ASSESSMENT OF NITRIFICATION RATES OF SOILS AND SCREENING OF PLANT MATERIALS FOR NITRIFICATION INHIBITION PROPERTIES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled Assessment of nitrification rates of soils and screening of plant materials for nitrification inhibition properties is a bonafide record of research work done by me during the course of research and that, the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or any other similar title from any other university or society

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Certified that the thesis entitled **Assessment of nitrification rates of soils and screening of plant materials for nitrification inhibition properties** is a record of the research work done by Kum. C Rekha under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her

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Introduction

INTRODUCTION

Nitrogen demand by today s high-yielding crops frequently exceeds the supply of this essential plant nutrient from soil, and a sustained production requires input of fertilizer nitrogen in large amounts However, the fertilizer nitrogen use efficiency in terms of the percentage recovery of fertilizer nitrogen by the crop is only 25 to 40 per cent in the tropics One method of increasing fertilizer use efficiency is to minimise loss of fertilizer nitrogen from the crop root zone and thereby improve the opportunity for plant uptake of applied nitrogen The ammoniacalform of nitrogen being relatively immobile in soil, is retained better than the nitrate form which is liable to losses through leaching and denitrification But the application of ammonium fertilizers seldom increases the fertilizer use efficiency since the ammoniacal form gets rapidly converted to the nitrate form through the biologically controlled process of nitrification Hence retardation of nitrification of the ammonium form may reduce nitrogen losses and increase fertilizer use efficiency under conditions favouring larger loss of nitrate nitrogen The important factors effecting the nitrification pattern in soils are supply of ammonium ion population of nitrifying organisms, soil reaction soil aeration, soil moisture and

temperature Low rates of nitrification have been reported earlier in the laterite and forest soils (Mathew, 1986, Zacharias, 1989) of Trichur district However, they failed to associate the low rates of nitrification to factors like lack of nitrifier population, soil pH, soil organic matter content or other soil chemical factors Apart from these soil characters, an influence of the associated crop on the nitrification rates of soils has been reported by many workers A possible influence of crop association on the low rates of nitrification in these soils has not been studied so far

Nitrification inhibitors specifically retard the activity of nitrifying bacteria and thereby nitrogen mineralization stops with the production of ammoniacal nitrogen which is not liable to loss by denitrificatiion and not as much liable to leaching Eventhough a number of synthetic chemicals (N-Serve AM etc) have been established as potential nitrification inhibitors, their adoption is highly limited by the high cost and lack of availability So a number of inexpensive and locally available plant products such as vegetable tannins waste tea non-edible oil seed cakes etc were identified as nitrification inhibitors In an earlier study (Mathew 1986) a number of indigenous plant materials were screened for nitrification inhibition

properties but it was not possible to identify a potential nitrification inhibitor So a further screening of these materials using a soil of reasonable nitrification potential was considered appropriate to assess their nitrification inhibition abilities

The objectivesof the present study taken up with this background in view were the following

1 To asses the relative rates of nitrification of laterite, forest and alluvial soils of Trichur district

2 To relate nitrification rates with cropping history

3 To assess the nitrification inhibition properties of a few plant materials based on laboratory and pot culture studied

Review of Literature

REVIEW OF LITERATURE

Literature on the factors affecting nitrification and nitrification inhibitors is reviewed in this chapter Literature on these were reviewed earlier by Mathew (1986) and Zacharias (1989) Those references which appeared in these two reviews are not included in this chapter and it covers literature on the two aspects published since 1987 only excepting a few important earlier references which are of historical importance

2 1 Factors affecting nitrification

2 1 1 Population of nitrifying organisms

Many microbiologists have investigated the abundance of nitrifiers in nature According to Alexander (1977) the numbers of ammonium oxidisers vary from zero to one million per gram of soil and the population of both groups of oxidisers may be enlarged by use of ammonium salts Soils differ in their ability to nitrify added ammonium compounds even under similar conditions of temperature, moisture and level of added ammonium and this may be due to the variation in the number of nitrifying organisms present (Tisdale et al 1985) Singh and Beauchamp (1986) observed that nitrifier

population is limited in an unlimed acid soil, but on sufficient liming, the population increases to such an extent that further nitrification is limited by a lack of substrate De Boer et al (1988) reported that enrichment of acid soils with NPK fertiliser increased the number of autotrophic ammonium and nitrite-oxidising bacteria although the pH hardly changed with fertilization Hankinson and Schmidt (1988) isolated two physiologically and serologically distinct strains of chemoautotrophic nitrite-oxidising bacteria One isolate responded as a neutrophile and the other as acidophile with maximal nitrite oxidising activity at pH 5 5 and pH tolerance range of 4 1 to 7 2 De Boer et al (1989) reported that the occurrence of acid-tolerant chemolithotrophic nitrification is an indirect evidence for the existence of previously unknown acid-tolerant, chemolithotrophic ammonium-oxidising bacteria According to Berg and Rosswall (1989), the numbers of ammonium and nitrite oxidisers correlated strongly with changes in water potential Bramley and White (1989) observed that nitrifier population is fairly adaptable to changes in its environment and that as a result, pH opt for an indigenous population is never far from the prevailing soil pH Further, it was also reported that the difference in nitrifying capacity among the soils is related to the size of initial nitrifier population and the nitrifier population in a soil under permanent pasture reached a maximum in May and

September Considerable flush in autotrophic nitrifiers occurred in coniferous forest soil in response to urea fertiliser addition due to a combined increase in soil pH and supply of substrate (Kilham, 1990) Nitrification in a fresh forest floor is brought about by autotrophic and heterotrophic nitrifiers whereas that in an aged (cleared) forest floor is solely by heterotrophic nitrifiers (Duggin et al.,1991).Laskar et al (1991) reported that nitrifying organisms failed to function in potential acid sulphate soils because of a very low pH Population of Nitrosomonas and Nitrobacter in the soil decreased as water content increased (Senapati et al , 1992) According to De Boer et al (1992), both acid-sensitive and acid-tolerant ammonium oxidising bacteria contribute to nitrification in the litter layer, but the acid-tolerant or even acidophilic bacteria are responsible for ammonium oxidation in the fermentation and humus layers of an acid forest soil Martikainen and De Boer (1993) also reported the occurrence of acid-tolerant chemolithotrophic ammonium oxidizers which nitrify at a higher rate at pH 4 than at pH 6

2.1.2 Supply of ammonium ions

Shaviv (1988) reported that increased ammonium concentrations in soil reduced nitrification rates Singh and Beauchamp (1989) studied the influence of placement of large

Nitrification takes place at a low rate in soils having a pH lower than 5 0 (Sims and MacKown, 1987 Sahrawat 1992) but, liming of acid soils to a near neutral pH increased the nitrification rate (Nyborg et al , 1988) Mai (1988) found that nitrification is strongly inhibited in acid forest soils but can be enhanced by acidity lowering treatments especially application of lime and urea Bramley and White (1990) observed that the optimum pH for nitrifier activity is close to the soil pH indicating that the indigenous nitrifier population adjusts to the prevailing soil pH The autotrophic nitrifying bacteria from acid soils were found to be sensitive to a pH increase (Stams and Marnette 1990) Javid and Fisher (1990) reported that significant stimulation of nitrification occurred by the addition of gypsum to reduce soil pH from 8 0 to 7 2 Sahrawat (1992) studied the extent of nitrification of applied urea-N in three different soils of varying pH and concluded that nitrification was positively correlated with pH It was observed that while 78% and 64% of the applied urea-N was nitrified in the two soils with pH 8 35 and 6 2 respectively only 1% of the urea-N was nitrified in the third soil of pH 4 5 in a period of 2 10 days

2 1 4 Soil moisture

Chandler (1985) based on studies involving moisture contents of soil maintained at 30 50 and 100 per cent field

capacity reported that nitrification decreased with increasing water content in soil eventhough it continued at low rates at 100 per cent field capacity Soil moisture content exerts a controlling influence on nitrifier activity (Berg and Rosswall 1989) although there is no significant correlations between soil moisture and nitrification (Bramley and White, 1989) According to Bramley and White (1990), soil moisture stress was not as critical in regulating nitrifier activity as was soil pH, may be because of the fact that there being a considerable variation in soil moisture status with season, the nitrifiers are more tolerant to changes in pF than changes in pH The optimum nitrifier activity occurred around pF 3 4 Eventhough nitrification potential rate decreased during the dry season a significant population remained viable when soil water potential was -9 MPa indicating that nitrifying bacteria can tolerate severe desiccation (Davidson et al , 1990) Kilham (1990) reported that nitrification in coniferous forest floor material is most often restricted by water potential stress

2 1.5 Soil temperature

Mac Lean and Mc Rae (1987) observed that nitrification was highly temperature dependent and it increased with temperature in a range of 4 18°C Nitrification was limited at 4°C extensive at 9°C, essentially complete after 48-68 d at

18°C, 90 per cent complete after 92 d at 9 and 13°C According to Teske et al (1988) the differences in nitrification rate between soils were small at 10°C, but it increased as the temperature decreased and at 5°C, it was absent in acid sandy soils, but was still rapid in biologically active soils Foster (1989) reported that nitrification is significantly influenced by variation in seasonal temperature and maximum nitrification occurred in a forest soil when incubated at 20°C Nitrification in oak-beech litter in Netherlands was optimum at 25°C and was inhibited at 0, 5 and 30°C (Emmer and Tietema, 1990) Kilham (1990) observed that nitrification in temperate coniferous forest soils is frequently limited by temperature

2.1.6 Soil management

Burton et al (1986) reported that addition of sludge promoted nitrification in forest floors and surface soils of all forest types which otherwise did not nitrify Mulching with polyethylene film to give soil sterilization with solar energy is reported to reduce nitrate production (Hasson et al , 1987) Clays-Josserand et al (1988) observed that nitrification potential reached its maximum value in the first two cm and then decreased with depth in a forest soil Kabista et al (1988) reported that continuous irrigation for a long period reduced nitrification rates and potential

nitrification capacity due to soil compaction accompanied by a decrease in water absorption and the maximum water holding capacity Soil burning (at 600°C) causes complete volatilisation of ammonium ions and compounds and significant increase in pH from 7 6 to 11 7, under which conditions, ammonification and nitrification reactions are inhibited (Kutiel and Shaviv 1989) Montagnini and Buschbacher (1989) observed a higher nitrification in the soils of slash and-burn agricultural sites when compared to that in undisturbed forests Staley et al (1990) studied the effect of no-tillage and or conventional tillage on soil potential nitrification activity It was observed that most of the nitrification activity was concentrated in the soil surface (0-3 8 cm) layer especially under no-tillage and decreased to low levels in the deepest (15-30 cm) layer examined Duggin et al (1991) reported that clear-cutting of forest stands accelerates nitrification but as forest regrowth proceeds, nitrification rates decline Nitrification was rapid following thinning to reduce stand density but it slowed down as the plantation aged (Javid and Fisher, 1991)

2 1 7 Type of vegetation

Lodhi (1978) suggested that vegetation can significantly affect populations of NH_4^+- oxidizers and found that the populations differed under different tree species

within a single forest community Chandler (1985) reported that nitrification is inhibited in oligotrophic tropical soils supporting climax vegetation Nitrification in arable soils in East Germany was least in fallow and successively greater under wheat potato and maize (Forster and Muller 1987) According to Ellis and Pennington (1989), the rate of nitrification is dependent upon the presence of particular tree species in a stand, upon its history of disturbance, and hence in part upon the successional status of the stand Nitrification generally increased as succession proceeded from mature grassland or eucalyptus forest towards climax temperate rain forest, but decreased in climax forests and the influence of individual tree species was paramount Contrary to this, Donaldson and Henderson (1990a) observed the highest potential for nitrification in soils collected from 63 years old mature oak stands compared to that from sites three years after clear cutting the forests Eventhough inhibitory compounds are produced in greater quantities in the more mature stands greater soil nitrogen levels enhance their decomposition thereby resulting in a greater nitrification in older oak stands (Donaldson and Henderson, 1990b) Low or negligible rates of net nitrification were reported in the forest floors of many coniferous forests by Kilham (1990) which he attributed to the combined effect of substrate availability pH, allelopathy water potential, nutrient status and

temperature Wheatley et al (1990) raised plants of barley, rye grass pea or turnip in pots of unfertilised soil and observed that nitrification rates were depressed compared with the fallow in all treatments except pea Troelstra et al (1990) reported a higher nitrification rate in the grass-dominated sites in comparison with the sites dominated by dwarf shrubs Nitrification varies significantly with the successional stage of vegetation and generally increases with successional age (Barford and Lajtha 1992)

2 1.8 Organic matter

Lodhi (1978) reported that variation in nitrification under different tree species in the same forest ecosystem is due to the variable tree litter under different species which in turn produces inhibitors of nitrification and nitrifiers According to White (1986), water extractable and volatile organics of the forest floor of a ponderosa pine ecosystem inhibited nitrate production by 17 per cent and 87 4-100 per cent respectively White and Gosz (1987) reported that organic quality of the substrate and temporal changes in organic quality controlled N-mineralisation and nitrification processes in forest floor Crescenzi et al (1988) reported hindered growth of nitrifiers and low nitrification in a soil ammended with glucose Mc Carty et al (1991) found that phenolic acids did not significantly retard nitrification in

soil even when their concentrations greatly exceeds the levels that have been reported to occur in soil Karmarkar and Tabatabai (1991) reported that the addition or production of organic acids in soils affects the microbial dynamics leading to significant changes in rates of nitrification According to Wedraogo et al (1993), the nitrogen mineralization behaviour varies depending on the type of plant litter and the difference between litter types in their nitrification ability can be related to their general biodegradability

2 2. Use of nitrification inhibitors

Nitrification inhibitors when applied to soil along with ammoniacal fertilizers postpone oxidation of NH_4^+ to NO_2^- and NO_3^- This reduces loss of nitrogen by leaching and denitrification and thus helps to achieve a more efficient use of nitrogen for crop production The interest in nitrification inhibitors followed the development of nitrapyrin as an effective inhibitor of nitrification by Goring (1962) Numerous compounds have since then been proposed for regulating nitrification in soils including organic and inorganic compounds, pesticides, chelating agents and plant products

2 2.1 Synthetic nitrification inhibitors

2.2.1.1 Nitrapyrin or N-Serve (2-Chloro-6-(trichloromethyl) Pyridine)

Chancy and Kamprath (1987) reported that higher nitrapyrin rates are required to reduce nitrification as the soil organic matter content increases, probably because of its sorption by organic matter Application of nitrogen with nitrification inhibitors increased the wheat grain yield and protein content and maize fresh fodder yield and crude protein content Reduced loss of applied N, greater N uptake, increased grain yield and zein content consequent to the application of nitrapyrin have been reported in corn by many workers (Dorich et al , 1987 Malzer, 1989 Somda et al , 1989 Said and Menyhert, 1990 Walters and Malzer, 1990a, Adriaanse and Human, 1990 Cerrato and Blackmer, 1990 Mc Cormick and Page 1992) Rodgers et al (1987) reported that application of N-Serve significantly retarded nitrification of both aqueous and prilled urea and increased the nitrogen uptake and grass yield Malhi and Nyborg (1988) found that placement of ammonium-based N fertilisers in widely-spaced bands or in nests with low rates of inhibitors slows nitrification enough to prevent much of the losses from autumn applied N Nitrapyrin at 2μg ml^{-1} was found to increase the nitrogenase activity of excised alfalfa nodules, and also the

nodule numbers on alfalfa plants, whereas higher rates of 20 μg ml^{-1} decreased nodule numbers and also nodule and plant weights (Rice and Olsen 1988) According to Katzar et al (1989) nitrapyrin increased nitrogen immobilisation and reduced nitrogen leaching losses Sychevskii and Gapienko (1989) also observed a significant reduction in the leaching losses of nitrogen after addition of N Serve although this was not reflected in the yields and quality of winter wheat grain Growth of a pure culture of Nitrosomanas europaea was reported to be suppressed completely by 10 ppm N Serve (Zacherl and Amberger, 1990) Walters and Malzer (1990b) reported that nitrapyrin influenced only the time of N loss but not the total nitrogen lost They observed that leaching losses of fertilizer derived nitrogen were delayed by 25 to 50 days when urea was incorporated along with nitrapyrin According to Chalk et al (1990) nitrapyrin (12 8 μg g^{-1}) had no effect on net nitrogen mineralisation though gross rates of nitrogen immobilisation and mineralisation were slightly inhibited by nitrapyrin Sutton et al (1990) reported that application of swine manure along with nitrapyrin (1 12 kg/ha) increased maize yields and reduced the incidence of stalk rot Bailey (1990) suggested that N-serve should not be applied to oil seed rape because of its negative effect on seed oil content eventhough application of N-Serve with urea in the fall resulted in higher seed yields and meal protein content

equivalent to that of spring application Mc Carty and Bremner (1990) observed that the residual effects of nitrification inhibitors including N-Serve decreased markedly with increase in soil temperature from 10 to 30°C The persistence of their effects at 20 or 30°C was found to be greater in the soil with higher organic matter content though the initial inhibitory effects on nitrification were greatest in the soil with lower organic matter content

2 2 1 2 Dicyandiamide (DCD)

Vilsmeier et al (1987) reported that DCD retarded the nitrification of urea and ammonium sulphate and that higher temperatures accelerated DCD breakdown Carrion et al (1987) observed a 41-72 per cent reduction in nitrification by the application of dicyandiamide DCD at 60 μg ml^{-1} decreased nitrogenase activity, nodule numbers and also nodule and plant weight of alfalfa grown in nutrient solutions (Rice and Olsen 1988) Udovidchenko et al (1989) reported that application of DCD-amended urea increased root and sugar yields of sugar beet compared with urea alone or urea amended with other inhibitors According to Amberger (1989), DCD is especially efficient when used with animal manure slurries or potato starch waste water and when amended with mineral nitrogen fertilizers, a single application can substitute for split application by reducing nitrate leaching and increasing yield

and nitrogen uptake Use of a DCD containing product (Alzon-22) was reported to reduce the nitrogen requirement of wheat and sugarbeet for maximum yield Bronson et al (1989) reported that the effectiveness of DCD decreased with increasing temperature Mc Carty and Bremner (1989) reported the results of an experiment conducted for the evaluation of dicyandiamide as a soil nitrification inhibitor The major conclusions were the following (i) DCD is less effective than N Serve (ii) It is more effective for inhibiting nitrification of ammonium-N than urea-N (iii) The effectiveness of DCD as a nitrification inhibitor is markedly affected by soil temperature, soil type and susceptibility to leaching (iv) DCD has very little, if any, effect on urea hydrolysis, denitrification and seed germination in soil (v) Products of DCD decomposition in soil (guanyl urea and guanidine) have little, if any effect on nitrification compared with DCD and (vi) In the absence of leaching, the persistence of inhibitory effect of DCD decreases with increase in soil temperature from 10 to 30°C Guiraud et al (1989) reported a decrease in nitrification and increase in immobilisation of applied nitrogen following application of DCD Dicyandiamide increased the uptake and yield effectiveness of fertilizer N applied pre plant in dry-seeded rice cultivation (Norman et al , 1989) Zacherl and Amberger (1990) observed that 300 ppm DCD inhibited the growth of a pure culture of Nitrosomonas

europaea by 83 per cent and reduced ammonia oxidation by 73 per cent Application of DCD along with ammonium sulphate nitrate increased tuber yields in potato (Zerulla and Knittel, 1991)

Apart from these two a number of other synthetic compounds have been proven to posses potential nitrification inhibition properties These include thiourea, potassium azide, AM terrazole, ATC (4-Amino 1, 2, 4-triazole hydrochloride), CMP (1-carbamoyl-3-(5) methyl pyrazole) etridiazole (5-ethoxy 3 trichlortomethyl-1, 2, 4-thiadiazole), potassium methyl xanthate etc Gaseous hydrocarbons such as methane ethane, ethylene and acetylene are reported to be competitive inhibitors of the mono oxygenase enzyme responsible for oxidation of ammonia by chemoautotrophic nitrifying microorganisms and thereby nitrification (Mc Carty and Bremner 1991 Porter 1992) Certain weedicides like Stomp (pendimethalin), Dicuran (chlorotoluron), Tribunil (methabenzthiazuron) Avelon (isoproturon), and simazine are also reported to inhibit nitrification in soil (Haleemi et al , 1988 Somda et al , 1989)

2.2.2 Indigenous materials as nitrification inhibitors

Eventhough the synthetic inhibitors are apparently effective both in reducing nitrogen losses and increasing crop

yield, the availability and application of these compounds in most countries is restricted by their relatively high costs So, efforts were made to develop nitrification inhibitors that are inexpensive, readily available locally and effective at reasonable rates of application Prasad et al (1986) reported that different non-edible oils viz , neem, karanj mahua, castor and ratanjyoti inhibited nitrification and increased yield and nitrogen uptake by wheat the highest nitrification inhibition was observed with application of castor followed by ratanjyoti and karanj oils Awasthe and Mishra (1987) observed that eventhough mineralisation of urea in the soil was delayed by neem seed cake, application of neem seed cake coated urea did not show any advantage over split application of urea in terms of rice yield, nitrogen use efficiency and apparent recovery of applied nitrogen Singh and Mishra (1987) reported that neem cake coated urea performed better than prilled urea when applied to transplanted rice Santhi and Palaniappan (1987) reported that neem cake and neem leaf (both fresh and dry) inhibited nitrification and fresh neem leaf was more effective resulting in higher grain yields of rice, higher nitrogen recovery and nitrogen response ratio According to Singh et al (1988) application of neem cake treated urea in two splits of 1/3 each of recommended dose at planting and 30 DAS maintained high maize yields, high grain protein content and enhanced

nitrogen utilisation through the economy of 1/3 (48 kg N/ha) of the nitrogen applied through ordinary urea Prasad et al (1989) studied the effect of application of urea treated with Azadirachta indica, Pongamia pinnata Madhuca indica, Ricinus communis or Onosma hispidium oil to paddy crop Of these, treatment with Onosma hispidium oil gave the highest nitrification inhibition (65 3 per cent), paddy yield and N uptake followed by Pongamia pinnata John et al (1989) reported that application of neem coated urea to low land rice increased fertiliser nitrogen recovery in the grain Singh and Singh (1989) observed significant increase in grain yield, nitrogen uptake and recovery of applied nitrogen on the application of neem oil coated urea to a wheat crop The efficacy of indigenous coating materials for urea under saline water irrigation was assessed by incubation for 25 days and the efficiency of inhibition of nitrification was in the order neem cake>mahua cake>sulphur>gypsum>coaltar (Mago and Totawat, 1989) Sharma et al (1989) reported a significant increase in seed cotton yield following the application of 40 kg N/ha as neem cake coated urea Turker et al (1989) reported that among the various nitrification inhibitors, viz , sal cake, neem cake mahua cake and karanj cake applied with urea, maximum grain and straw yields of wheat were given by karanj cake and sal cake respectively Sal cake coated urea produced maximum protein N in grain and straw, followed by

karanj cake Bhagat and Verma (1989) reported that cutch obtained from the bark of Acacia catechu effectively inhibited nitrification and that it can be used as a substitute for N Serve

Rice yields and nitrogen uptake were significantly increased and nitrogen losses reduced by the application of urea treated with alcohol extract of neem seeds (Reddy and Chhonkar, 1990) Tomar et al (1991) also obtained higher number of productive tillers and grain yields by the application of neem extract coated urea Neem and karanj cake blended urea significantly increased sugarcane yield and N use efficiency (Yadav and Singh 1991) Kholdebarin and Oertli (1992) found that cotyledon powder of tea and certain oak species reduced nitrification rate and the effect is mainly due to chemical ammonium fixation and microbial immobilisation Application of neem cake blended urea increased rice grain yield and recovery of applied N (Upadhyay and Patel, 1992 Bhardwaj and Singh 1992) Geethalakshmi and Palaniappan (1992) reported that coating of urea with neem cake cashew shell powder turmeric powder or tea waste increased dry matter production uptake of N and K and nitrogen use efficiency in cotton

Materials and Methods

MATERIALS AND METHODS

The present study was aimed at assessing the relative rates of nitrification of laterite alluvial and forest soils of Trichur district, to relate nitrification rates with cropping history and to assess the nitrification inhibition properties of a few plant materials reported to have bactericidal or allelopathic properties

The study comprised of two parts

Laboratory experiments

Pot experiment

The experiments were conducted during the period from August 1992 to August 1993 at the College of Horticulture Vellanikkara, Trichur which is situated at 10° 32 N latitude and 76° 10 E longitude at an altitude of 22 25 m above mean sea level

The laterite, alluvial and forest soil samples for laboratory experiments were collected from different parts of Trichur district Laterite soil samples were collected from seven different locations with different cropping histories and alluvial from five such locations The list of the 13 samples selected for the laboratory study is given in Table 1

Table 1 Soil samples selected for the laboratory study and their cropping histories

Sl No	Soil type	Location		Cropping history
1	Laterite	Vellanikkara	1	Cashew
			2	Cocoa
			3	Coconut
			4	Rubber
			5	Seasonals
			6	Banana
			7	Rubber & Cocoa
2	Alluvial	Manaloor	1	Banana
			2	Coconut
			3	Rice
			4	Tapioca
			5	Turmeric
3	Forest	Peechi		Teak

The chemical properties of one sample each of the three soils are given in Table 2

3 1 Laboratory experiments

3 1 1 Experiment No.1

A laboratory incubation study was undertaken to assess the nitrification rate of soils after the addition of 100 ppm nitrogen as urea

3 1 1 1 Details of the incubation study

The study was conducted during the one month period starting from 14th January 1993 In the case of laterite-banana incubation was done on 7th March, 1993 One kg each of 2 mm sieved samples were mixed with enough urea to supply 100 ppm N on moisture-free basis and sufficient water to bring the moisture level to 65 per cent of field capacity The field capacity values of the soil samples were estimated and these along with the moisture content were considered for arriving at the quantity of water to be added to bring these to 65 per cent field capacity From this 1 kg lot, samples of 10 g were transferred to 250 ml conical flasks and the mouths of the flasks were plugged with cotton Adequate number of such samples were set so that duplicate samples could be removed at the required intervals for one month The moisture

Table 2 Chemical properties of the soil types used for the laboratory studies

Constituent	Content in soil			Method used for estimation
	Laterite	Alluvial	Forest	
Organic carbon (%)	0 81	0 27	2 10	Walkley and Black method (Piper 1942)
Available P (Bray I extract) (ppm)	12 80	25 40	11 40	Chlorostannous reduced molybdo-phosphoric blue colour method (Jackson, 1958)
Available K (Neutral normal ammonium acetate extract) (ppm)	120	150	100	Flame photo-metric method (Jackson, 1958)
pH (1 2 5 soil water ratio)	5 4	6 7	5 5	pH meter (Jackson, 1958)

level was maintained throughout the period of incubation by frequent replenishment of the water lost Samples were drawn at five days intervals for one month and analysed for ammonium and nitrate nitrogen

3 1 1 2 Soil analysis

Soil samples drawn were immediately extracted for 1 hour with 2 M neutral KCl solution and filtered through Whatman No 42 filter paper The extract was used for analysis Ammoniacal and nitrate nitrogen contents were determined by steam distillation method (Bremner, 1965)

3.1 2 Experiment No 2

This experiment was aimed at the assessment of the nitrification inhibition properties of a few plant materials with reported bactericidal or allelopathic properties

The treatments were

1 Urea alone
2 Urea + N-Serve
3 Urea + neem cake (Azadirachta indica)
4 Urea + cashew shell (Anacardium occidentale)
5 Urea + tobacco waste (Nicotiana tabaccum)
6 Urea + calotropis leaf (Calotropis gigantea)
7 Urea + eucalyptus leaf (Eucalyptus globulus)

8 Urea + turmeric leaf (Curcuma longa)

9 Urea + neem leaf (Azadirachta indica)

10 Urea + cassava leaf (Manihot esculenta)

11 Urea + moringa leaf (Moringa oleracea)

12 Urea + sesamum cake (Sesamum indicum)

13 Urea + marotti cake (Hydnocarpus laurifolia)

14 Urea + castor cake (Ricinus communis)

15 Urea + arecanut (Areca catechu)

16 Urea + punna cake (Calophyllum inophyllum)

17 Urea + Eupatorium leaf (Eupatorium odoratum)

18 Control (no nitrogen)

3 1 2 1 Details of the incubation study

One kg of 2 mm sieved sample of the soil type showing highest rate of nitrification in experiment No 1 (alluvial-banana) was mixed with 100 ppm N in the form of urea as per treatment schedules in urea-material ratios of 5 3 excepting in the case of standard materials like N-Serve and neem cake The plant materials used were oven-dried and powdered before use The urea-neem cake ratio was 5 1 and in the case of N-Serve, the chemical was diluted with acetone and added at the rate of 1 per cent of N Adequate quantity of water was added to bring the soil moisture level to 65 per cent of field capacity From this 10 g soil was transferred to incubation

tubes, the mouths of which were then plugged with cotton Adequate number of samples to facilitate use in duplicates at fixed intervals for one month were kept Samples were drawn at five days interval and analysed for ammoniacal and nitrate nitrogen as in experiment No 1

3.2 Pot experiment

A pot experiment was conducted to study the response to the application of five most promising materials selected after experiment No 2 along with two standard materials, N-Serve and neem cake on a crop of fodder maize supplied with 100 ppm nitrogen

3.2 1 Soil

The soil chosen for experiment No 2 was selected for pot experiment also

3 2.2 Season and climate

The pot experiment was conducted during the period from 11th June 1993 to 10th August 1993 The meteorological data for the crop period are presented as weekly averages in Appendix-I The maximum temperature during the crop period ranged between 28 0°C and 32 8°C and the range of minimum temperature was from 22 6°C to 24 5°C Rainfall was

almost distributed throughout the growth period of the crop and a total of 1532 4 mm rainfall was received

3 2 3 Layout

The experiment was laid out in completely randomised design with four replications

3.2 4 Treatments

T_1 Without urea and nitrification inhibitor

T_2 With urea and without nitrification inhibitor

T_3 With urea and N-Serve

T_4 With urea and neem cake

T_5 With urea and cashew shell

T_6 With urea and calotropis leaf

T_7 With urea and tobacco waste

T_8 With urea and neem leaf

T_9 With urea and castor cake

3.2 5 Planting material

Test crop	Fodder maize
Variety	African Tall maize

3.2 6 Culture

The pots were filled with 6 kg soil each after mixing

with urea and nitrification inhibitors as per the treatment schedule The urea material ratios were the same as adopted in the incubation study Seeds were dibbled at 5 cm depth and watering was done as and when needed

3 2 6 1 Fertiliser application

Urea superphosphate and muriate of potash were applied to provide 100 ppm of nitrogen 30 ppm of phosphorus and 20 ppm of potassium per pot

3 2 6 2 After cultivation

Weeding was done whenever necessary and the pots were kept weed-free throughout the experimental period

3.2 7 Observations

3 2 7 1 Growth characters

Plant height

Height was recorded at 15 days interval from the base of the plant to the tip of the longest leaf

Number of leaves

Counts of the green leaves (fully emerged) were taken at 15 days interval

Dry matter production

After harvesting, the plants were oven-dried to constant weight at 70 $\pm$ 2°C and the total dry weight was expressed as g plant $^{-1}$

3 2 7 2 Chemical analysis

The plant samples were ground and N contents were determined using micro-Kjeldahl method (Jackson, 1958)

Uptake of nitrogen

The nitrogen contents were multiplied with their dry matter production and uptake was calculated and expressed as mg plant^{-1}

3 3 Statistical analysis

The data from the laboratory and pot experiments were subjected to the analysis of variance technique (Panse and Sukhatme 1967)

RESULTS

The data from the laboratory experiments are presented first and these are followed by the results from the pot experiment

4 1 Laboratory experiments

4 1 1 Experiment No.1

The aim of this experiment was to assess the nitrification rates of laterite, alluvial and forest soils with different cropping histories It was done after the addition of 100 ppm nitrogen as urea Assessment was made through the estimations of NH_4^+ and NO_3^- N contents

4 1 1 1 Ammoniacal nitrogen (Table 3 Fig 1)

The changes in NH_4^+-N in laterite soil were inconsistent Those samples from cocoa, coconut, banana and rubber + cocoa showed a decrease in NH_4^+-N content to 128 1 ppm, 114 8 ppm, 74 9 ppm and 102 9 ppm on the 30th day, from 140 0 ppm 133 7 ppm, 84 0 ppm and 142 8 ppm respectively on the 5th day after incubation In the samples collected from cashew rubber and seasonal crops the NH_4^+-N decreased from 125 3 ppm 140 7 ppm and 102 2 ppm on the 5th day after incubation to 100 8 ppm 109 2 ppm and 95 2 ppm respectively,

on the 20th day after incubation But the NH_4^+-N contents in these three samples were found to be maximum on the 30th day after incubation, the concentrations being 140 7 ppm, 160 3 ppm and 127 4 ppm, respectively

Among the laterite soil samples, that from cocoa maintained a higher NH_4^+-N content throughout the incubation period except on the 5th and 30th days after incubation and that from the banana field maintained a lower content On the 5th day, the highest content of ammoniacal nitrogen was noticed in the sample from the rubber + cocoa mixed stand (142 8 ppm) and the least in the sample from banana (84 0 ppm) On the 30th day after incubation, maximum NH_4^+-N content of 160 3 ppm was observed in the sample from rubber plantation

In alluvial soil, there was a gradual decrease in NH_4^+-N content with incubation period in all the samples except that from rice fields in which case the ammonium content remained more or less constant throughout the 30 day period In the samples from the sites planted with banana, coconut, tapioca and turmeric, the ammoniacal nitrogen decreased to 32 2 ppm, 46 2 ppm, 68 6 ppm and 113 4 ppm, respectively on the 30th day from 68 3 ppm, 80 5 ppm, 91 7 ppm and 140 7 ppm on the 5th day after incubation The sample from the site cultivated with turmeric consistently maintained a higher

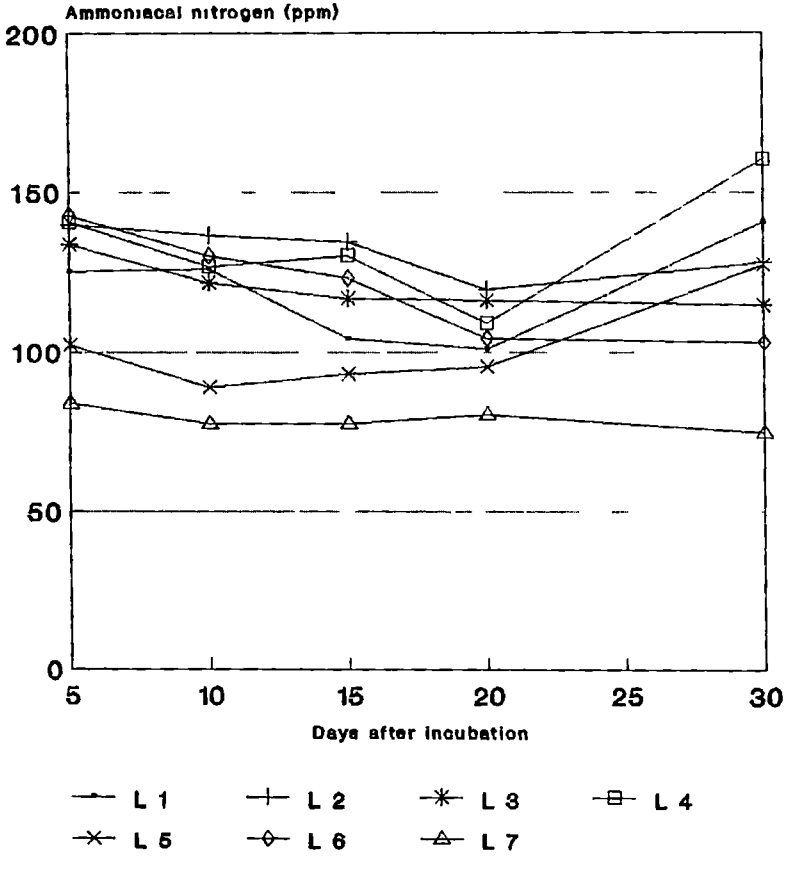
Table 3 Content of ammoniacal nitrogen in soil after varying periods of incubation

Soil type and cropping history	Content of NH_4-N (ppm)				
	Days after incubation				
	5	10	15	20	30
Laterite soil					
Cashew	125 3	126 0	104 3	100 8	140 7
Cocoa	140 0	136 5	134 4	119 7	128 1
Coconut	133 7	121 8	116 9	116 2	114 8
Rubber	140 7	126 7	130 2	109 2	160 3
Seasonal crops	102 2	88 9	93 1	95 2	127 4
Rubber + cocoa	142 8	130 2	123 2	104 3	102 9
*Banana	84 0	77 7	77 7	80 5	74 9
Alluvial soil					
Banana	68 3	64 4	63 7	52 5	32 2
Coconut	80 5	58 1	70 7	73 5	46 2
Rice	80 7	77 9	87 0	83 5	81 4
Tapioca	91 7	104 3	93 1	95 2	68 6
Turmeric	140 7	126 7	133 7	132 3	113 4
Forest soil					
Teak	138 6	141 4	128 8	114 1	132 3

* Incubation done during the period from 7 3 93 to 6 4 93

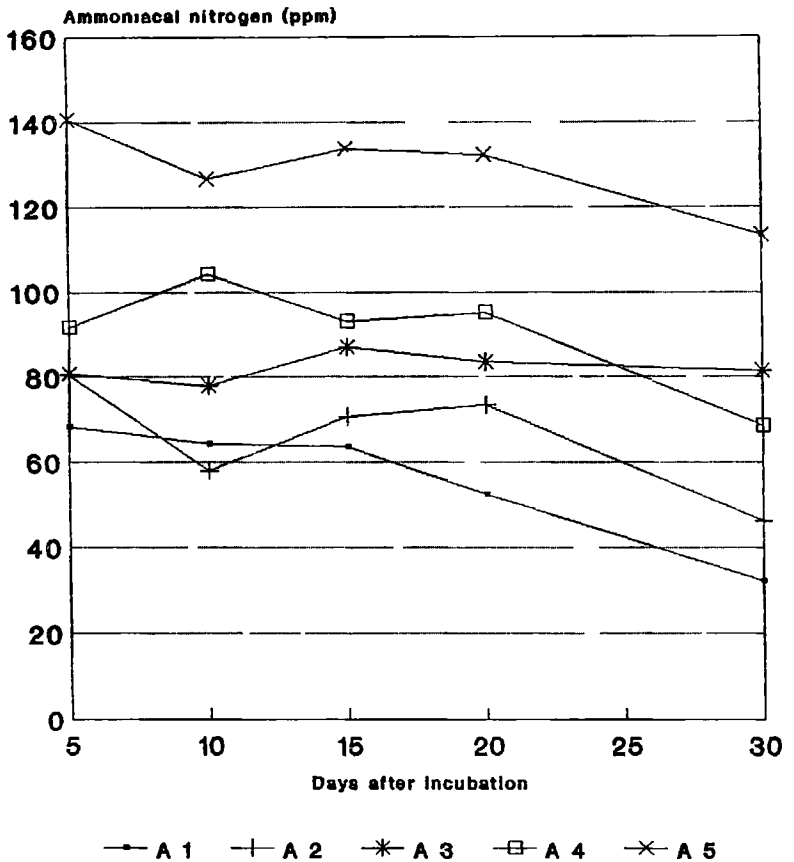
All the other samples incubated during 14 1 93 to 13 2 93

FIG 1a AMMONIACAL NITROGEN IN LATERITE SOIL AFTER VARYING PERIODS OF INCUBATION



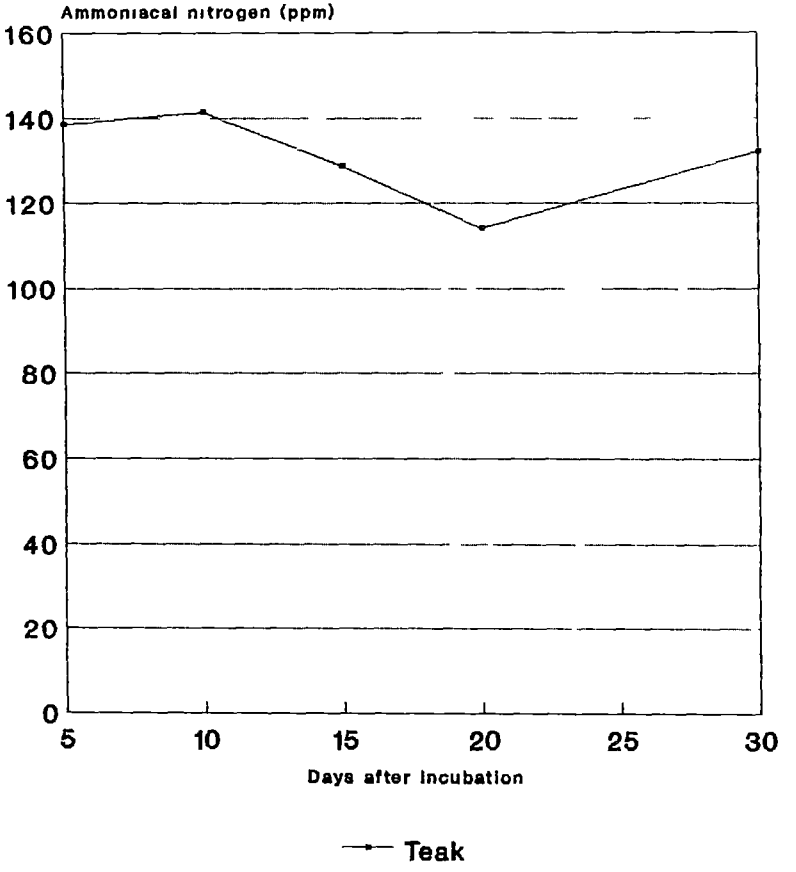
L 1 Cashew
L 2 Cocoa
L 3 Coconut
L 4 Rubber
L 5 Seasonal crops
L 6 Rubber + cocoa
L 7 Banana

FIG 1b AMMONIACAL NITROGEN IN ALLUVIAL SOIL AFTER VARYING PERIODS OF INCUBATION



A 1 Banana
A 2 Coconut
A 3 Rice
A 4 Tapioca
A 5 Turmeric

FIG 1c AMMONIACAL NITROGEN IN FOREST SOIL AFTER VARYING PERIODS OF INCUBATION



content of NH_4^+-N and that from banana maintained a lower content throughout the entire incubation period The corresponding values in ppm were 140 7 and 68 3 on the 5th day, 126 0 and 64 4 on the 10th day, 133 7 and 63 7 on the 15th day, 132 3 and 52 5 on the 20th day and 113 4 and 32 3 on the 30th day after incubation

In the forest soil, the ammoniacal nitrogen content remained nearly the same throughout the incubation period apart from a decrease to 114 1 ppm on 20th day after incubation

4 1 1 2 Nitrate nitrogen (Table 4 Fig 2)

In all the three soil types, the NO_3^--N content showed a trend, though inconsistent of increase with incubation period Among laterite soil samples, on the 5th, 10th and 15th days after incubation, higher NO_3^--N content was observed in the sample from cashew (32 3 ppm, 23 8 ppm and 44 8 ppm, respectively) Highest NO_3^--N content of 30 8 ppm on the 20th day after incubation was noticed in the samples from the field of seasonal crops as well as banana On the 30th day, maximum nitrate content was observed in the sample from rubber plantation (31 5 ppm) The sample from the rubber plantation had the lowest nitrate content on the 5th and 15th days (3 5 ppm and 13 3 ppm, respectively) and that from banana on the

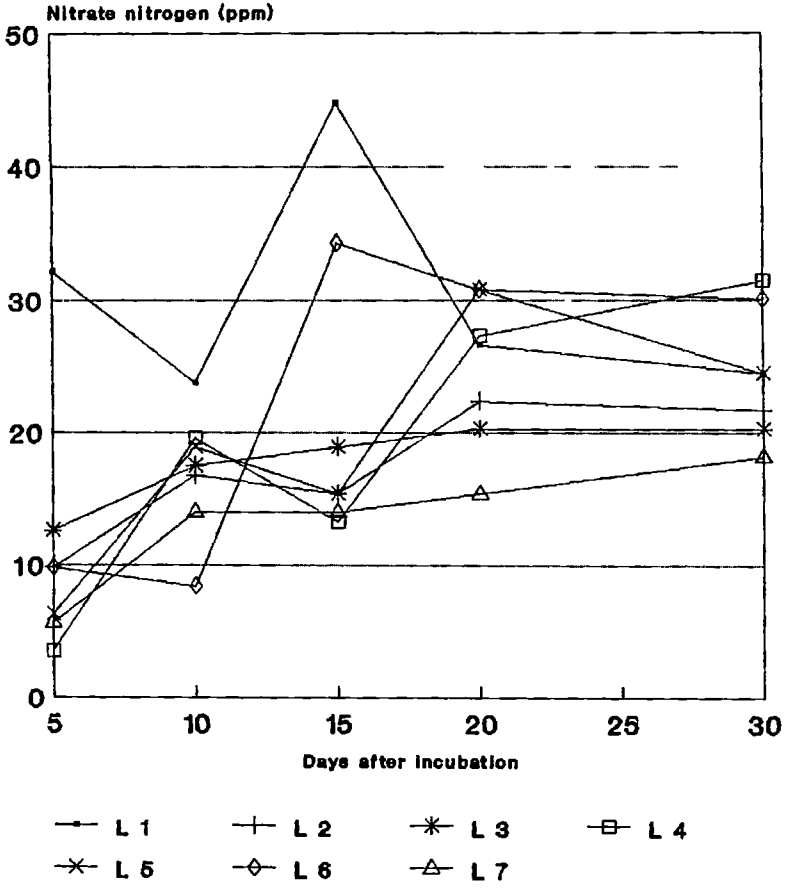
Table 4 Content of nitrate nitrogen in soil after varying periods of incubation

Soil type and cropping history	Content of NO_3^--N (ppm) Days after incubation				
	5	10	15	20	30
Laterite soil					
Cashew	32 2	23 8	44 8	26 6	24 5
Cocoa	9 8	16 8	15 4	22 4	21 7
Coconut	12 6	17 5	18 9	20 3	20 3
Rubber	3 5	19 6	13 3	27 3	31 5
Seasonal crops	6 3	18 9	15 4	30 5	24 5
Rubber + cocoa	9 8	8 4	34 3	30 8	30 1
*Banana	5 6	14 0	14 0	15 4	18 2
Alluvial soil					
Banana	24 5	27 3	43 4	52 5	57 1
Coconut	7 7	14 7	9 8	8 4	16 8
Rice	9 8	10 5	11 2	11 2	18 9
Tapioca	15 4	7 0	15 4	9 2	18 9
Turmeric	11 2	17 5	13 3	13 3	16 1
Forest soil					
Teak	21 0	12 6	26 6	36 4	30 1

* Incubation done during the period from 7 3 93 to 6 4 93

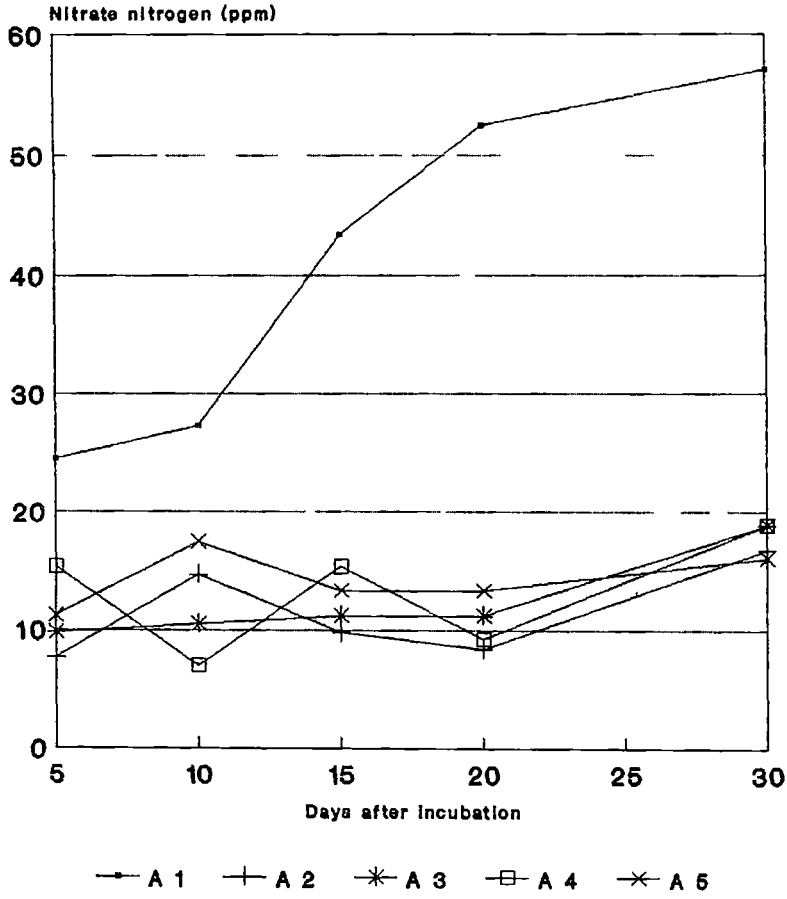
All the other samples incubated during 14 1 93 to 13 2 93

FIG 2a NITRATE NITROGEN IN LATERITE SOIL AFTER VARYING PERIODS OF INCUBATION



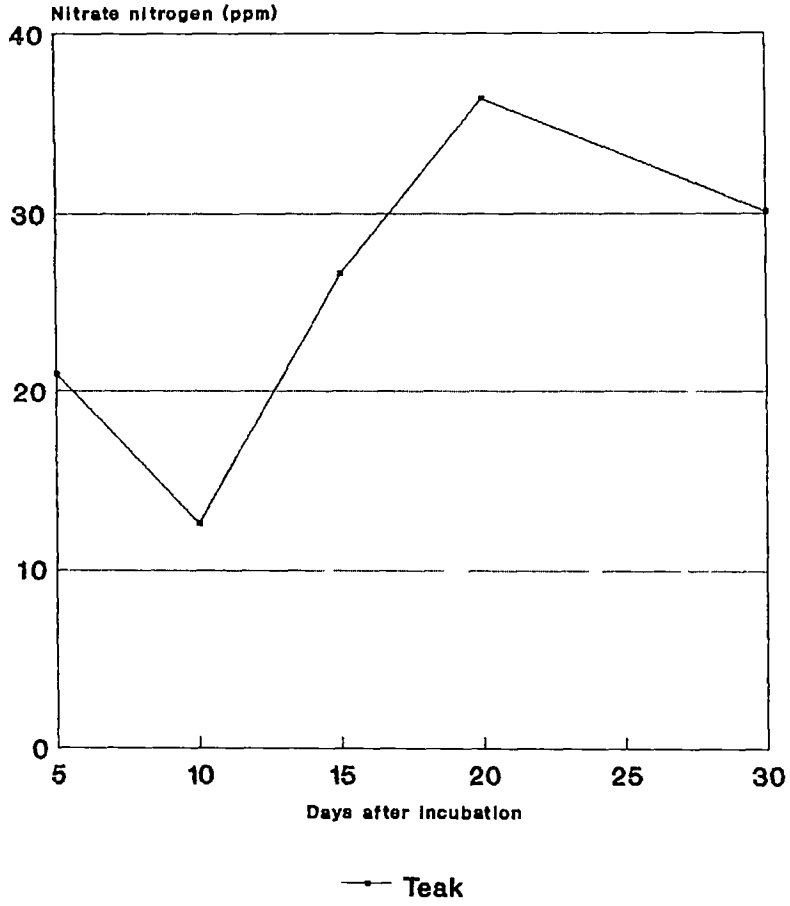
L 1 Cashew
L 2 Cocoa
L 3 Coconut
L 4 Rubber
L 5 Seasonal crops
L 6 Rubber + cocoa
L 7 Banana

FIG 2b NITRATE NITROGEN IN ALLUVIAL SOIL AFTER VARYING PERIODS OF INCUBATION



A 1 Banana
A 2 Coconut
A 3 Rice
A 4 Tapioca
A 5 Turmeric

FIG 2c NITRATE NITROGEN IN FOREST SOIL AFTER VARYING PERIODS OF INCUBATION



10th, 20th and 30th days (14 0 ppm, 15 4 ppm and 18 2 ppm respectively)

Among the alluvial samples, that collected from the banana cultivated site maintained a higher NO_3^--N content throughout the incubation period and showed a sharp increase with time from 24 5 ppm on the 5th day to 57 1 ppm on the 30th day after incubation In the other samples, the NO_3^--N was never as high and the increase also was not very marked The lowest NO_3^- N contents on the 5th, 15th and 20th days after incubation were observed in the sample from coconut (7 7 ppm, 9 8 ppm and 8 4 ppm, respectively) NO_3^--N content was minimum in the sample from sites planted with tapioca (7 0 ppm) and turmeric (16 1 ppm) on the 10th and 30th days, respectively

In the case of forest soil, maximum NO_3^--N content was observed on the 20th day (36 4 ppm) and minimum on the 10th day (12 6 ppm) after incubation

4.1.2 Experiment No.2

This laboratory experiment was conducted to assess the nitrification inhibition properties of a few plant materials reported to possess bactericidal or allelopathic properties Alluvial soil sample drawn from banana cultivated soil which were found to have the highest rates of nitrification in

experiment No 2 wereused for this experiment The plant materials were incorporated at urea - material ratio of 5 3

4 1 2 1 Ammoniacal nitrogen (Table 5 Fig 3 Appendix-II)

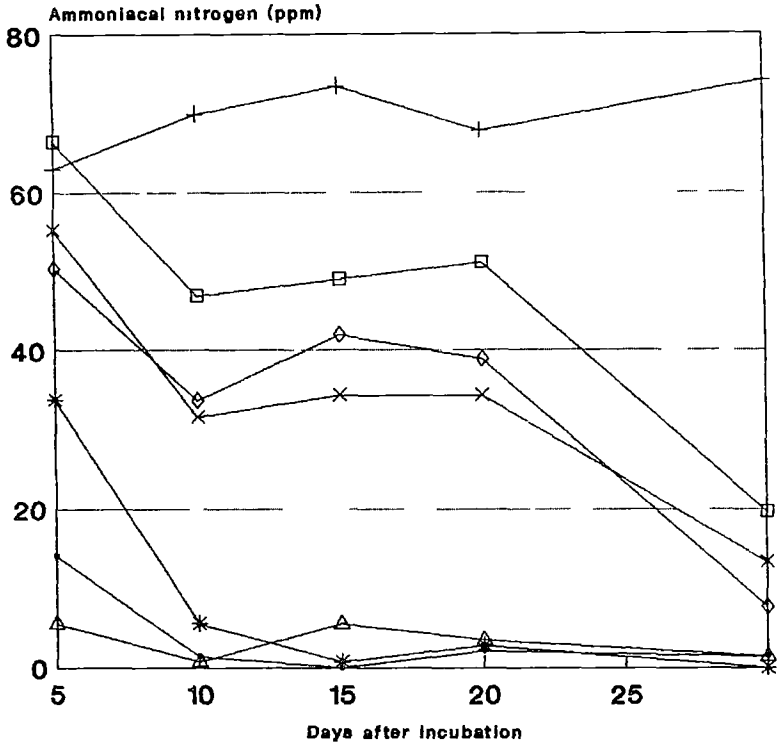
Ammoniacal nitrogen contents in various treatments were compared with untreated urea to assess the benefit of mixing urea with the various materials Values of control at every sampling were subtracted from values of treatments with added inhibitor or plant material so that the content of NH_4^+ N given comprise only that fraction mineralised from added urea

On all days of sampling, significant differences in the ammoniacal nitrogen content were noticed in the samples receiving various treatments though the trends were far from consistent Maximum ammoniacal nitrogen content on all sampling days except 5th was observed in the treatment of urea with N-Serve The values in ppm on the 10th, 15th, 20th and 30th days after incubation were 70 0 73 5 67 9 and 74 2 respectively On the 5th day, highest NH_4^+ N content (66 5 ppm) was observed in T_4 (urea + cashew shell) Among the plant materials tried, the treatment urea + cashew shell (T_4) maintained the highest NH_4^+-N content throughout the incubation period In this, it was next only to N-Serve The NH_4^+-N content in this was 46 9 ppm on 10th day 49 0 ppm on 15th day, 51 1 ppm on 20th day and 19 6 ppm on the 30th day after

Table 5 Mineralisation pattern of treated and untreated urea - content of NH_4^+-N (ppm)

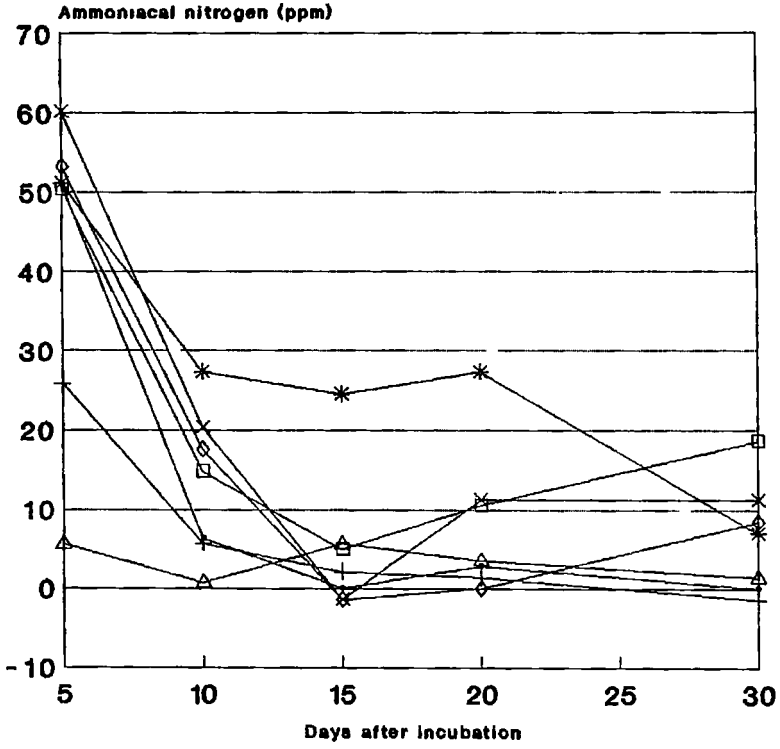
	Treatments	Days after incubation				
		5	10	15	20	30
1	Urea alone	14 0	1 4	0 0	2 1	1 4
2	Urea + N-Serve	63 0	70 0	73 5	67 9	74 2
3	Urea + neem cake	33 7	5 6	0 7	2 8	0 0
4	Urea + cashew shell	66 5	46 9	49 0	51 1	19 6
5	Urea + tobacco waste	55 3	31 5	34 3	34 3	13 3
6	Urea + calotropis leaf	50 4	33 6	42 0	38 9	7 7
7	Urea + eucalyptus leaf	51 1	6 3	0 0	2 8	0 0
8	Urea + turmeric leaf	25 9	5 6	2 1	1 4	-1 4
9	Urea + neem leaf	51 1	27 3	24 5	27 3	7 0
10	Urea + cassava leaf	50 4	14 7	4 9	10 5	18 5
11	Urea + moringa leaf	60 2	20 3	-1 4	11 2	11 2
12	Urea + sesamum cake	53 2	17 5	1 4	0 0	8 4
13	Urea + marotti cake	50 4	22 4	13 3	19 6	14 0
14	Urea + castor cake	60 9	34 3	22 4	30 1	19 6
15	Urea + arecanut	51 8	27 3	21 7	25 2	7 0
16	Urea + punna cake	44 1	9 8	-2 8	0 7	8 4
17	Urea + eupatorium leaf	34 3	14 0	-1 4	1 4	5 6
	CD (5%)	8 23	9 57	11 42	13 21	5 53
	SEm ±	3 89	4 54	5 41	6 26	2 62
18	NH_4^+-N in control	5 6	0 7	5 6	3 5	1 4

FIG 3
MINERALISATION PATTERN OF TREATED AND UNTREATED UREA



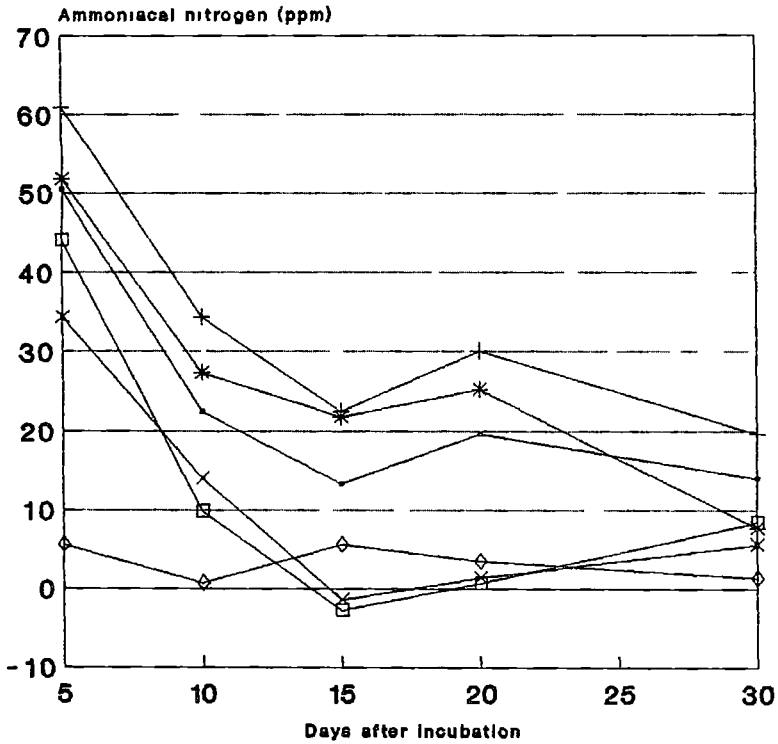
T_1 Urea alone
T_2 Urea + N-Serve
T_3 Urea + neem cake
T_4 Urea + cashew shell
T_5 Urea + tobacco waste
T_6 Urea + calotropis leaf

FIG 3 Contd
MINERALISATION PATTERN OF TREATED AND UNTREATED UREA



T_7 Urea + eucalyptus leaf
T_8 Urea + turmeric leaf
T_9 Urea + neem leaf
T_{10} Urea + cassava leaf
T_{11} Urea + morringa leaf
T_{12} Urea + sesamum cake

FIG 3 Contd
MINERALISATION PATTERN OF TREATED AND UNTREATED UREA



T_{13} Urea + marotti cake
T_{14} Urea + castor cake
T_{15} Urea + arecanut
T_{16} Urea + punna cake
T_{17} Urea + eupatorium leaf

incubation Among the remaining treatments, T_5 (urea + tobacco waste), T_6 (urea + calotropis leaf), T_9 (urea + neem leaf) and T_{14} (urea + castor cake) were found to maintain a higher NH_4^+-N content on all sampling days, than most of the other treatments except 30th day when certain other treatments had a slightly higher NH_4^+-N content than these

On 5th and 10th days after incubation, NH_4^+-N content was minimum in the sample receiving untreated urea (14 0 ppm and 1 4 ppm respectively) Negative values for NH_4^+-N content were noted in treatments T_{11}, T_{12}, T_{16} and T_{17} on the 15th day and in T_8 on the 30th day

In all treatments except T_2 (urea + N-Serve) maximum ammoniacal nitrogen content was observed on the 5th day after incubation, In T_2, maximum NH_4^+-N content of 74 2 ppm was observed on the 30th day after incubation when no other treatments maintained an NH_4^+-N content higher than 20 ppm

As a whole the treatments T_4 (urea + cashew shell) T_5 (urea + tobacco waste), T_6 (urea + calotropis leaf), T_9 (urea + neem leaf) and T_{14} (urea + castor cake) showed a consistent superiority over other treatments in maintaining higher NH_4^+ N contents in soil Neem cake recommended as an effective nitrification inhibitor was found to be inferior to most of the plant materials tried Maximum NH_4^+ N content in

the treatment urea + neem cake was 33 7 ppm on the 5th day and by the 30th day, it was 0 0 ppm

4 1 2 2 Nitrate nitrogen (Table 6 Fig 4 Appendix-II)

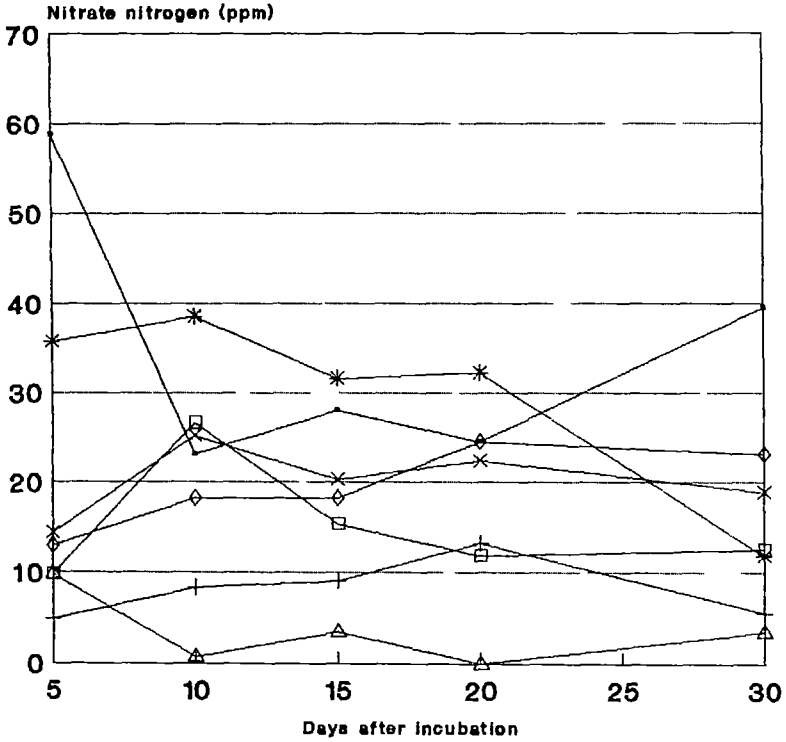
AS in the case of NH_4^+-N content, here also values of control have been subtracted from values of treatments receiving plant materials/N-Serve and, the NO_3^--N appearing in the various treatments were compared with that of untreated urea for assesssing the efficacy of the materials used as nitrification inhibitors

Except on the 30th day, NO_3^--N estimated at the various sampling stages showed significant differences among treatments Maximum NO_3^--N content of 79 7 ppm over all the sampling days was observed in T_8 (urea + turmeric leaf) on 15th day after incubation On the 5th day after incubation maximum nitrate content was observed in the treatment receiving untreated urea (58 8 ppm) This was significantly higher than in all other treatments except T_8 (urea + turmeric leaf) in which the NO_3^--N content was 48 3 ppm The lowest nitrate content of 4 9 ppm on the 5th day after incubation was noticed in T_2 (urea + N-Serve) which was on par with all other treatments except T_1 (untreated urea), T_3 (urea + neem cake), T_7 (urea + eucalyptus leaf) T_8 (urea + turmeric leaf) and T_{12} (urea + sesamum cake)

Table 6 Mineralisation pattern of treated and untreated urea - content of NO_3^- N (ppm)

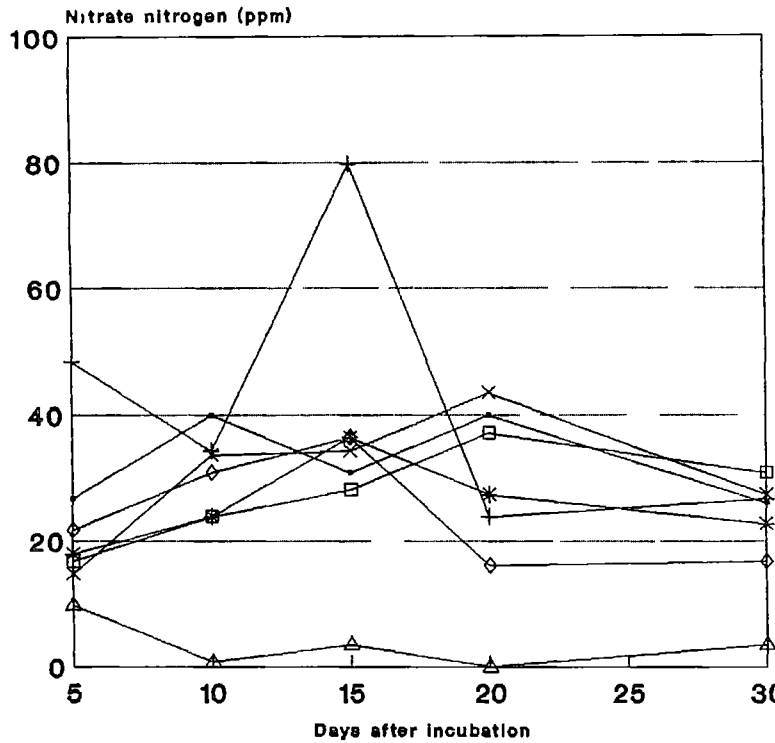
	Treatments	Days after incubation				
		5	10	15	20	30
1	Urea alone	58 8	23 1	28 0	24 5	39 5
2	Urea + N-Serve	4 9	8 4	9 1	1 3	5 6
3	Urea + neem cake	35 7	38 5	31 5	32 2	11 9
4	Urea + cashew shell	9 8	26 6	15 4	11 9	12 6
5	Urea + tobacco waste	14 4	25 2	20 3	22 4	18 9
6	Urea + calotropis leaf	13 0	18 2	18 2	24 5	23 1
7	Urea + eucalyptus leaf	26 6	39 9	30 8	39 9	25 9
8	Urea + turmeric leaf	48 3	34 3	79 7	23 8	26 6
9	Urea + neem leaf	17 9	23 8	36 4	27 3	22 6
10	Urea + cassava leaf	16 8	23 8	28 0	37 1	30 8
11	Urea + moringa leaf	14 7	33 6	34 3	43 4	27 3
12	Urea + sesamum cake	21 7	30 8	36 4	16 1	16 8
13	Urea + marotti cake	18 2	31 5	37 1	44 1	44 1
14	Urea + castor cake	13 3	30 1	16 1	29 4	34 3
15	Urea + arecanut	9 8	30 1	28 0	28 0	32 2
16	Urea + punna cake	7 7	25 2	9 8	10 5	14 7
17	Urea + eupatorium leaf	11 9	19 6	9 8	4 9	20 3
	CD (5%)	15 39	10 47	10 56	10 07	NS
	SEm ±	7 29	4 96	5 01	4 77	12 14
18	NO_3^- N in control	9 8	0 7	3 5	0 0	3 5

FIG 4
MINERALISATION PATTERN OF TREATED AND UNTREATED UREA



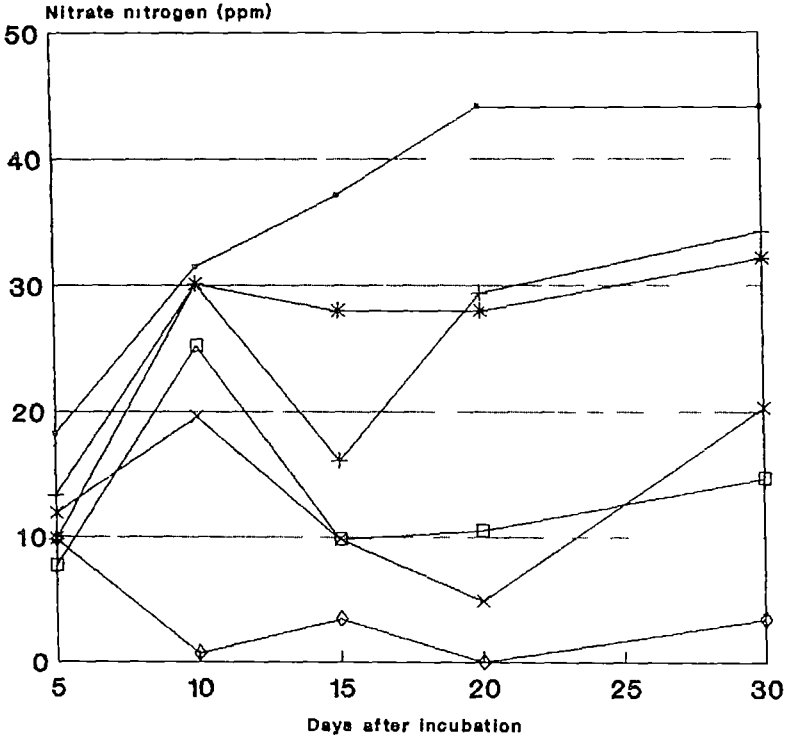
T_1 Urea alone
T_2 Urea + N-Serve
T_3 Urea + neem cake
T_4 Urea + cashew shell
T_5 Urea + tobacco waste
T_6 Urea + calotropis leaf

FIG 4 Contd
MINERALISATION PATTERN OF TREATED AND UNTREATED UREA



T_7 Urea + eucalyptus leaf
T_8 Urea + turmeric leaf
T_9 Urea + neem leaf
T_{10} Urea + cassava leaf
T_{11} Urea + morringa leaf
T_{12} Urea + sesamum cake

FIG 4 Contd
MINERALISATION PATTERN OF TREATED AND UNTREATED UREA



T_{13} Urea + marotti cake
T_{14} Urea + castor cake
T_{15} Urea + arecanut
T_{16} Urea + punna cake
T_{17} Urea + eupatorium leaf

On the 10th day, T_2 (urea + N-Serve) recorded significantly lower NO_3^--N content (8 4 ppm) than other treatments except T_6 (urea + calotropis leaf) in which the value was 18 2 ppm T_7 (urea + eucalyptus leaf) had the maximum nitrate content (39 9 ppm) at this stage T_8 (urea + turmeric leaf) had a significantly higher NO_3^--N content (79 7 ppm) than all other treatments on 15th day after incubation Lowest nitrate content of 9 1 ppm on that day was noticed in T_2 (urea + N-Serve) Maximum NO_3^--N content (44 1 ppm) on the 20th day after incubation was observed in T_{13} (urea + marotti cake) and minimum (4 9 ppm) in T_{17} (urea + eupatorium leaf) On the 30th day after incubation there was no significant difference in NO_3^- N content among the different treatments The lowest (5 6 ppm) NO_3^- N content was observed in T_2 (urea + N-Serve) and highest (44 1 ppm) in T_{13} (urea + marotti cake)

Among the different treatments, T_2 (urea + N-Serve) consistently maintained a lower nitrate content throughout the incubation period

4 2 Pot experiment

The results from the pot experiment conducted to study the response to the application of five materials, viz , cashew shell, calotropis leaf tobacco waste, neem leaf and castor cake identified as possessing better nitrification

inhibition properties from Experiment No 2 in comparison with two standard nitrification inhibitors N-Serve and neem cake are furnished in this section The test crop was fodder maize and nitrogen in the form of urea was supplied at 100 ppm Seeds failed to germinate in the pots receiving N-Serve and observations from this set are hence not presented

4 2 1 Growth characters

4 2 1 1 Plant height (Table 7 Appendix-III)

No significant difference between treatments with respect to plant height was observed on 15th day after sowing However, maximum height of 45 8 cm was observed in T_6 (urea + calotropis leaf) closely followed by T_8 (urea + neem leaf) in which the height was 45 4 cm Minimum height (35 6 cm) at this stage of observation was noticed in T_1 (without urea) On the 30th 45th and 55th days after sowing, significant differences in plant height between treatments could be noticed The treatment receiving no urea had the minimum height at all the three stages while T_5 (urea + cashew shell) maintained the highest mean values throughout The corresponding values on 30 45 and 55 days after sowing were 70 1 cm (T_1) and 108 7 cm (T_5), 91 cm (T_1) and 134 3 cm (T_5) and 97 4 cm (T_1) and 143 3 cm (T_5) respectively On 30th and 45th days after sowing all other treatments except T_7

(urea + tobacco waste) were significantly superior to T_1 (without urea) Fifty five days after sowing, T_1 had a significantly lower plant height than all other treatments On the 30th day, plant height in all treatments receiving the various inhibitors except T_5 (urea + cashew shell) were on par with that in the treatment receiving urea alone Plant height values in T_7 (urea + tobacco waste), T_6 (urea + calotropis leaf) and T_4 (urea + neem cake) were found to be on par with T_2 (urea alone) on the 45th day On 45 and 55 days after sowing only T_5 (urea + cashew shell) and T_8 (urea + neem leaf) were found to be significantly superior to the treatment receiving only urea

4 2 1 2 Number of leaves (Table 7 Appendix-III)

On the 15th day after sowing, there was no significant difference between the treatments in the number of leaves The mean number of leaves at this stage in the different treatments ranged between five and six Maximum number of leaves in all the treatments was observed on the 30th day after sowing which was found to decrease after this At this stage the number of leaves in the treatment receiving no urea was significantly lower than all other treatments But no treatment exhibited a significant superiority over the untreated urea The average number of leaves in T_1 (urea

Table 7 Effect of nitrification inhibitors on plant height and number of leaves at different growth stages of maize *

Treatments	Plant height (cm) Days after sowing				Number of leaves Days after sowing			
	15	30	45	55	15	30	45	55
T_1 (without urea)	35 6	70 1	91 0	97 4	5 3	5 3	4 5	5 0
T_2 (with urea alone)	42 8	96 0	114 3	125 8	5 5	6 8	5 5	5 0
T_4 (urea + neem cake)	42 0	93 9	116 3	126 0	5 3	6 3	5 0	4 8
T_5 (urea + cashew shell)	40 8	108 7	134 3	143 3	6 3	7 0	6 0	6 3
T_6 (urea + tobacco waste)	45 8	92 3	111 5	122 0	5 3	6 5	4 8	4 8
T_7 (urea + calotropis leaf)	39 3	84 6	104 8	115 5	5 0	6 8	4 8	5 3
T_8 (urea + neem leaf)	45 4	93 8	125 5	134 5	5 3	7 0	5 3	6 3
T_9 (urea + castor cake)	44 2	95 7	120 7	127 3	5 0	7 0	4 7	5 0
CD (5%) 1	NS	15 33	15 37	16 19	NS	0 98	NS	1 07
2		16 55	16 57	17 51		1 06		1 15
3		17 69	17 74	18 71		1 14		1 23
SE m± 1	5 13	7 39	7 41	7 81	0 49	0 47	0 54	0 52
2	5 54	7 98	7 99	8 44	0 53	0 51	0 59	0 56
3	5 93	8 53	8 55	9 02	0 57	0 55	0 63	0 59

* T_5 and T_9 values are the mean of three replications only

1 CD and SE m ± for comparison between all treatments except T_5 and T_9

2 CD and SE m ± for comparing T_5 and T_9 with the remaining treatments

3 CD and SE m ± for comparison between T_5 and T_9

alone) was 5 3 as compared to 6 3 to 7 0 in the other treatments On the 45th day after sowing, there was no significant difference between treatments with respect to the number of leaves However, the lowest number of leaves (4 5) was noticed in T_1 (without urea) and highest (6 0) in T_5 (urea + cashew shell) In the treatments, T_4 (urea + neem cake) and T_6 (urea + calotropis), the number leaves was found to be lesser than even T_1 (without urea) Maximum number of leaves (6 3) was noticed in T_5 (urea + cashew shell) and the only treatment on par with this was T_7 (urea + tobacco waste)

4 2 1 3 Dry matter production (Table 8, Appendix-IV)

In dry matter production, the treatments T_2 (urea alone) and T_5 (urea + cashew shell) differed significantly from rest of the treatments T_5 (urea + cashew shell) produced the highest amount of dry matter among all the treatments, the value being 25 3 g plant^{-1} at harvest The next highest dry matter production (19 0 g plant $^{-1}$) was observed in T_2 (urea alone) which was on par with T_5 The lowest dry matter yield (10 1 g plant^{-1}) was in the treatment receiving no urea (T_1) The dry matter production figures in all other treatments were on par with that in T_1 (without urea)

4 2.2 Chemical analysis

4 2 2 1 Nitrogen content of plants (Table 8 Appendix-IV)

The nitrogen content of the plants at harvest was estimated The results indicated that the nitrogen content in the two control treatments, i e without urea (T_1) and with urea alone and no inhibitor materials (T_2) were on par with each other and were significantly lower than that in the other treatments The nitrogen content in both was 0 74 per cent The remaining treatments though were significantly superior to the control, did not show any significant difference among themselves. However, the highest nitrogen content of 1 17 per cent was observed in the treatment receiving urea + cashew shell and the lowest nitrogen content (1 02 per cent) among the various treatments receiving the different inhibitory materials was observed in T_4 (urea + neem cake)

4 2 2 2 Total nitrogen uptake (Table 8 Appendix-IV)

The total nitrogen uptake in treatments T_5 (urea + cashew shell) T_8 (urea + neem leaf) and T_9 (urea + castor cake) were significantly superior to that in treatment receiving no urea (T_1) The maximum nitrogen uptake of 299 1 mg plant^{-1} was observed in T_5 (urea + cashew shell) and it was significantly superior to all other treatments The remaining treatments were all on par with T_2 (urea alone) The lowest

Table 8 Effect of nitrification inhibitors on dry matter production nitrogen content and total nitrogen uptake of maize at harvest*

Treatments		Dry matter (g plant^{-1})	Nitrogen content (%)	Nitrogen uptake (mg plant^{-1})
T_1 (without urea)		10 1	0 74	75 8
T_2 (with urea alone)		19 0	0 74	132 8
T_4 (urea + neem cake)		11 8	1 02	117 3
T_5 (urea + cashew shell)		25 3	1 17	299 1
T_6 (urea + tobacco waste)		12 6	1 09	139 5
T_7 (urea + calotropis leaf)		10 6	1 05	112 5
T_8 (urea + neem leaf)		16 8	1 09	184 6
T_9 (urea + castor cake)		16 2	1 07	175 2
CD (5%)	1	7 15	0 21	78 38
	2	7 74	0 23	84 66
	3	8 25	0 25	90 51
SE m±	1	3 45	0 10	37 79
	2	3 73	0 11	40 82
	3	3 98	0 12	43 64

* T_5 and T_9 values are the mean of three replications only

1 CD and SE m ± for comparison between all treatments except T_5 and T_9

2 - CD and SE m ± for comparing T_5 and T_9 with the remaining treatments

3 - CD and SE m ± for comparison between T_5 and T_9

nitrogen uptake (75 8 mg plant ^{1}) was observed in T_1 (without urea), as expected In the treatments, T_7 (urea + calotropis leaf) and T_4 (urea + neem cake), the nitrogen uptake was lesser than that in T_2 (urea alone), the values in mg plant^{-1} being 112 5, 117 3 and 132 8 in T_7, T_4 and T_2, respectively A distinct advantage of mixing cashew shell with urea on nitrogen uptake is evident from the data

Discussion

DISCUSSION

The present study was aimed at assessing the nitrification rates of laterite, alluvial and forest soils of Trichur district, to relate nitrification rates with cropping history and to assess the nitrification inhibition properties of a few plant materials reported to have bactericidal or allelopathic properties The assessment was done based on laboratory incubation studies and a pot experiment A total of 13 soil samples including laterite samples from seven different locations with different cropping histories, alluvial samples from five such sites and forest soil sample from one site were used for assessing nitrification rates

Direct assessment of the nitrification rate of the different soils was done by incubating the samples at 65 per cent field capacity after the addition of 100 ppm nitrogen as urea for a period of one month Estimations of NH_4^+- and NO_3^-- were done at intervals of 5, 10, 15, 20 and 30 days

Data on NH_4^+-N content showed that there was no marked decrease in the content of this nitrogen fraction with incubation period in the laterite or forest soil In the laterite and forest samples, the NH_4^+-N content was almost always higher than 100 ppm indicating a contribution through

the ammonification of soil organic nitrogen The NH_4^+-N content at all the sampling days being high in these two soil types, it is indicated that nitrification occurs only at very low rates in these two soil types Similar observation was made by Zacharias (1989) also Low or negligible rates of nitrification in soil under different forest tree species have been reported by Ellis and Pennington (1989) and Killham (1990) The decrease in ammoniacal nitrogen content in none of the laterite samples being marked, a distinct crop associated variation in nitrification was not indicated In the alluvial samples, there was a reasonable decrease in the NH_4^+-N content with incubation period indicative of the conversion of the ammoniacal nitrogen formed The only exception for this was the sample from rice in which the NH_4^+-N content remained more or less constant throughout the 30 days period One of the reasons for this may be a very low initial nitrifier population in this soil due to continuous submergence, a condition not conducive to the occurrence of aerobic nitrifiers In alluvial samples the ammoniacal nitrogen content was never as high as in laterite or forest soils at any stage from 5 to 30 days indicating that the contribution from organic nitrogen was relatively low in this soil The values were, in all cases, less than 100 ppm excepting in the case of one crop association involving

turmeric In this soil also, there was no consistent and appreciable decrease in content of this nitrogen fraction beyond five days of incubation to justify substantial nitrification The only exception to this was in the case where banana was the crop associated The extent of decrease in NH_4^+-N content was from the initial 68 to final 32 ppm in this crop association Here again, it is difficult to assign the reason for the exceptional behaviour of banana-associated soil just only to the effect of crop as there can be a variety of other factors which may influence the nitrification abilities of soils The fact that in none of the other crop associations studied, there was any crop-dependent pattern of variation in decrease in NH_4^+-N content will further support this conclusion

A perusal of the data on the NO_3^--N content in the different soils would indicate that the changes were highly erratic although the overall trend was one of lack of appreciable build up of nitrate fraction As expected, the only exception to this was the banana-associated soil sample in which there was an appreciable and near-consistent increase in NO_3^--N content with incubation period In all other samples, the trend was one of inconsistency This unexpected trend especially that of a decrease is attributable to the various degrees of immobilisation and remineralisation which

must have occurred in the different samples That there was the overriding influence of these two nitrogen transformations was also evident from the trend of NH_4^+-N content variations It is to be noted that the contents of the two fractions also never added upto either the quantity of fertiliser nitrogen initially added or to the initial ammoniacal nitrogen content at the first stage of sampling A total lack of nitrification process, as such also cannot be ruled out as was earlier concluded by Mathew (1986) and Zacharias (1989)

The overall conclusion from the available data is to be that nitrification in the three soils studied is low and that there appears to be no influence of cropping history on the nitrification capacities of these soils There were, however, exceptions in which substantial nitrification occurred in isolated cases

The second part of the laboratory study was aimed at assessing the nitrification inhibition properties of a few plant materials which are reported to have bactericidal or allelopathic properties The alluvial soil sample with banana association in which nitrification was found to occur at reasonable rates in the previous experiment was chosen for this Screening was done using the two already proven nitrification inhibiting materials, N-Serve (2-chloro 6(trichloromethyl) pyridine) and neem cake as references The

effectiveness of the various materials was assessed based on the ammoniacal and nitrate nitrogen contents in the different samples at 5, 10, 15, 20 and 30 days intervals

Contrary to the observation from the previous experiment (Table 3) the conversion of NH_4^+-N in this case was much rapid as indicated by a very low ammonium content on the fifth day and a total lack of this nitrogen fraction on the 15th day after incubation (Table 5) in the treatment receiving urea alone The change in season of soil sample collection and incubation may be the probable reason for this Samples for the first experiment was collected during the month of August, a relatively wet period whereas the second sample was collected during April, a dry month This might have affected the nitrifier population and activity in the soil leading to a change in the rapidity of ammonium conversion in the two studies Seasonal variabilities in nitrifier population, nitrifier activity and nitrification have been reported by many earlier workers (Bramley and White, 1989 Foster, 1989, Donaldson and Henderson, 1990) The higher temperature of the incubation period of the second season is yet another attributable factor

Distinct superiority of N-Serve in maintaining a higher NH_4^+-N content throughout the incubation period is

apparent from the data The only plant material which was nearly comparable and which maintained a high ammonium content in the soil was cashew shell But even this material was found to be effective for 20 days only after which the NH_4^+-N content decreased and was only 19 6 ppm on the 30th day In the N-Serve treated sample, the ammonium content continued to remain as high as 74 ppm Most of the other plant materials tried with the exceptions of tobacco waste, calotropis leaf, neem leaf and castor cake were not found to have any nitrification inhibitory properties in that, the extent of reduction in ammoniacal nitrogen content was comparable to that observed in untreated urea Neem cake recommended as a potential nitrification inhibitor was not found to significantly reduce the rate of conversion of ammoniacal nitrogen in the incubated soil and there was a near-total conversion within 15 days So from the data on ammoniacal nitrogen content only a few materials were found to be effective (though marginally) in reducing the rate of conversion of the ammonium form and maintaining a certain concentration of it in the soil throughout the incubation period

Inconsistency in nitrate build up is revealed from the data on NO_3^--N content of this incubation study also A substantial production of nitrates, corresponding to the

decrease in ammoniacal nitrogen was not observed These data, hence were in accordance with those obtained in the earlier experiment This inconsistency and a lack of substantial nitrate build up in the soil affirms the influence of immobilisation mineralisation activities on this However, as expected, the nitrate nitrogen contents remained lower in those treatments which maintained a higher ammonium content

Based on the above results of this part of the laboratory study the overall conclusion may be drawn as follows

1 Among the different nitrification inhibitors studied, N-Serve remained the most effective

2 Cashew shell is a potential plant material which possesses reasonable nitrification inhibition properties

3 Some of the other useful materials include tobacco waste, calotropis leaf, neem leaf and castor cake

A pot experiment was taken up to study the influence of application of the five materials viz , cashew shell, tobacco waste calotropis leaf, neem leaf and castor cake on a crop of fodder maize taking N-Serve and neem cake as experimental checks The crop was grown for a period of 55

days and the dry matter production, nitrogen content and nitrogen uptake at harvest were recorded Observations on plant height and number of leaves were taken at 15 days intervals during the growth period

Significant differences between treatments were not observed with respect to plant height or number of leaves at 15 days But thereafter, most of the treatments were found to be significantly superior to unfertilised control However, only cashew shell maintained the beneficial effect consistently eventhough during the early stages of observation effects of all the inhibitors were found to be on par with that of the application of urea alone During the late stages i e , by 45 and 55 days after sowing, the treatment in which urea alone was applied was significantly inferior to certain treatments particularly that with cashew shell

Data on dry matter production, nitrogen content and total nitrogen uptake showed significant differences between treatments Cashew shell was found to be the most promising material in this case also in that this treatment had the maximum dry matter production, nitrogen content and total nitrogen uptake The distinct advantage of mixing urea with cashew shell on growth characters including plant height, number of leaves and dry weight as also on the nitrogen content and uptake by plant is thus evident from the data

The beneficial effect of applying cashew shell powder along with urea on the dry matter production and nitrogen uptake in cotton has been reported by Geethalakshmi and Palaniappan (1991) Contrary to what was expected, neem cake was found to be less effective than many other materials tried, particularly neem leaf which was next only to cashew shell However, a precise ranking of the materials in the order of their effectiveness was not possible because no material other than cashew shell maintained a consistent superiority in all the characters studied In all probability, better growth of the test crop because of addition of these plant materials was mainly because of nitrification inhibition and the consequent decrease in leaching losses The fact that there was inhibition of nitrification noted in the incubation study and that the conditions were favourable for substantial leaching will support this Another indication in favour is that there was enhanced growth of the crop due to fertiliser supplementation as compared to the control of no nitrogen supply, the necessary conclusion from which is that the inherent nitrogen supplying power of the soil was sub-optional and that any improvement in utilisation of this nutrient would reflect itself in crop performance It must, however, be noted that improved growth of plants because of addition of these materials may arise from factors other than nitrogen

supply and that higher nitrogen utilisation may be the result of factors other than nitrification inhibition also

One important observation from the incubation study is that N-Serve is the material with the highest degree of nitrification inhibition This aspect, however, is not to be given much of importance because at the recommended dose, this chemical was found to be toxic to the test crop The reasons for this toxicity are not very clear and in an identical study on the same crop, maize, there was healthy growth in the earlier study (Zacharias, 1989) In all probability, this was the result of long storage of the chemical

The important aspects of the discussion may be summarised as follows

1 Cashew shell appears to be a material of potential for development as a nitrification inhibitor The rate of application tried (5 3) however is too high for adoption and attempts on extraction of active fraction may be worthwhile

2 Mixing urea with other materials like tobacco waste, calotropis leaf, neem leaf and castor cake was also found to be advantageous though to a lesser extent than cashew shell

3 All the materials screened in and included for further evaluation (cashew shell, tobacco waste calotropis leaf neem leaf and castor cake) were as good as if not better than neem cake in improving crop growth and N uptake

4 As was reported by earlier workers, the three soil types tested, laterite, alluvial and forest, supported very low rates of nitrification There were, however, exceptions and in a few samples, the rates were moderate

5 There were no evidences of crop-associated differences in nitrification rates of soils

Summary

SUMMARY

A study was conducted at the College of Horticulture, Vellanikkara, Trichur from January 1993 to August 1993 to assess the nitrification rates of laterite, alluvial and forest soils, to relate nitrification rates with cropping history and to assess the nitrification inhibition properties of a few plant materials The assessment of relative rates of nitrification was done through a laboratory incubation study A total of 13 samples, seven of laterite soil, five of alluvial and one of forest were included For this study, the soils were supplied with 100 ppm N and maintained at 65 per cent field capacity Samples were drawn at intervals of 5, 10, 15, 20 and 30 days and NH_4^+ and NO_3^- contents were estimated Screening of plant materials for nitrification inhibition properties was done through a laboratory incubation study and a pot experiment In the laboratory study, a total of 14 materials were used for screening using standard nitrification inhibition materials like N-Serve (2-chloro - 6(trichloromethyl) pyridine) and neem cake for comparison The soil was supplied with 100 ppm N as urea and maintained at 65 per cent field capacity Here also, sampling was done at five days intervals for one month and NH_4^+ and NO_3^--N contents were estimated The alluvial sample from banana association

which showed a reasonable rate of nitrification in the first study was chosen for this Five most effective materials viz , cashew shell, tobacco waste, calotropis leaf, neem leaf and castor cake identified based on the incubation study were again screened for their effect on crop growth through a pot experiment by raising a test crop of fodder maize N-Serve (2-chloro - 6(trichloromethyl) pyridine) and neem cake were used as standards Urea was applied to provide 100 ppm N and the test materials were added at urea-material ratio of 5 3 There were also experimental checks without added fertiliser nitrogen and with 100 ppm N as untreated urea The fodder maize variety, African Tall Maize, was grown for a period of 55 days and the total dry matter production, N content and uptake at harvest were recorded Observations on growth characters like plant height and number of leaves were taken at periodic intervals The results of the laboratory incubation studies showed a lot of sample to sample variations which made it difficult to explain some of them Those that appeared to be dominant are summarised below

1 Among the three soil types studied, laterite and forest soils were found to maintain higher ammoniacal nitrogen contents throughout the incubation period compared to alluvial soil

2 The extent of reduction in ammoniacal nitrogen content in all the samples except alluvial from banana association was only marginal

3 A distinct crop associated pattern of ammonium conversion was not apparent the only exception being the alluvial sample from banana association

4 Significant nitrate nitrogen build up was not observed in any of the samples, excepting the alluvial soil with banana association

5 In the alluvial soil with banana association, there was an increase in nitrate nitrogen content with incubation period and the maximum content of 57 1 ppm was noticed on the 30th day after incubation

6 The change in NO_3^--N content in all the soils were highly erratic However, a general increase in its content from an initial value was noticed

7 Reduction in ammoniacal nitrogen content to a greater extent was observed during the second incubation study in the banana-associated alluvial soil Complete loss of ammoniacal nitrogen by 15th day after incubation was noticed in this

8 Treatment with N-Serve maintained a higher NH_4^+-N content throughout and a content of 74 2 ppm was noticed even on the 30th day

9 Cashew shell was found to be the most effective plant material for nitrification inhibition and it maintained a high NH_4^+-N content of 50 1 ppm on the 20th day

10 Most of the other plant materials excepting tobacco waste, calotropis leaf, neem leaf and castor cake, were not effective in preventing ammonium conversion

11 The nitrate nitrogen content in the treatment receiving N-Serve was found to be consistently low and the maximum content observed at any stage was only 13 3 ppm

12 Cashew shell was also observed to maintain a low soil nitrate content

13 The change in nitrate nitrogen contents were highly erratic and they did not follow any consistent trend

14 Cashew shell, tobacco waste, calotropis leaf, neem leaf and castor cake were the only five materials found to show consistent nitrification inhibitory properties

15 In the pot experiment, N-Serve was found to inhibit the germination of maize seeds

16 Plant height at 15 days after sowing was not significantly different between treatments However, at later stages, plant height value in the control treatment (without urea) was found to be lower than all other treatments

17 With respect to the number of leaves, a significant difference between treatments was not observed on the 15th and 45th days after sowing But on the 30th day after sowing, the treatment without urea was found to be significantly inferior to all other treatments At harvest, maximum number of leaves was noticed in the treatment receiving cashew shell and the only treatment on par was urea along with tobacco waste

18 Maximum dry matter production at harvest was observed in the treatment with cashew shell, but it was on par with untreated urea Dry matter production figures in all other treatments were significantly lower than that in cashew shell treatment

19 Plant nitrogen content and total nitrogen uptake at harvest were found to be maximum in the treatment, urea + cashew shell In both cases, it was significantly superior to untreated urea

20 All the materials tested in the pot experiment were either comparable to or better than neem cake in effectiveness

21 The overall conclusions from the study were the following

(i) All the three soil types viz , laterite, alluvial and forest studied had low nitrification rates eventhough there were a few exceptions

(ii) A distinct crop associated influence on the nitrification rate was absent in the soils studied

(iii) Cashew shell appears to be a promising material of high nitrification inhibition potential

(iv) Tobacco waste, calotropis leaf, neem leaf and castor cake are also materials with nitrification inhibition properties

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* Originals not seen

Appendices

Appendix I

Weather data (weekly average) for the cropping period (June 1993 to August 1993)

Week No	Month and date	Rainfall (mm)	Temperature		Relative humidity (%)	
			Maximum (°C)	Minimum (°C)	Forenoon	Afternoon
					I	II
22	28th May - 3rd June	103 8	32 8	24 0	90	69
23	4th June - 10th	236 6	29 6	23 3	95	80
24	11th - 17th	237 9	29 2	23 8	95	81
25	18th - 24th	85 5	30 4	24 5	94	73
26	25th - 1st July	186 4	29 2	23 6	94	82
27	2nd July - 8th	188 9	28 6	22 7	95	78
28	9th - 15th	167 8	28 7	22 6	92	83
29	16th - 22nd	128 1	28 9	22 9	94	76
30	23rd - 29th	101 0	28 0	23 1	94	80
31	30th - 5th Aug	96 4	29 1	23 7	95	76

Source Meteorological Observatory, Vellanikkara

Appendix II

Analysis of variance for NH_4^+ and NO_3^- nitrogen content in soil

Source	df	Mean squares									
		NH_4^+-N (ppm)					NO_3^--N (ppm)				
		5th day	10th day	15th day	20th day	30th day	5th day	10th day	15th day	20th day	30th day
Treatment	16	383 37**	605 27**	984 77**	817 57*	592 72**	427 85**	121 14**	553 63**	270 49**	210 09
Error	17	15 20	20 58	29 29	39 21	6 88	53 25	24 62	25 05	22 77	147 32
Total	33										

* Significant at 5% level

** Significant at 1% level

Appendix III

Analysis of variance for the effect of nitrification inhibitors on height of plants and number of leaves at different stages of growth of maize

Source	df	Mean squares							
		Mean height (cm)				Mean number of leaves			
		15 DAS@	30 DAS	45 DAS	55 DAS	15 DAS	30 DAS	45 DAS	55 DAS
Treatment	7	44 99	439 41**	629 47**	678 01**	0 17	1 35	0 82	1 46*
Error	22	52 68	109 16	109 71	128 08	0 49	0 45	0 59	0 53
Total	29								

* Significant at 5% level

** Significant at 1% level

@ Days after sowing

Appendix IV

Analysis of variance for the effect of nitrification inhibitors on dry matter production, nitrogen content and total nitrogen uptake of maize at harvest

Source	df	Mean squares		
		Dry weight (g plant^{-1}) at harvest	Nitrogen content (%) at harvest	Nitrogen uptake (mg plant^{-1}) at harvest
Treatments	7	90 99**	0 10**	15346 45
Error	22	23 79	0 02	2856 60
Total	29			

** Significant at 1% level

ASSESSMENT OF NITRIFICATION RATES OF SOILS AND SCREENING OF PLANT MATERIALS FOR NITRIFICATION INHIBITION PROPERTIES

By

C REKHA

ABSTRACT OF A THESIS

Subm tted n partial fu filment of
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ABSTRACT

The present study assessment of nitrification rates of soils and screening of plant materials for nitrification inhibition properties was conducted during January 1993 to August 1993 at the College of Horticulture, Vellanikkara, Trichur The three soil types, laterite, alluvial and forest were used for nitrification rate assessment The two soil types, laterite and alluvial were taken from different locations of variable crop association A total of 13 samples were assessed One soil sample with the maximum rate of nitrification from these was taken for screening of plant materials for nitrification inhibition properties Fourteen different locally available plant materials were chosen for screening using N-Serve and neem cake as the standard inhibitors for comparison Nitrification rate in nearly all the soils was low and there was no appreciable conversion of NH_4 form to NO_3 A distinct crop associated influence on nitrification rate was absent in the soils studied The only exception was the alluvial sample with banana as the associated crop and this soil was hence chosen for screening of plant materials N-Serve was found to be the most effective nitrification inhibitor Among the plant materials

tested, cashew shell was the only material which showed a distinct advantage over other materials including neem cake Highest mean values in plant height and number of leaves at different growth stages and dry matter production N content and N uptake were observed in the treatment receiving cashew shell Other useful materials identified were tobacco waste calotropis leaf, neem leaf and castor cake