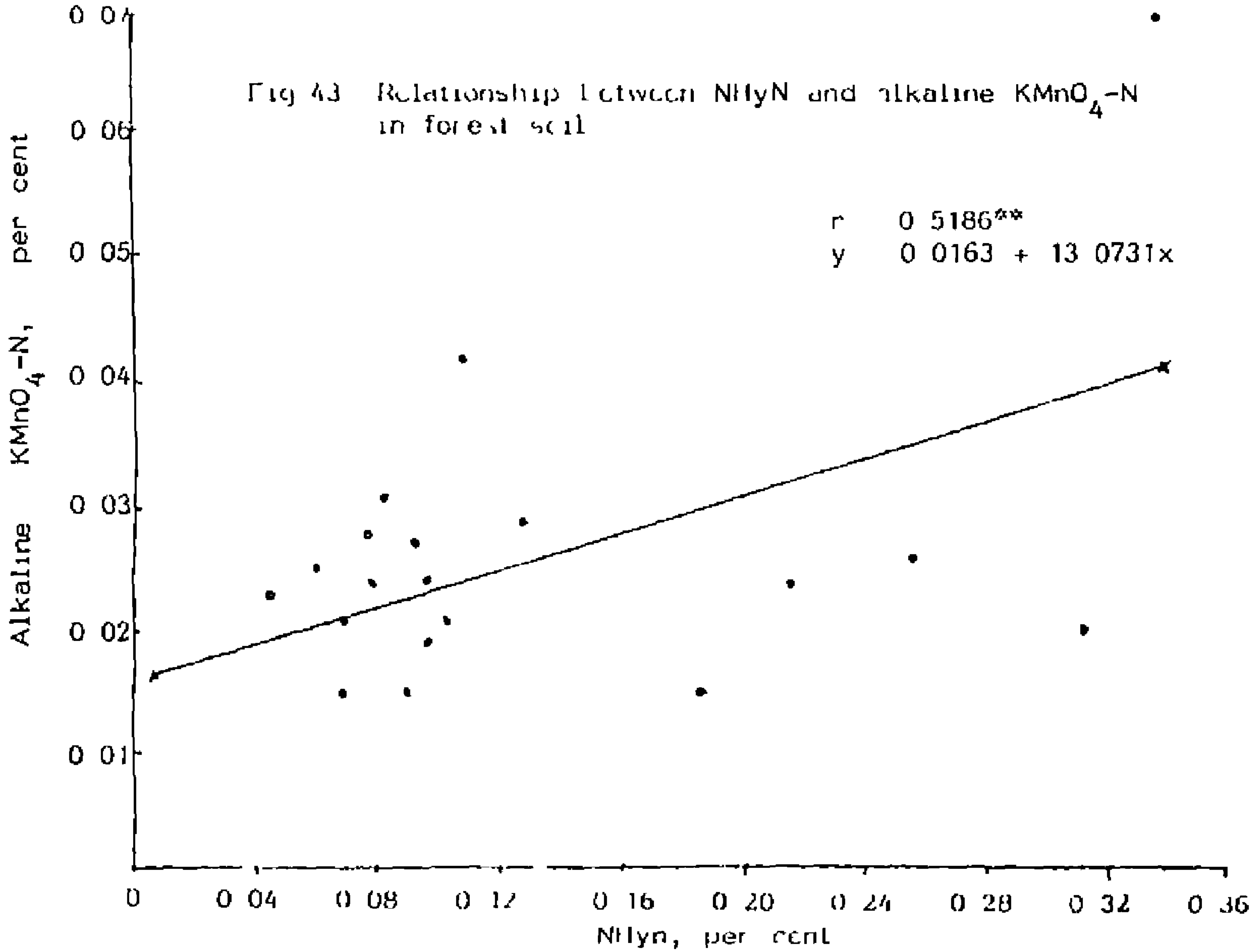
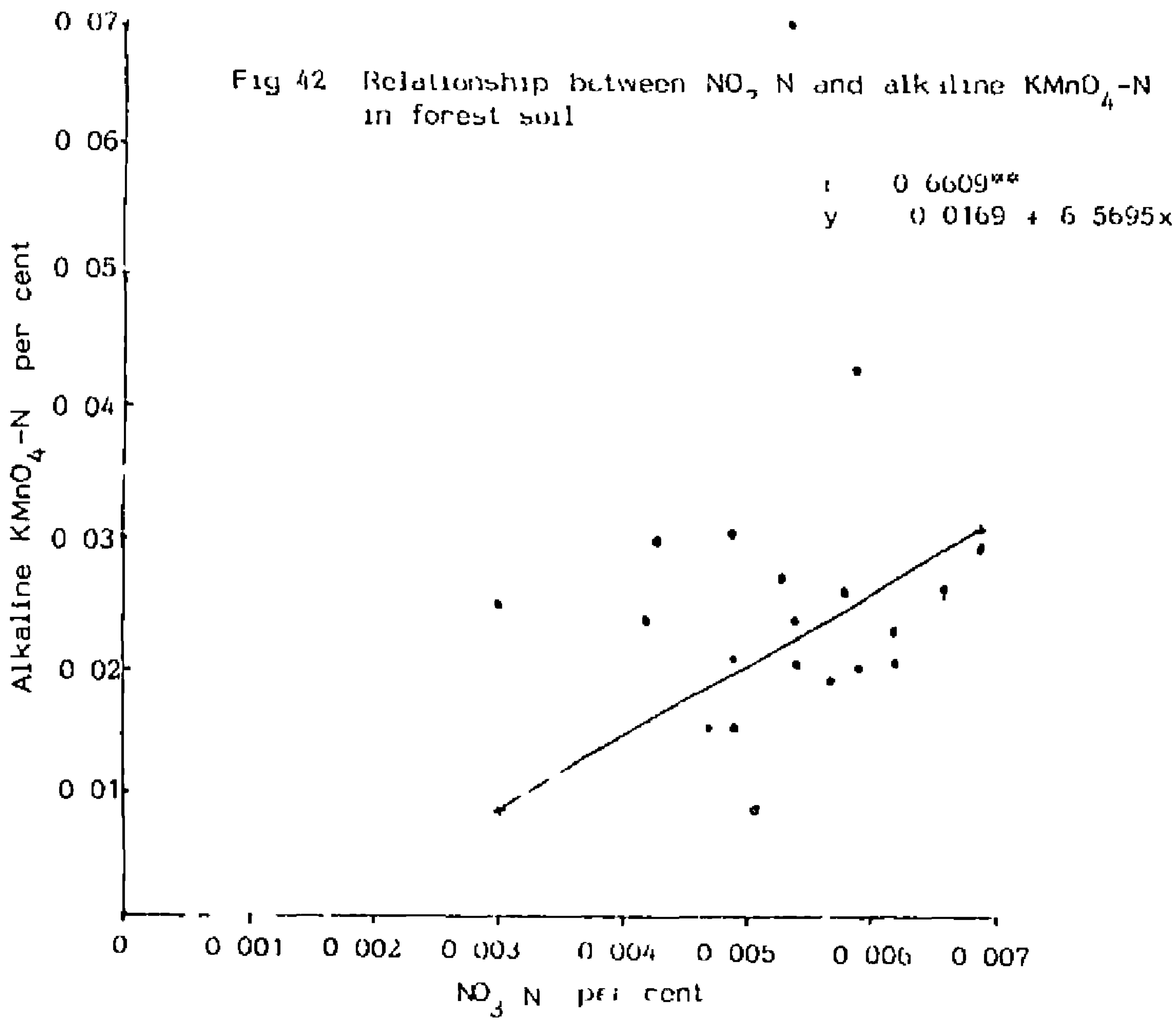


Fig 43 Relationship between NHyN and alkaline $KMnO_4$-N in forest soil

Fig 42 Relationship between NO_3 N and alkaline $KMnO_4$-N in forest soil



Alkaline $KMnO_4$-N = 0.052 + 4.83 NH_4-N + 0.158 NO_3-N - 0.825 FAN - 0.217 AaN - 1.355 HaN - 2.90 HyAN + 0.135 NHyN + 0.956 UHyN (R^2 = 0.44).

10.4. Coastal alluvium

The mean content of alkaline $KMnO_4$-N for this type is per cent (0.0021 to 0.0066 per cent).

Simple regression and multiple regression analysis showed that various fractions of nitrogen does not significantly influence the alkaline $KMnO_4$-N in soil. Multiple regression equation is

Alkaline $KMnO_4$-N = 0 0016 + 0.324 NH_4-N + 0.275 NO_3-N - 0.216 FAN - 0.022 AaN + 0.473 HaN + 0.397 HyAN + 0.008 NHyN + 0 073 UHyN (R^2 - 0 49).

10.5. Kuttanad alluvium

The mean content of alkaline $KMnO_4$-N for this type is 0.0188 per cent (0.0032 to 0.0389 per cent).

Simple regression and multiple regression analysis showed that various fractions of nitrogen did not influence the alkaline $KMnO_4$-N in soil.

Alkaline $KMnO_4$-N = 0.009 - 0.935 NH_4-N + 0.295 NO_3-N - 0.047 FAN + 0.263 AaN 0.187 HaN - 0.441 HyAN + 0.002 NHyN + 0.173 UHyN (R^2 = 0.28).

In the three soil types viz., brown hydromorphic, coastal alluvium and Kuttanad alluvium a significant relationship between the alkaline $KMnO_4$-N and nitrogen fraction could not be established. So for these types of soil, a better analytical method of available nitrogen than that of alkaline $KMnO_4$-N has to be taken up.

11. Relationship between nitrogen uptake and nitrogen fractions

The data on nitrogen uptake by rice seedlings in the selected soil types is given in Table 13. Among the five types of soil studied none of the soil type established a significant relationship between nitrogen uptake and the nitrogen fractions. These findings are in contrast to the previous reports (Aggarwal, 1971; Singh, 1972, Black and Waring, 1972; Keerthisinghe et al , 1984; Baethgan and Alley, 1987). But a negative relation of NHyN to nitrogen uptake in rice is reported by Mohapatra (1988).

Eventhough not significant, 62, 32, 24, 52 and 38 per cent variations in the nitrogen uptake can be explained by the nitrogen fractions of the laterite, forest, brown hydromorphic, coastal alluvium and Kuttanad alluvium soils respectively

The nitrogen uptake in the present study was calculated from the data obtained from the Neubauer experiment. The nonadaptability of the Neubauer technique for nitrogen uptake studies was reported due to the highest nitrogen content in the paddy seeds. It is

Table 13. Nitrogen uptake, ~~per cent~~

Sample No	Uptake	Sample No.	Uptake	Sample No.	Uptake	Sample No.	Uptake	Sample No.	Uptake
L_1	0.028	F_1	0 065	B_1	0.042	C_1	0.049	K_1	0 047
L_2	0 040	F_2	0.082	B_2	0 049	C_2	0.048	K_2	0 034
L_3	0 066	F_3	0.043	B_3	0.041	C_3	0.038	K_3	0 051
L_4	0.056	F_4	0 029	B_4	0 042	C_4	0.039	K_4	0 051
L_5	0.023	F_5	0.025	B_5	0.045	C_5	0.055	K_5	0 052
L_6	0.046	F_6	0.039	B_6	0.041	C_6	0 035	K_6	0 060
L_7	0.030	F_7	0.076	B_7	0.025	C_7	0.033	K_7	0 059
L_8	0 056	F_8	0 024	B_8	0.026	C_8	0.046	K_8	0 056
L_9	0 057	F_9	0.046	B_9	0.023	C_9	0.034	K_9	0 033
L_{10}	0.04[illegible]	F_{10}	0.042	B_{10}	0.027	C_{10}	0.045	K_{10}	0 045
L_{11}	0 040	F_{11}	0.068	B_{11}	0 059	C_{11}	0.034	K_{11}	0 042
L_{12}	0.048	F_{12}	0 032	B_{12}	0.034	C_{12}	0.046	K_{12}	0 031
L_{13}	0 041	F_{13}	0.049	B_{13}	0 055	C_{13}	0 027	K_{13}	0 034
L_{14}	0.042	F_{14}	0.047	B_{14}	0 039	C_{14}	0 031	K_{14}	0 054
L_{15}	0.038	F_{15}	0.027	B_{15}	0.041	C_{15}	0.046	K_{15}	0 054
L_{16}	0 050	F_{16}	0 045	B_{16}	0 054	C_{16}	0.029	K_{16}	0.053
L_{17}	0.054	F_{17}	0 045	B_{17}	0.050	C_{17}	0.059	K_{17}	0 029
L_{18}	0.050	F_{18}	0.044	B_{18}	0.048	C_{18}	0 050	K_{18}	0 053
L_{19}	0.047	F_{19}	0 056	B_{19}	0.048	C_{19}	0.038	K_{19}	0 038
L_{20}	0.025	F_{20}	0.074	B_{20}	0.031	C_{10}	0 036	K_{20}	0 014
Mean	0.044		0.048		0.041		0 041		0 045

Table 14. C/N Ratio of soils

Sample No.	C/N Ratio	Sample No.	C/N Ratio	Sample No	C/N Ratio	Sample No.	C/N Ratio	Sample No	C/N Ratio
L_1	4.0	F_1	10.29	B_1	4.29	C_1	1.97	K_1	5.17
L_2	4.86	F_2	7.84	B_2	3.87	C_2	1.88	K_2	5 17
L_3	3.69	F_3	4.94	B_3	4 66	C_3	1 56	K_3	3 89
L_4	2.79	F_4	4.82	B_4	4 68	C_4	1.17	K_4	7.28
L_5	5.09	F_5	7 58	B_5	4 16	C_5	1.09	K_5	9.18
L_6	7.43	F_6	9.48	B_6	4 61	C_6	1.33	K_6	4 53
L_7	6.47	F_7	10 86	B_7	2 97	C_7	1 67	K_7	6.96
L_8	5.30	F_8	9.15	B_8	5 57	C_8	3 00	K_8	2.25
L_9	10 50	F_9	9.43	B_9	7.08	C_9	2.17	K_9	7.54
L_{10}	4.05	F_{10}	4 56	B_{10}	6.88	C_{10}	2.72	K_{10}	8 93
L_{11}	5.00	F_{11}	9.64	B_{11}	4.73	C_{11}	1 43	K_{11}	1 36
L_{12}	10.15	F_{12}	7.51	B_{12}	4 44	C_{12}	2 71	K_{12}	10.05
L_{13}	5.77	F_{13}	3.32	B_{13}	5.97	C_{13}	2 62	K_{13}	3.54
L_{14}	9.55	F_{14}	6.10	B_{14}	5 10	C_{14}	7.33	K_{14}	1.24
L_{15}	9.75	F_{15}	8.37	B_{15}	6 45	C_{15}	1.86	K_{15}	2 23
L_{16}	6.77	F_{16}	6.65	B_{16}	6.91	C_{16}	0.77	K_{16}	1.86
L_{17}	5.58	F_{17}	6.65	B_{17}	1 85	C_{17}	0.88	K_{17}	4.91
L_{18}	5.48	F_{18}	7.34	B_{18}	4.60	C_{18}	5.16	K_{18}	7.10
L_{19}	3.25	F_{19}	5.23	B_{19}	7 40	C_{19}	2 36	K_{19}	6.26
L_{20}	11.13	F_{20}	10.99	B_{20}	5 00	C_{20}	2.38	K_{20}	13.50
Mean	6 33		7.54		5.06		2.30		5.65

presumed that this nitrogen is sufficient for seedling growth and absorption of N from the soil might have taken place only to a very limited extent

12. C:N ratio

The C N ratio of the selected soil types is presented in Table 14. The mean value of C:N ratio in the selected soil types were 6.33 (2.79 to 11 13), 7 54 (3 32 to 10 99), 5 06 (1.85 to 7 4), 2.30 (0.77 to 7 33) and 5 65 (1 24 to 13 50) in the laterite, forest, brown hydromorphic, coastal alluvium and Kuttanad alluvium respectively. The forest soil reported the highest C/N ratio and the least by coastal alluvium. This may be due to the variation in organic matter content The C/N ratio of the soil is mainly decided by the organic matter content of soil, rather than the content of total nitrogen (Usha and Jose, 1983)

Summary

SUMMARY

Surface samples belonging to five soil types viz., laterite, forest, brown hydromorphic, coastal alluvium and Kuttanad alluvium, selected from various places of the State were analysed to find out the various fractions of nitrogen. The results of the study are summarised as follows.

1) Among the various nitrogen fractions, AaN reported the maximum for laterite soil followed by FAN, HyAN, UHyN, HaN, NHyN, NH_4-N and NO_3-N in the descending order.

2) In the case of forest soil, the major fraction is the NHyN followed by AaN, HaN, UHyN, FAN, HyAN NH_4-N and NO_3-N

3) As in the case of laterite soil, brown hydromorphic soil also reported AaN as major fraction, followed by UHyN, NHyN, FAN, HaN, HyAN, NH_4-N and NO_3-N

4) In the case of coastal alluvial soil type, major fraction is NHyN followed by AaN, UHyN, FAN, HaN, HyAN NH_4 N and NO_3-N.

5) In the case of Kuttanad alluvial soil, major fraction is NHyN, followed by AaN, FAN, HaN, UHyN, NO_3-N, NH_4-N and HyAN.

6) In all the five soil types, a significant positive correlation between cation exchange capacity and FAN is reported.

7) On studying the relationship of various nitrogen fractions to organic carbon on the selected soil types of Kerala, it is revealed that,

75 per cent variation of organic carbon in laterite soil, 87 per cent variation of organic carbon in forest soil and 70 per cent variation of organic carbon in brown hydromorphic soils can be explained by the nitrogen fractions of the soils. But in the case of coastal alluvium and Kuttanad alluvium a significant relationship between the nitrogen fractions and organic carbon could not be established

8) The significant relationship obtained between AaN and alkaline $KMnO_4$-N, considers alkaline $KMnO_4$-N, as a reliable method of available nitrogen estimation, in the laterite soils of Kerala.

9) In the three soil types viz., brown hydromorphic, coastal alluvium and Kuttanad alluvium, a significant relationship between the alkaline $KMnO_4$-N and nitrogen fraction could not be established. So for these types of soil, a better analytical method of available nitrogen than that of alkaline $KMnO_4$-N has to be taken up.

10) Among the five types of soil studied, none of the soil type established a significant relationship between the nitrogen uptake and the nitrogen fractions in the simple regression and multiple regression analysis conducted.

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* Originals not seen.

FRACTIONATION OF ORGANIC AND INORGANIC NITROGEN IN IMPORTANT SOIL TYPES OF KERALA

By

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ABSTRACT OF A THESIS

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ABSTRACT

In order to study the distribution of various organic and inorganic fractions of soil nitrogen in different soil types of Kerala, 100 surface soil samples belonging to five types were selected from various places of the state. The five soil types were laterite, forest, brown hydromorphic, coastal alluvium and Kuttanad alluvium.

Observations on the general characteristics of soil revealed that total nitrogen and organic carbon was highest for forest soil and was least in the case of coastal alluvium. In general all the soil types were acidic in reaction. Electrical conductivity was highest in the case of Kuttanad alluvial soil

Fractionation of nitrogen showed that the most dominant fraction in the case of laterite and brown hydromorphic soils are AaN and that for forest, coastal alluvium and Kuttanad alluvium is NH_yN. Mean total nitrogen content for laterite soils is 0.174 per cent. Of this, 27 59 per cent was AaN, 20.69 per cent FAN, 16.67 per cent NHyN, 14.94 per cent HyAN, 11.67 per cent UHyN, 3.85 per cent NH_4-N, 2 64 per cent NO_3-N and 1 95 per cent HyAN. The mean value of total nitrogen content of the forest soil was 0 304 per cent. Of this 41 45 per cent was NHyN, 17 86 per cent AaN, 12.24 per cent HaN, 10.63 per cent FAN, 10.36 per cent UHyN 3.36 per cent NH_4-N, 2 37 per cent HyAN and 1 74 per cent NO_3-N The mean total nitrogen content of the brown hydromorphic soil was 0 180 per cent Of this, 21.60 per cent was AaN, 21 25 per cent UHyN, 18.20 per cent NHyN,

17.20 per cent FAN, 13.76 per cent HaN, 3.16 per cent HyAN, 3.11 per cent NH_4-N and 1.67 per cent NO_3-N. The mean content of total nitrogen of the coastal alluvial soil was 0.161 per cent. Of this, 27.65 per cent NHyN, 22.26 per cent AaN, 19.96 per cent UHyN, 12.40 per cent FAN, 6.51 per cent HaN, 6.26 per cent HyAN, 3.10 per cent NH_4-N and 1.74 per cent NO_3-N. The mean content of total nitrogen of the Kuttanad alluvial soil was 0.2705 per cent. Of this, 37.04 per cent was NHyN, 15 16 per cent AaN, 14.94 per cent FAN, 11.42 per cent HaN, 10.76 per cent UHyN, 3.99 per cent NO_3-N, 3 70 per cent NH_4-N and 2.96 per cent HyAN

In all the five soil types there was significant positive correlation between cation exchange capacity and FAN On studying the relationship of various nitrogen fractions to organic carbon on the selected soil types of Kerala revealed that 75 per cent variation of organic carbon in laterite soil, 87 per cent variation of organic carbon in forest soil and 70 per cent variation of organic carbon in brown hydromorphic soil can be explained by the nitrogen fractions of the soils The significant relationship obtained between AaN and alkaline $KMnO_4$-N, considers alkaline $KMnO_4$-N as a reliable method of available nitrogen estimation, in the laterite soils of Kerala. In the three soil types, viz., brown hydromorphic, coastal alluvium and Kuttanad alluvium, a significant relationship between the alkaline $KMnO_4$-N and nitrogen fraction could not be established. So for these types of soil, a better analytical method of available nitrogen than that of alkaline $KMnO_4$-N has to be taken up.