TRANSFORMATION AND PLANT AVAILABILITY OF AMIDE NITROGEN IN SELECTED SAVANNA SOILS.

BY

AROWOSHEGBE, TEMITOPE ANTHONIA.

A Thesis Submitted to the Post-graduate School, Ahmadu Bello University, Zaria in Partial Fulfilment of the Requirements for the Degree of:

Master of Science

in

Soil Science

DEPARTMENT OF SOIL SCIENCE

FACULTY OF AGRICULTURE

AHMADU BELLO UNIVERSITY

ZARIA, NIGERIA.

JULY, 1987,

DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research works. It has not been presented before in any previous application for a higher degree.

T. A. Arowoshegbe
Name & Signature of Candidate

Date: 23/7/87

Y. Arora
Name & Signature of Major Supervisor

Date: 23/7/87

CERTIFICATION

This thesis entitled 'TRANSFORMATION AND PLANT AVAILABILITY OF AMIDE NITROGEN IN SELECTED SAVANNA SOILS by T. A. Arowoshegbe meets the regulations governing the award of the degree of Master of Science (Soil Science) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Chairman, Supervisory Committee	Date
Member, Supervisory Committee	Date
Member, Supervisory Committee	Date
Head, Department of Soil Science	Date
Dean, Postgraduate School	Date

DEDICATION

Dedicated to Sunday Sinkaiye, my husband; Seun, my daughter and Juliana, my late mother.

ACKNOWLEDGMENT

I wish to express my sincere gratitude to Dr. Y. Arora, whose patience, encouragement and supervision made this work possible. My profound gratitude also goes to Professor L. G. Lombin and Dr. S. Abdulmumini for their constructive criticisms and invaluable suggestions.

I am very grateful to Professor Olugbemi and his family for their love and kindness to Seun and I. My thanks to all staff of the Soil Science Department and the Students who have contributed one way or the other to the success of this work. To all my friends who have helped me during my period of study, I say thank you all. My gratitude and deep appreciation goes to my parents, sisters and aunties who have contributed to my education financially and morally.

Finally, I am most grateful to Sunday for his care, love and understanding throughout my stay in Zaria.

ABSTRACT

Amides added to soils are hydrolyzed to ammonium (NH) and their corresponding carboxylic acids[+] Studies of 4_4 of amide - N in soils deserve attention because amides have potential as nitrogen (N) fertilizers. In this study, six amide compounds (acetamide, calcium cyanamide, dimethyl fornamide, phenyl acetamide, N, N-dimethyl acetamide and succinamide) were used. The potential of these amides as N fertilizer was determined through incubation, greenhouse and field experiments. Urea was used as the standard for comparison. Soils used for the incubation and greenhouse experiments came from Samaru, Mokwa and Bakura. The field trial was conducted at Samaru and the test crop used was maize (Zea mays L.).

The transformations of amide - N (60)ugN/g of soil) were studied in field - moist soils incubated under aerobic conditions at 30 C for 8 weeks. All the amides were readily hydrolyzed in the three soils except dimethyl formamide which did not nitrify, with most of the amides studied, the inorganic N (NHL, NO" + NO") produced was accumulated as 3 The recovery of N varied from 35% to 93%. Phenyl acetamide, N, N-dimethyl

acetamide, CaCNL and Succinamide did not decrease the soil pH as much as urea while dimethyl formamide did not decrease the pH at all.

In the greenhouse trial, maize responded to the application of the amide N fertilizers. The dry matter yield increase with rate of N application. Total DMY obtained with succinamide was not significantly different from that obtained with urea at the three rates of N application. That of acetamide tended to be lower than urea while phenyl acetamide was markedly inferior to other amides. The recoveries of N ranged from 51$ (phenyl acetamide) in Mokwa soil to 103% (succinamide) in Bakura soil. In the field, succinamide was similar to urea in the DMY and N uptake. The yield from acetamide was much lower than urea. The recoveries of N (at the rate of 120KgN/ha) ranged from 21% (CaCNL) to 68$ (succinamide). Generally, recovery of N from succinamide was better than urea and urea was followed by acetamide.

TABLE OF CONTENTS

Chapter		Page
	Declaration	ii
	Certification	iii
	Dedication	iv
	Acknowledgements	v
	Abstract	vi
	Table of Contents	viii
	List of Tables	xi
	List of Figures	xii
	List of Plates	xiii
	List of Appendices	xiv
1	INTRODUCTION	1
2	LITERATURE REVIEW	4
	2.1 Nitrogen-status of Savanna soils	4
	2.2 Response of crop to N application in Savanna soils	5
	2.3 Factors affecting efficiency of N fertilization	7
	2.3.1 Leaching of Nitrogen	7

	2.3.2	Nitrification Rate in soils	9
	2.3.3	Rate and time of N- application ...	10
	2.4	Residual effect of N fertilizers on soil chemical properties	11
	2.5	Forms of N fertilizers used in the Savanna soils	13
	2.6	Slow-release fertilizers	15
	2.6.1	Sulphur coated urea	16
	2.6.2	Synthetic Organic N- fertilizers ...	17
3	MATERIALS AND METHODS		24
	3.1	Description of sample sites	24
	3.1.1	Sample Collection and Handling ...	24
	3.2	Physical and Chemical Analysis ...	25
	3.2.1	Soil inorganic N analysis	26
	3.3	Laboratory Incubation Studies. ...	27
	3.3.1	Soil pH determination	29
	3.4	Greenhouse Experiment	30
	3.4.1	Plant Analysis	32
	3.5	Field Experiment	32
4	RESULTS AND DISCUSSION		35
	4.1	The Chemical and Physical properties of the three soils ...	35

4.1.2	Properties of the amides	36
4.2	Soil incubation	37
4.2.1	Inorganic N recovery	37
4.2.2	Rate of Amides Transformation ...	37
4.2.3	Mineralization in the control soils	46
4.2.4	Structural relationship of the amides to N recovery	46
4.3	Residual effect of amides on soil pH	53
4.4	Greenhouse Study	56
4.4.1	Dry Matter Yield	57
4.4.2	Plant Nitrogen uptake	63
4.4.3	Apparent Nitrogen recovery ...	65
4.5	The results of the Field Experiment	67
4.5.1	Dry matter yield	67
4.5.2	Total N recovered	69
5	SUMMARY AND CONCLUSIONS	71
	REFERENCES.	75

LIST OF TABLES

Table		Page
3.1	Properties of Amides	28
4.1	Chemical properties of the soils ...	38
4.2	Physical properties of the soils ...	39
4.3	Molecular structures of the amides ...	48
4.4	pH of soils (soil:water, 1.2) at different incubation intervals of the three soils.	
	(a) Samaru soil.	54
	(b) Mokwa soil	54
	(c) Bakura soil.	55
4.5	N uptake (MgN) by the dry matter in the greenhouse experiment	64
4.6	% N recovered by the plants from the various amides at different rates of N application in the greenhouse	66
4.7	Effect of application of different amides in soil on the yield, N content, N uptake and recovery in a field trial as Samaru	68

LIST OF FIGURES

Figure		Page
1	Mineralization of amides in Samaru soil	40
2	Mineralization of amides in Mokwa soil	41
3	Mineralization of amides in Bakura soil	42
4	The response of maize to various amides in the greenhouse experiment in Samaru, Mokwa and Bakura soils.	61

LIST OF PLATES

Plate		Page
A representative of maize plants in the greenhouse for each treatment and N rate at 6 weeks of growth in:		
i	Samaru soil	58
ii	Mokwa soil	59
iii	Bakura soil	60

LIST OF APPENDICES

Appendix		Page
	Ammonification and nitrification of the amides during incubation experiment in :	
1	Samaru soil	89
2	Mokwa soil	89
3	Bakura soil	90
4	Dry matter weight (g/pot) of maize from greenhouse experiment using various amides in the three soils ...	91
5	% N in the dry matter of the green-house experiment	92

CHAPTER ONE

INTRODUCTION

Most Nigerian soils under cropping are low in nutrient status, particularly nitrogen (Jones, 1976a). In order to increase and maintain crop yields, use of N fertilizers is therefore necessary.

Urea, Calcium ammonium nitrate and ammonium sulphate are the commonly used N sources in the country (Jones, 1974). These fertilizers have low efficiency of N due to losses through volatilization and leaching (Arora and Juo, 1982; Jones, 1974). High temperatures increase volatilization losses and high rainfall tend to encourage leaching. The savanna area has high temperature and high rainfall concentrated over a period of five months of the year. The prolonged use of these conventional fertilizers also gives rise to residual soil acidity and cation depletion (Jones, 1976a; Bache and Heathcote, 1969; Bache, 1965).

Cereal crops largely grown in the savanna region of Nigeria require large applications of Nitrogen on a continuous basis. Due to problems encountered with the already established fertilizers, other sources are being explored for more efficient N fertilization. Attention is being directed towards slow release compounds. The controlled or slow availability should supply N continously

over an extended period, thus avoiding the need for repeated applications of conventional water soluble fertilizers. They should also reduce N losses by leaching, decrease gaseous losses of N, and reduce the hazard of seedling injury from over application, (Allen et al, 1986; Beaton et al, 1967). Among the various N compounds being tested for possible greater efficiency than conventional N sources are amides and their derivatives. Amides are known to release N slowly in the soil and have been proved to be very efficient for crop production. (Hunter, 1974; Terman et al, 1968 Hauck, 1964). Amides could not be used on a wide scale due to high cost of production. Recent literature indicates that some amides can be produce economically from industrial wastes (Worthy, 1980; Van Gordon and Gilbert, 1976; Jones et al, 1966). When produced in large quantity the unit cost of amides can be economically low (Cummings and Gleason, 1971).

The potentials of formamide and oxamide as fertilizers are well documented but the use of other amides as N fertilizers has not been well explored. The possibility of using amides as N sources for plant growth and development deserve attention because it seems feasible to synthesize amides with resistance to degradation by enzyme attack and controlled release of N would be possible. Before use, howeve information about the rate of mineralization of amides in

tropical soils, their efficiency as N fertilizers and their residual effect on the soil is required. Therefore, the objectives of the present study are:

(1) To study the rate of mineralization of various amides in savanna soils.

(2) To evaluate the effectiveness of various amides as N sources for maize.

(3) To find out the residual effect of amides on soil chemical properties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Nitrogen - Status of Savanna Soils

Nitrogen is the main limiting nutrient in the savanna areas (Stockinger, 1966). Nye and Greenland (1960) have recorded deficiencies in mineral N content is a characteristic of high grass savanna soils. Most of the soil N is present in organic forms.

The low N content of savanna soils is due to the amount and duration of rainfall (Aweto, 1981; Yahuza and Mokwunye, 1976). Nitrogen added to the soil through rainfall at Samaru is small (Jones, 1960; Jones and Bromfield, 1970). However, Wild (1972) found that at the start of rainy season, there was a high concentration of nitrate - N in the surface soil in Samaru.

Soils from Sudan and Sahel Savanna of Nigeria have been reported to have low N supplying power, Omeje (1981) attributed this to the low native N content of the soils. Okeagu (1981) reported that the low nitrate levels were just what one would expect in the presence of a fibrous root system of plants which not only utilise nitrate readily, but also ammonia. He admitted that this did not directly explain observations of reduced nitrification in grassland soils receiving ammonium fertilizers.

The soil - N system is a dynamic one. The magnitude of the value depends on such factors as climate, moisture, temperature, soil texture and type of clay mineral, vegetation, topography, soil acidity, C:N ratio, micro-organism interaction with other nutrients, soil management and aeration.

Climate is the most important single factor, the N content of soils is increased due to the addition of N from rainfall (Ataga and Nnadbuchi, 1978). About 8.8KgN/ha was added to Savanna soils annually via incorporation of crop residues (Balasubramanian and Nnadi, 1977).

The N content of soils has direct relationship with moisture content (Agboola and Udom, 1967, Enyi, 1967) and soil profile saturated with moisture and waterlogging favour denitrification (Jones and Wild, 1975). Excess water also leaches soluble N beyond the root zone.

Other losses of N from the soil-plant system are burning, erosion, run off plant uptake loss by removal of animal products, denitrification and volatilization of ammonia (Jones, 1971; Kowal, 1970; Nye and Greenland, 1960).

2.2. Response of Crop to N application in Savanna Soils

High N - fertilizer response have been observed in Nigeria (Kayode and A$_g$boola, 1982; Ojeniyi, 1980; Balasubramanian et al, 1978; Adetunji and Agboola, 1973; Goldsworthy, 1967), response is more frequent in the

savanna than in the forest area. However, cases of no response to N application have also been reported (Ojeniyi et al, 1982; Ataga, 1978; Obakin, 1978). The yield response of cotton to N fertilizations are often very small and inconsistent (Goldsworthy and Palm er, 1971); Lombin and Ogunlela, 1979).

The response of N is influenced by environmental factors which differ in different ecological zones (Westerman et al, 1972; Carter et al,1967). However, Arora and Juo (1982) reported that the leaching loss of NO_3^- is an important factor affecting the N - use efficiency by crops such as maize and upland rice under high rainfall conditions. It has been observed that about 50 to 60% of fertilizer N applied to soil is usually recovered by crop plants (Fagi and De Datta, 1981; Raney, 1960). However higher recovery has been reported with split applications (Arora and Juo, 1982; Olsen et al 1970).

The incomplete recovery is as a result of rapid dissolution of the applied material and therefore release of the nutrient at high concentration (Richards, 1972). The amount recovered can be improved by developing compounds with limited water solubility and latering soluble materials so as to retard release to the soil solution.

2.3 Factors affecting efficiency of N - Fertilization

2.3.1. Leaching of Nitrogen

Nitrate is subject to leaching because being an anion, it is held by electrostatic forces only when the soil contins sufficient positive charges (Bates and Tisdale, 1957). Hence Nitrate is the most mobile forms of soil N compounds (Sauchelli, 1964) Nitrate - N concentrates at the wetting front and moves readily with water penetrating soil profiles (Arora and Juo, 1982). Nitrogen leached from the rootzone of plants is virtually all in the form of NO_3^- and may be considered lost, since upward movement of NO_3^- with water is largely limited to the upper 45 cm of soil (Westelaar, 1961).

Ammonium - N is quite immobile, even in light textured soils (Pleysier et al, 1982; Broadbent et al, 1958). Very little NH_4^{+-} N is ever recovered in soil leacheates, except under peat soils (Kohnke et al, 1940) Urea - N moves quite readily in sandy soils (Broadbent et al, 1958; Volk and Sweat, 1955) but there is an appreciable resistance to its movement in heavier soils.

Leaching in Samaru soils is generally slow (Jones, 1975; Nnadi, 1975) and it takes about two years for applied nitrogen to be leached out of the soil profile (Nnadi and Stockinger, 1980). Leaching could be a problem in the southern Guinea zone with deep sandy profile and moderate

amounts of rainfall. In the Sudan vegetation zone most of the soils are very sandy but because rainfall is low, little leaching occurs. Apart from plant uptake, low N levels in Samaru soils may therefore be attributed to denitrification (Nnadi and Arora, 1986).

According to Jones (1976b) a low leaching efficiency of 0.38 - 0.66cm/cm rainfall, was related to very slow wetting of tge subsoil, a phenomenon which could be assuming that part of the rain passed through the profile relatively quickly in the larger pores. The slow leaching of native soil nitrate at Samaru could be due to the rapid drainage of storm water through deep cracks and channels in the soil, leacing much of the nitrate within fine pores from which diffussion was slow. (Wild, 1972). Terry and McCants (1968) reported that the magnitude of leaching is closely related to the amount of percolating water and to soil porosity, particularly the percentage of large pores. Irrigation of soils is also related to nitrate leaching (Hanle et al, 1977).

2.3.2 Nitrification Rate in Soils

Microbial fixation of elemental N is another process whereby mineral N is added to savanna soils (Nye and Greenland, 1960). Soil N transformations are also brought about by microbial activities.

Nitrification of soil organic matter and fertilizer nitrogen can be an important regulator of N leaching losses (jones and Wild, 1975). Dancer et al (1973) reported that liming an acid soil (pH 4.7 to 6.6) did not affect rate of nitrification significantly. Arora et al (1986) reported that the ammonification os soil organic N and added source proceeded readily in an highly acidic Ultisol and was not affected by lime rate. But nitrification occurred in both limed and unlimed soils. The rate of nitrification depended upon the rate of lime application. The nitrification of ammonium - N from ammonium sulphate was absent in soils receiving lower rates of lime and added ammonium source was nitrified readily after a 3 - week delay period in the soil which received a higher rate of lime.

The good nitrification capabilities of Samaru and Mokwa soils have been reported. The very low rate of nitrification in some soil inspite of the high amount of organic nitrogen was attributed to very low pH, high concentration of Al^{3+} ions and very low counts of Nitrosomonas and Nitrobacter Species (Arora et el, 1986; Ayanaba and Kang, 1976).

2.3.3 Rate and time of N - application

Nitrogen added to soil in form of fertilizers may or may not be available to the growing crops depending on certain practices such as method of application, and some other factors (Krauter, 1974).

Chinwuba and Fayemi (9170) and Agboola (1968) agreed that the efficiency of applied N fertilizer can be increased by the split application. This ensures adequate supply of N to the crop at critical stages of growth and also help to reduce N losses from the system (Balasubramanian and Singh, 1982; Fagi and De Datta, 1981). Split nitrogen applications are generally recommended for maize, wheat, sorghum and cotton (Balasubramanian et al, 1979).

Jones (1973) did not obtain any advantage in maize yield at Samaru from split N application over unsplit application at the rate of 112KgN/ha. Balasubramanian et al (1978) reported significant differences in maize yield by splitting urea but not CAN. Generally, response to splitting N in the Northern Guinea Savanna are sporadic.

In the Southern Savanna, Lombin and Ogunlela (1979) obtained a significant response to split application of N to cotton on the soils derived from Sedimentary Sandstones. Jones (1976b) calculated that the leaching of nitrate from fertilizer nitrogen at Mokwa could be

4 - 5 times the rate at Samaru. The work of Jones (1976a) indicates that since AS, CAN and Urea acidified the sub-soil at Mokwa, leaching of N is quite rapid and therefore split application would be advantageous.

Fayemi (1966) reported that time of application of fertilizer N greatly influence the yield of grain, the percentage of N and the crude protein of the grain under Nigeria conditions.

Goldsworthy (1967) reported response of maize to N fertilization and recommended a rate of 65kgN/ha for maximum yield response throughout the savanna areas. Since the introduction of the high yielding maize varieties, higher rates of N have, however, been observed to be necessary for maximum grain production in this ecological zone (Ologunde and Ogundele, 1982; Balasubramanian et al 1978; Jones, 1974), maximum yield was obtained with 120kgN/ha.

2.4 Residual effect of N fertilizers on Soil Chemical Properties

Nitrogen fertilization has been shown to affect soil properties, especially in chemically fragile savanna soils. Most of the soils have very low clay and organic matter contents and are dominated by kaolinitic clay. As a result most of these soils have very low cation exchange

capabities and are poorly buffered (Nnadi and Arora, 1986). Bache (1965) reported that 14 annual applications of ammonium sulphate at the rate of 22kgN/ha lowered soil pH at Samaru to 3.53 compared to 4.56 in the control plot. Amounts of exchangeable Al and Mn were markedly increased. Acidification was accompanied by losses of exchangeable Ca and Mg (Lombin, 1978; Bache and Heathcote, 1969).

Jones (1976a) recorded significant changes in soil chemical properties to a depth of 35cm in a leached ferreginous soil at Samaru and to at least 50cm in sandy ferrisol at Mokwa after the use of high rates of N fertilizers for three years.

Balasubramaniam and Singh (1982) found no difference in soil pH between calcium ammonium nitrate (CAN) and urea after two years of irrigated wheat at Kadawa but high rates, irrespective of the source depressed soil pH by 0.56 units. Similarly Nnadi and Abed (1983b) found no difference between CAN and sulphurcoated urea (SCU) with respect to their acidification effect after years of cropping, but the application of 120kgN/ha from soluble and delayed release sources resulted in decrease of 0.2 - 0.3 pH units relative to the control in the sandier soils at Mokwa and Kadawa.

The elemental sulphur used for coating urea may be the source of acidity found in SCU (Nnadi and Abed, 1983b). On oxidation, the elemental sulphur froms sulphuric acid.

$$S + 3/2O_2 + H_2{}^{0} \longrightarrow 2H^{+} + SO_4^{2-}$$

From a review of published data on residual effect of N sources, Nnadi and Arora (1986) concluded that acidification of savanna soils is likely to occur with continuous application of N fertilizers irrespective of the source though it is more rapid with ammonium sulphate.

2.5 Forms of N fertilizers used in the Savanna soils

Urea, AS and CAN are the commonly used N sources in Northern Nigeria (Jones, 1974). There is little difference between the sources in terms of their effectiveness in increasing crop yield (Nnadi and Arora, 1986; Jones, 1974; Brown, 1965). These fertilizers are water soluble and are converted to the nitrate form rather quickly. The nitrate is often subject to leaching or denitrification, particularly if large amounts of the fertilizers are applied to tropical soils which are sandy and poorly buffered. Among the classes of N fertilizers,

most of the ammoniacal forms are acid forming and their continued used will lower soil pH values (Jones, 1976a). All these N-sources have low efficiency in tropical soils (Kang et al, 1977; Oyedokun, 1976; Jones, 1973).

In a study involving different N sources and rates Jones (1974) reported a drastic fall in maize yield at high rates of ammonium sulphate (AS). Within three years, maize yield from AS plots decreased by 56 and 25% respectively at Samaru and Mokwa with annual application of 280KgN/ha. Yields from urea were also depressed but not as much as by AS. However at N rates normally recommended for maximum yield there were no significant differences between sources. Balasubramanian and Singh (1982) conducted a maize - wheat rotation study at Kadawa using urea and CAN and N rates ranging from 0 to 180KgN/ha and found that urea gave significantly higher yields than CAN in one out of four seasons. They concluded that urea is equally effective as CAN for maize and wheat in semi-arid savanna soils. The above conclusion appears valid for most of the soils of the savanna zone when these N sources are applied at optimum rates to relatively short season ($<$ 120 days) crops (Nnadi and Arora, 1986).

The efficiency of highly soluble N sources may be increased by split application in the Southern Guinea and Sudan zones (Nnadi and Arora, 1986). The use of calcium cyanamide in association with urea seems promising in increasing its efficiency. Arora et al (1987) and Nnadi and Arora (1986) reported that even amounts of less than 10mgN/Kg may effectively slow down the nitrification of urea, which occurs quite rapidly in most of the soils.

2.6 Slow - release fertilizers

Attention is being directed towards compounds with slow-release N fertilizers because of the high N leaching losses and low efficiency of conventional fertilizers in the tropical soils (Arora et al, 1987; Nnadi and Abed, 1983a; Arora and Juo, 1982). The slow-release N fertilizers that are being tested are sulphur coated urea and synthetic organic N compounds.

It has been reported that slow-release N fertilizers should have the advantage of N supply to crop continuously over an extended period, thus avoiding the need for repeated applications of conventional water-soluble fertilizers which could lead to reduced expenses and labour

(Allen et al, 1968; Beaton et al, 1967). They would also minimize luxury consumption of N and upset of nutrient balance as well as reduce N losses by leaching, decrease gaseous losses of N and reduce the hazard of injury from over-application particularly with seedlings. Olsen et al (1970) also cited advantages as reduction of nutrient loss via leaching and runoff; reduction of chemical and biological immobilization reactions in soils. They should also have higher N residual effects as compare to those from soluble fertilizer (Nnadi and Abed, 1983a).

The benefit to be d rived from the use of slow-release N fertilizers will depend on climate, soil, crop and patterm of fertilizer application (Sandhu, 1974).

2.6.1 Sulphur Coated Urea (SCU)

The low recovery from water-soluble fertilizer led to the development of SCU which has been tried and found to be better than the conventional sources for long duration crops (Nnadi and Abed, 1983a; Diamond and Mayers, 1972; Allen et al, 1971; Mays, 1970), Lunt (1968) also reported that SCU produced a markedly higher yield of maize than did uncoated urea where leaching occurred.

In a lysimeter experiment at Samaru Nnadi (1975) reported that CAN gave high yields of maize than urea and SCU (SCU-30) with 30% dissolution rate in 7 days. However, there was not much difference between SCU and urea. In field trials, Nnadi and Abed (1983a) compared two types of SCU having 11 and 30% dissolution rates in 7 days with CAN using cotton and sorghum as test crops. They found that at low N rates of application (30 - 40KgN/ha), SCU - 11 was more effective than SCU - 30 and CAN. However, SCU has its drawback of residual acidity as a result of sulphur oxidation (Nnadi and Abed, 1983b).

2.6.2 Synthetic Organic N- fertilizers

They are insoluble, harmless to crop, particularly when used carelessly or in excess (Hignett, 1971). Amides are the common forms of organic N- fertilizers that are receiving attention.

In United States, amides have been tried as slow-release N fertilizers. They have been reported to be less soluble in water and have slow release properties, when added to soils are hydrolyzed to ammonia and their corresponding carboxylic acids through amidase activity (Frankenberger and Tabatabai, 1981, 1980a, 1980b).



where R in structure represent the other groups in amide, R is CH_3 in acetamide and H in formamide. R represent NH_2 in urea.

NH_4^+ is not readily lost compared to NO_3^- in the soil, it is either held at the exchange site for plant use or fixed in clay lattice, or converted to NO_3^- by nitrifying organism under favourable conditions.

Recent studies showed that acrylamide is biodegradable in soils (Abdelmagid and Tabatabai, 1982), and can be obtained by acid hydrolysis of waste products, such as *acrylonitrite - containing resins* used in the food packing industry. Acrylamide seems to be promising as a cheap source of amide. Van - Gordon and Gilbert (1976) reported the formation of acrylamide by acid hydrolysis of Barex 210 high barrier resin. Kapoor and Mathur (1983) also showed the preparation of this amide and reported that polymers of acrylamide are being used in the industries all over the world. It has been reported too that carbon monoxide and other intermediates

produced in coal gasification can be used as feed stock for production of formamide and oxamide (Worthy, 1980). Calcium cyanamide can be manufactured by reacting calcium carbide with elemental nitrogen (Tisdale and Nelson, 1975). Organic fertilizers have been in existence but due to the high cost of production then, they were not given much attention.

Frankenberger and Tabatabai (1982) reported the possibility of using amides as N sources because it seems feasible to synthesize organic N fertilizer in which both specific and non specific metabolic inhibitor groups are a part of the whole molecular configuration. Such functional groups would provide the molecule with resistance to degradation by enzyme attack through properties such as Isomerism, chain length, assymmetry, steric hinderance and resonance. Through selective inhibition, a controlled release of N would be possible.

Amides, particularly formamide seem to have potential as N fertilizers, because greenhouse tests and field trials have shown that crop yields with amides as sources of N are similar to those obtained with urea and other conventional N fertilizers. (Hunter, 1974;

Terman et al, 1968; Brown and Reid, 1937; Rehling and Taylor, 1937).

Oxamide: $(CONH_2)_2$, containing 31.8% N. It has been reported to be promising and it is slightly soluble in water and must be decomposed microbiologically before crops can use the N. Its rate of action is controlled by varying its granule size as surface area governs the amount dissolved in unit time and temperature (Allen et al, 1971; DeMent et al, 1961). It hydrolyzes in soils as

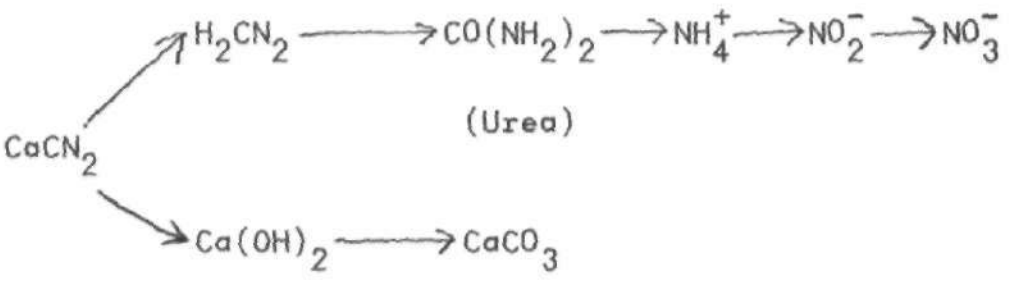
$$NH_2COCONH_2 + 4H_2O \rightleftharpoons (COOH)_2 + 2NH_4OH$$

and it's recovery is similar to those of conventional fertilizers.

Formamide: $HNCONH_2$, closely related to urea, is a clear liquid containing 31% N has been reported to have indicated possible utility as N fertilizer (Hunter, 1974). Rehling and Taylor (1937) reported that nitrification of formamide and the product of its hydrolysis, ammonium formate, proceeds in the soil in the same manner as that of urea. Formamide has been reported to be effective sources for N (Jones et al, 1966; Brown and Reid, 1937).

Calcium Cyanamide: $CaCN_2$ may be a better form of N fertilizer for humid tropics where the rapid rate of nitrate leaching is a major limiting factor affecting the efficiency of N use by crops (Arora et al, 1987; Pleysier et al, 1982). It is also reported to be efficient as N source for irrigated wheat (Nnadi and Arora, 1986). Leaching loss of N from this source also seems to be less than urea. It has been shown that small amounts of $CaCN_2$ decrease the nitrification of urea effectively (Nnadi and Arora, 1986; Arora et al, 1987).

Commercially produced $CaCN_2$, contains 21% N, has a slow rate of nitrification in the soil. Greenhouse studies with maize and rice have shown that dry matter yield with $CaCN_2$ as a source of N are similar to those obtained with conventional N fertilizers (Pleysier et al, 1982). The nitrogen of $CaCN_2$ becomes available to plants after hydrolysis in the soil followed by the formation of urea, ammonium and nitrate as shown in the following scheme (Temmer, 1946).



This stepwise breakdown of $CaCN_2$ makes it a slow release N fertilizer.

The rate of transformation of $CaCN_2$ is more rapid in organic soils than in sandy soils (Bjalfve, 1957). However, Normmik (1958) showed that soil texture, pH and humus content have little effect on the rate of ammonification of $CaCN_2$. The rate of transformation in organic soils is reported to be affected by moisture (Rotimi et al, 1971), and Vilsmeir and Amberger (1978) found that temperature has less effect on $CaCN_2$ than moisture.

Dicyanadiamide is one of the products of $CaCN_2$ in the soil and contains 42% N. Nommik (1958) observed that heavy application of $CaCN_2$ results in dicyanadiamide which is slowly available to the plant. It has been reported that both free cyanamide, which is formed during hydrolysis in the soil and dicyanadiamide are inhibitors of the microbial nitrification process (Rathsack, 1978).

Thiourea: $CSNH_2$, contains 36.8% N, inhibits biological nitrification and so may slow down losses of N caused by leaching or denitrification of NO_2^- or NO_3^-

(Hignett, 1971; Carter et al, 1967). They tested several sources of N as fertilizer in field experiment and, concluded that thourea was significantly better than other sources of N and had residual effects which the other N - sources did not show.

Other amides: Canterella and Tabatabai (1980) reported that acetamide, 2 - cyana acetamide and glycinamide can serve as N fertilizers with results similar to those obtained with urea and ammonium nitrate. Out of 25 amides tested, results showed that with the exception of cyanamide, dicyana - diamide, benzesulfonamide and sulfanilamide which resisted decomposition all other amides were readily hydrolyzed in soils during incubation. The average recovery of the amide - N as inorganic N range from 4% with dicyanadiamide to 100% with formamide (Frankenberger and Tabatabai, 1982). It was reported that the efficiency of formamide, acetamide, 2 - cyanoacetamide, glycinamide, oxamide and azodicarbonamide as N sources were similar to conventional fertilizers.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Sample Site

Samples were collected from Savanna zone of Nigeria, which extends from latitude 6^{o} 21' - 14^{o}N and from longitude 2^{o} 44' - 14^{o} 42' E. Samples were collected from 3 sites in the zone.

The sites are:

(i) Mokwa, which lie in the Southern Guinea Savanna. The sampling was done at the former Agric. Research Station farms of I.A.R. The soil at the site is classified as Paleustalts (Malgwi and Ibanga, 1982).

(ii) Samaru (Northern Guinea Savanna). Samples were collected from I.A.R. farm. The soil is classified as Haplustult (Valette and Ibanga, 1983).

(iii) Bakura lies in the Sudan Savanna. Sampling was at the School of Agric Farm. The soil is classified as Fluvaquent, (Odunze, 1987).

3.1.1 Sample Collection and Handling

The samples were collected in January 1986. Surface soils (0 - 20cm) were selected to give a range in chemical

and physical properties representing the major vegetation zones of the Savanna and were from fields that had not received N fertilizer at least the year proceeding sampling. At each site, about 1m by 1m area was dug up to a depth of 20cm. About 300kg of each soil samples were collected and put into clean polyethylene bags. They were taken to the laboratory, air - dried, crushed and sieved through 2mm screen and stored in polyethylene bags.

Subsamples of each soil were removed for chemical and physical analyses. The subsamples were stored in polyethylene bags and later crushed to pass through suitable sieves as required by each analysis while the remaining samples were kept for incubation and greenhouse experiments.

3.2 Physical and Chemical Analysis

Particle size distribution was obtained by the hydrometer method. Fifty grammes of each of the 2mm sieved soil samples were dispersed in 100ml of 5% Calgon solution which was made up to one litre using the method of Day (1965). The results were expressed as means of duplicate readings.

The pH values of the soils were determined by a glass electrode in water and 0.01m $CaCl_2$ (Soils: solution, 1:2). Organic carbon content of the soils was determined by the dichromate oxidation procedure as described by Walkley and Black (1934). The total N was determined using Bremner's method (1965). Plant available phosphorus was determined using modified Bray I method (Bray and Kurtz, 1945) in which the soil: solution ratio was 1:10. Cation Exchange Capacity was determined by ammonium saturation method (Chapman, 1965). Exchangleable acidity was determined by leaching the soil with 1N KCl and then titrating the leachate with 0.05N NaOH (Dewis and Freitals, 1970).

Organic Carbon and total N analysis were determined on samples ground to pass through 0.1mm sieve. All other analyses were carried out using 2mm soil samples. All the results were expressed as means of the duplicate values.

3.2.1 Soil inorganic N analysis

The inorganic N in the soils were extracted with 2N KCl solution (Bremner, 1965). Ten grams of the soil

sample was weighed into $30cm^3$ of 2N KCl in a $50cm^3$ centrifuging tube. The suspension was shaken for one hour on a to - and - fro - shaker and then centrifuged. The extract was analysed for inorganic N(NH_4^+, NO_2^- + NO_3^-) using Kjeldahl catalyst and micro-kjeldahl's distilation set (Black, 1965). The NH_4^+ - N in the aliquot was determined by distillation with Mgo and the NO_2^- + NO_3^- was determined with Mgo + Devarda's alloy separately. The distillate was collected in 2% Boric acid and titrated against $0.005NH_2SO_4$ to a purple endpoint using mixed indicator. The quantity of N present in the aliquot was calculated from the volume of acid used.

3.3 Laboratory Incubation Studies

The incubation study was conducted to determine the rate of transformation of various amides into inorganic form of N in the 3 savanna soils (Samaru, Mokwa and Bakura).

The amides used for the incubation and their properties are shown below.

Table 3.1 Properties of amides used in incubation Studies

Amides	Chemical formular	Molecular weight	% N
(i) Acetamide	CH_3CONH_2	59.1	24
(ii) Calcium cyanamide	$CaCN_2$	80.0	36
(iii) Dimethyl formamide	$HCON(CH_3)_2$	73.0	19
(iv) Phenyl acetamide	$C_6H_5CH_2CONH_2$	119.0	12
(v) N,N-Dimethyl acetamide	$CH_3CON(CH_3)_2$	87.0	16
(vi) Succinamide	$H_2NCOCH_2CH_2CONH_2$	116.0	24
(vii) Urea	H_2NCONH_2	60.1	47

The transformation of amide N was studied in field-moist soils incubated under aerobic conditions at 30°C for 8 weeks.

Seventy-two pots with lids of about 1 litre capacity were used for the incubation. Five hundred grams of each soil sample were weighed into 24 pots and treated with the amides (60 µgN/g soil). Each treatment had three replicates. A control treatment (without amide) was also included. All the amides (reagent-grade chemicals) were applied on an individual pot basis and mixed thoroughly with

the soil before potting. The insoluble amides (succinamide, phenyl acetamide and Calcium cyanamide) were furnished as fine powders whereas all other amides were added as solutions.

The pots containing the treated soil samples and the controls were incubated in controlled temperature cabinets maintained at 30°C. The moisture was maintained at field capacity of the soils. (Samaru 20%, Mokwa 18% and Bakura 22% by weight). Within each cabinet the experimental units were arranged in a randomized complete block design. The pots were opened for a minute once in every two days to ensure proper aeration and the moisture content was also maintained by adding water once a week. The recovery of inorganic N(as NH_4^+, $NO_2^- + NO_3^-$) mineralized at intervals of 1, 2, 3, 4 and 8 weeks of incubation was determined. The pH in water was also determined at these intervals. NH_4^+, $NO_2^- + NO_3^-$ was determined as stated in section 3.2.1

3.3.1 Soil pH

Ten grams of the (air-dry weight basis) moist soil was stirred with 20ml water and allowed to stand for 30 minutes with occasional stirring. The soils pH values were read off using glass electrode pH meter.

3.4 Greenhouse Experiment

A greenhouse experiment for the uptake of N from various amides by maize in the 3 soils was conducted. The amides used in the greenhouse are the following:

(i) Acetamide

(ii) Succinamide

(iii) Phenyl acetamide and

(iv) Urea.

One hundred and seventeen plastic pots were used as greenhouse pots. Each pot contained 2kg of air-dried soil. The soils of all the pots were treated uniformly with the following nutrients.

P	50 ppm	as	CaH_4PO_4
K	60 "	"	KCl
Mn	3.5 "	"	$MnSO_4$
Fe	4.0 "	"	$FeSO_4$
Cu	1.5 "	"	$CuSO_4$
B	0.5 "	"	H_3BO_3
Zn	4.0 "	"	ZnO
Mg	4.5 "	"	$MgSO_4$

For each of the soil sample, there were 3 rates of N application. Each treatment was replicated 3 times and

a control without N source was also included. The control treatment received all fertilizer except N.

The N rates were:

(i) 120 mgN/pot
(ii) 240 mgN/pot
(iii) 360 mgN/pot.

The nutrients were added to the soil in solution forms where they are soluble. The insoluble amides were added as in the incubation studies. The experimental layout was a randomized complete block design.

Four maize seeds were planted in each pot a day after application of the amides. The plants were thinned down to two plants per pot after germination.

The pots were watered daily with a volume of distilled water equal to that lost during the previous 24 hour period, as determined by weighing few selected pots. The moisture level of the soils was maintained approximately at field capacity to avoid leaching loss of N. The pots were rotated within the blocks once a week.

The plants were clipped from the soil surface after 6 weeks' of growth. The plant materials were packed in

paper envelopes and dried in the oven at 65°C for 3 days, weighed, ground to pass through a 40-mesh sieve and were analyzed for total N.

3.4.1 Plant Analysis

The ground plant samples were analysed for total N using micro-Kjedahl distillating set. A sample of 0.1gm was weighed into a Kjedahl flask with 15ml of conc H_2 SO_4 and Kjedahl Catalyst. The mixture was digested on a Technicon Block digestor for 2 hours. The digest was allowed to cool down and made up to 100ml with distilled water. A sample of 20ml was distilled with 20ml of 10N NaOH into 10ml. of 2% boric acid. The distillates were titrated against 0.05N H_2SO_4 and N quantity calculated from the titre values (Nelson and Sommer, 1973). N uptake was calculated by multiplying the % N in maize with the dry matter yield.

3.5 Field Experiment

This was designed to study the efficiency of various amides as N - supplying source to crops using maize as test crop.

The experimental field was at Samaru, I.A.R. farm. The area was not cropped the previous year. It was cleared of weeds, ploughed, harrowed and levelled with hoes. The size of the field was 19m x 15m and was divided into 20 plots, having 5 plots as a replicate. Each plot was 3m by 3m with 1m gap between plots. Each plot has 5 rows and was planted with maize. Two maize seeds per stand were planted at a distance of 70cm between rows and 25cm within rows. The plants were thinned down to one plant per stand after a week of germination.

Phosphorus and Potassium were broadcast as single supper phosphate and muriate of potash at the time of planting at the rates of 45kg P_2O_5/ha and 30kg K_2O/ha respectively. Micronutrients were not supplied as they have not been reported to be defficient in the area.

The source of N were Acetamide, Calcium cyanamides, Succinamide, Urea and control (no N - source). They were applied by broadcasting at the rate of 120KgN/ha in 2 splits except calcium cyanamide which was applied once at the time of planting. The layout was randomized

complete block design. The field was weeded 3 times before harvesting.

Twenty-seven plants were harvested at the middle of each plot. They were cut down from ground surface and their weights recorded. The weights of the grain and stover were determined separately and a subsample from each plot was taken to the laboratory for total N analysis. The N uptake was computed as in section 3.4.1.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The Chemical and Physical Properties of the Soils

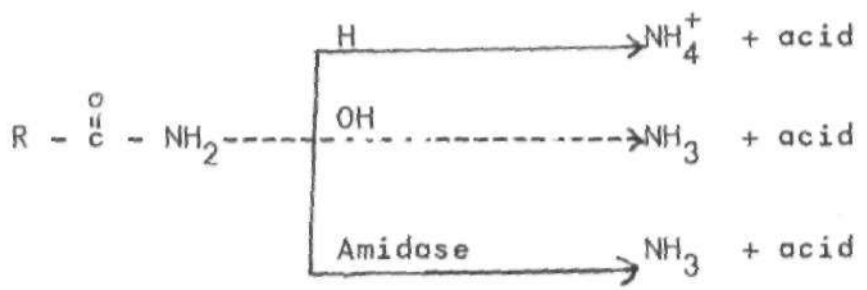
The chemical and physical properties of the three soils used are presented in Tables 4.1 and 4.2 The soils are moderately acidic. The pH (1:2; soil: water) of the soils varied from 5.2 in Samaru soil to 6.1 in Mokwa soil. The pH in water was consistently higher than the corresponding pH in 0.01 M $CaCl_2$ solution. This indicates that the soils have net negative charges and hence anions like NO_3^- will not be absorbed on their exchange sites (Van Raiji and Peech, 1972).

The soils have low total N and organic carbon (0.5% to 1.05% O.C) content. The variation is probably as a result of difference in precipitation between the savanna zones (Jones and Wild, 1975). The C.E.C. of the soils are low too (1.09 to 2.6 Me/100g). This may be due to the dominances of Kaolinite and iron and aluminum oxyhydroxide in the clay fraction. The soils texture vary from loamy sand to loam (Table 2). While the clay content vary from 4% in Mokwa to 20% in Bakura soils.

4.1.1 Properties of the Amides

The chemical formular, molecular weight, and percentage N of each of the amides used in the study are given in the materials and methods (Table 3.1). The percentage N content of the amides ranged from 16% in N, N-Dimethyl acetamide to 47% in urea. Phenyl acetamide is the only aromatic amide while others are aliphatic compounds.

Urea was used as standard for comparison because it is widely used as N source, and the chemical structure is similar to those of amides. Amides are organic compounds derived from ammonia (NH_3) by substitution of one or more of its hydrogen atom by organic acid radicals. Amides are characterised by an acyl group ($-CONH_2$) usually having a basic unit of a carbonyl and an amine group. Amides can be hydrolyzed in the soil through amidase activity or with either acid or basic catalysis, the products being respectively the free acid and ammonium ion (NH_4^+).



Amide hydrolysis in soil.

4.2 Soil Incubation

The transformation of various amides to NH_4^+ and NO_3^- was studied at 30°C and field capacity moisture content. This temperature was selected because it is close to the mean temperature at shallow depths in the tropics during most cropping season (Sandhu, 1974) and it is optimum for nitrification of NH_4 - N (Alexander, 1965).

4.2.1 Inorganic N Recovery

Figures 1, 2 and 3 show the rate of mineralization of various amides in Samaru, Mokwa and Bakura soils respectively. The values in the figures represent the difference in the observed and the control. Out of the 60 µgN/g of soil applied from the amides, amount recovered at the end of 8 weeks of incubation (average of all amides) varied from soil and was highest in the Bakura soil. Recoveries in the other two soils were similar. The range of total recoveries (NO_3^- + NH_4^+) at the end of incubation were 39% ($CaCN_2$) to 88% (Succinamide) in Samaru soil, 35% (Dimethyl formamide) to 86% (Succinamide) in Mokwa soil and 45% (Dimethyl formamide) to 93% (urea) in Bakura soil. Theoretically, 100% N from amides are recoverable, but lesser amounts recovered may be due to loss through volatilization, immobilisation or N not mineralized.

4.2.2 Rate of Amides Transformation

The rate of transformation of the amides in general followed the same pattern in the three soils.

Table 4.1 Chemical properties of the soils

Soils	Soil pH		Organic Carbon	Total N %	Plant available P(PPM	Exchangeable Bases Meq/100g				C E C Meq/ 100g	Exch. acidity Meq/100g	Effect C E C Meq/100g
	$CaCl_2$	H_2O				Ca	Mg	K	Na			
Samaru	4.4	5.2	1.05	0.08	3.5	2.01	0.31	0.24	0.13	2.0	0.25	2.94
Mokwa	5.1	6.1	0.54	0.03	9.8	1.0	0.18	0.14	0.06	1.09	0.05	1.45
Bakura	4.8	5.7	0.50	0.04	1.75	2.5	0.51	0.26	0.25	2.6	0.10	3.62

Method of determination

(i) Plant available P - Modified Bray I Method

(ii) C E C - ammonium saturation method

(iii) Effective E C E C - The sum of exchangeable bases and exchangeable acidity.

Table 4.2 Soils Physical properties

Soils	% Clay	% Silt	% Sand	Field capacity (M.C. %)
Samaru	10	50.4	39.60	20
Mokwa	4	13.40	82.56	18
Bakura	20	32.0	48.0	22

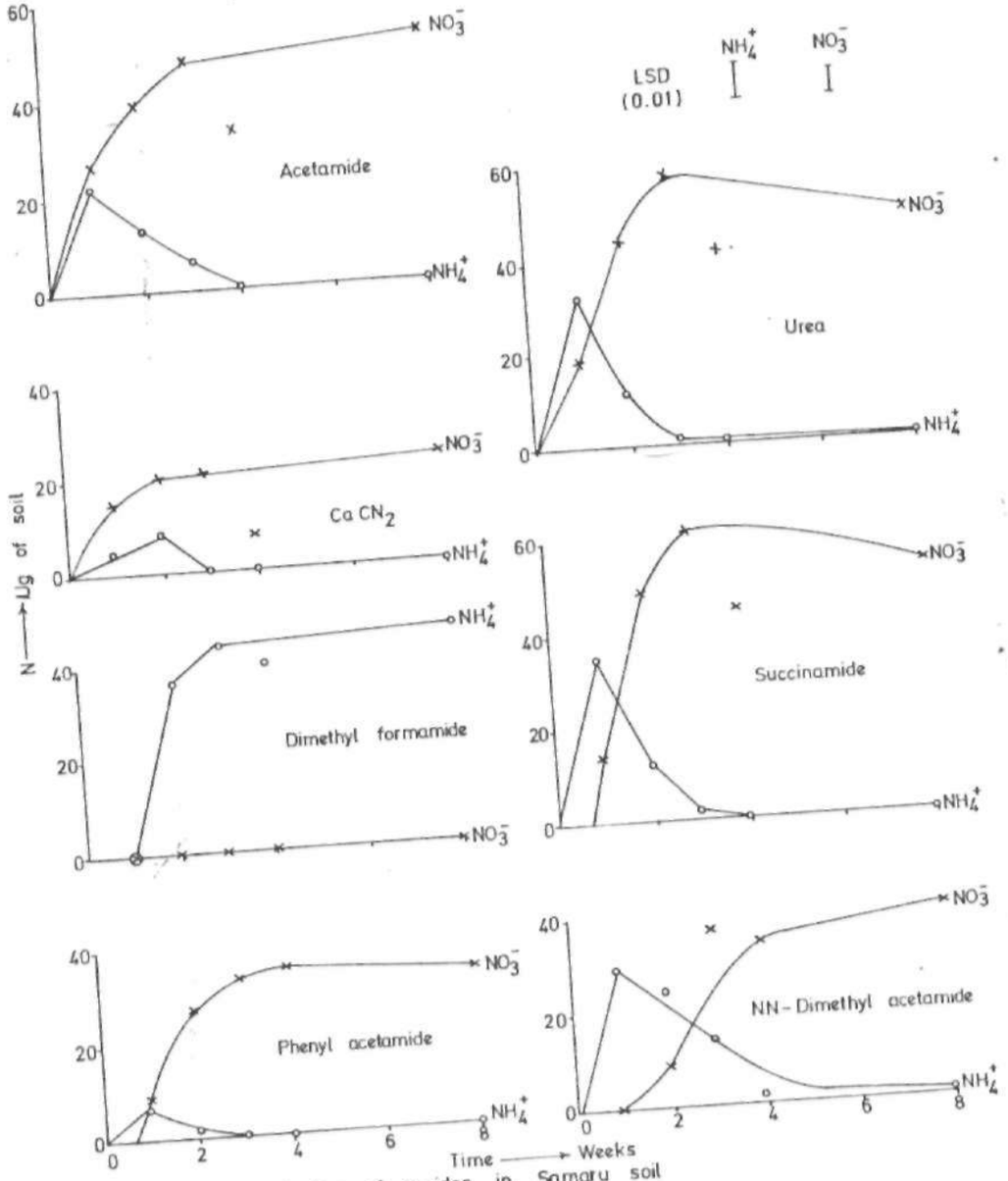


Fig.1 Mineralization of amides in Samaru soil

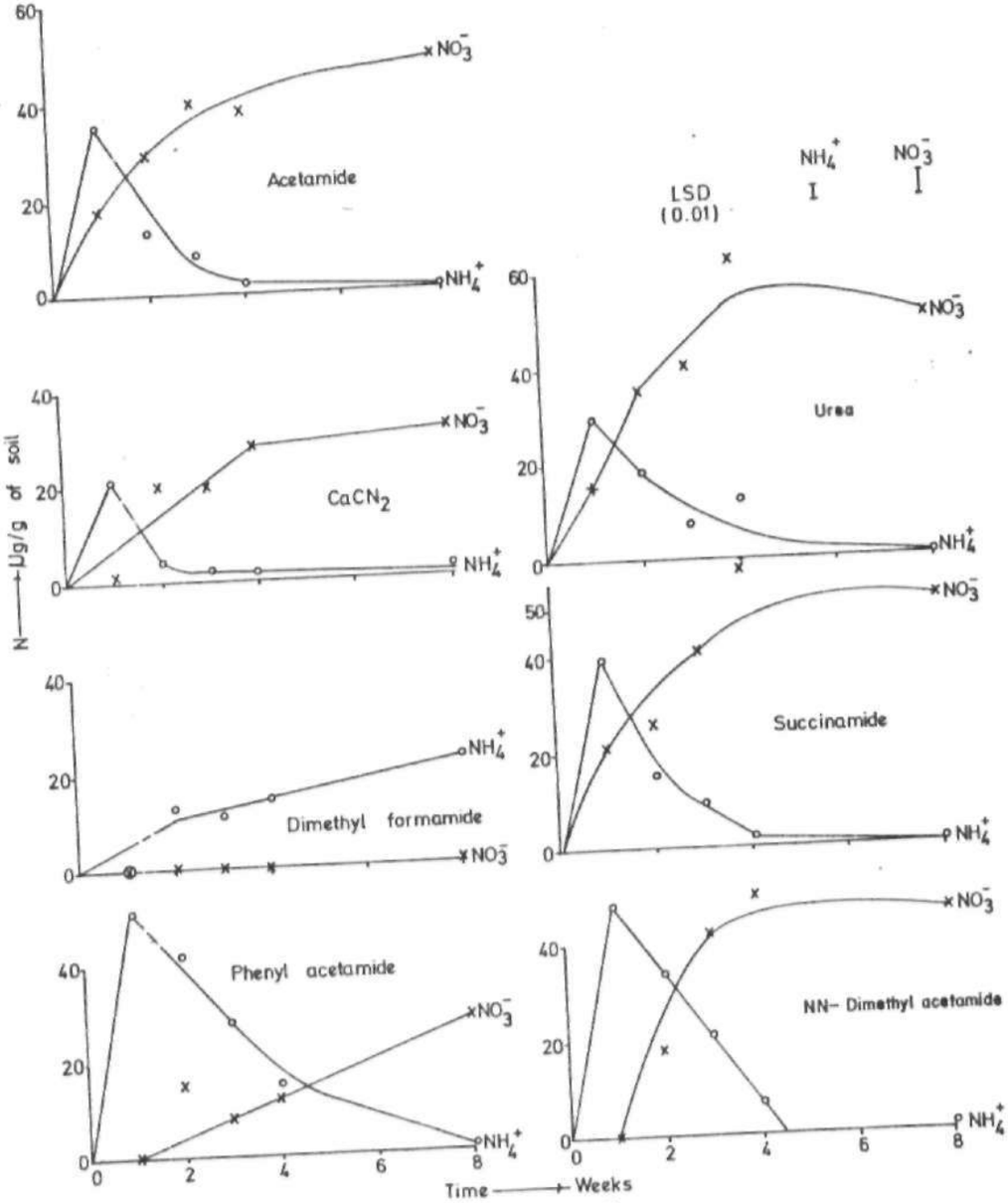


Fig. 2 Mineralization of amides in Mokwa soil

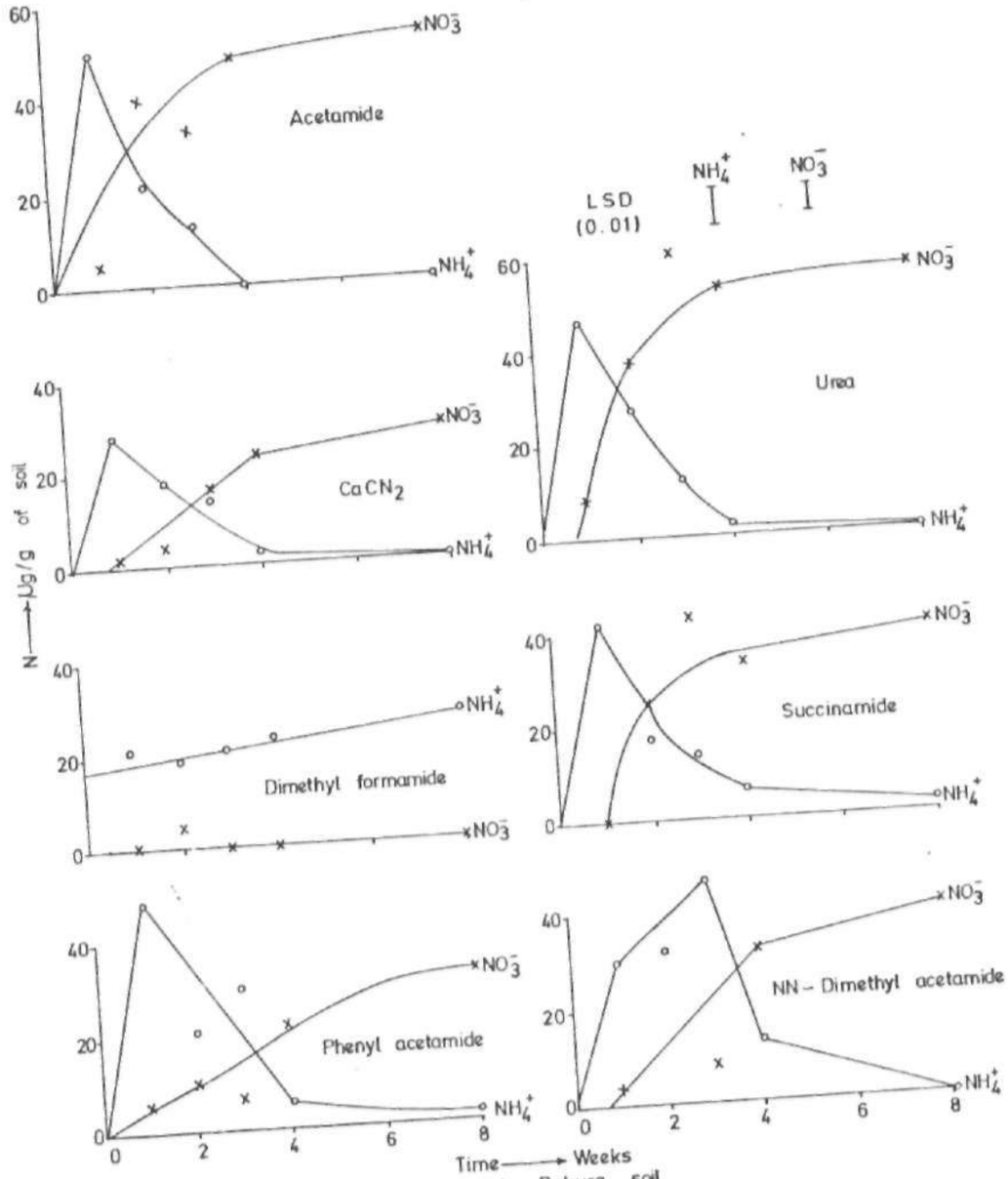


Fig. 3 Mineralization of amides in Bakura soil

Ammonification of amides in Samaru Soil: Amide including urea added to the soil started ammonifying with the first week of incubation (Figure 1). Dimethyl formamide was an exception the ammonification of which was delayed to second week of incubation and has a different trend from the other amides. The rate of mineralization of amides was similar to that of urea throughout the 8 weeks incubation period. In all the amides, NH_4^+ recovered was highest in the first week of incubation and decreased gradually as incubation progressed. The decrease in NH_4^+ might be due to nitrification of accumulated NH_4^+. NH_4^+ recovered from the amides after one week incubation was in the order;

Succinamide > urea > N, N Dimethyl acetamide > acetamide > Phenyl acetamide > $CaCN_2$ > Dimethyl formamide.

At the end of third week of incubation, the amount of NH_4^+ from $CaCN_2$ and Phenyl acetamide were zero while the NH_4^+ in other amides were higher than urea. At the end of incubation except for N, N Dimethyl acetamide, NH_4^+ was zero for other amides including urea.

Dimethyl formamide has slower rate of transformation compared to urea and other amides. There was increase in mineralization as incubation progressed. As from the second week of incubation NH_4^+ accumulation was higher than others.

Nitrification in Samaru Soil: Nitrification of accumulated NH_4^+ from most of the amides in Samaru soil started within the first week of incubation (Figure 1). All the amides had different rate of nitrification but dimethyl formamide did not nitrify at all. The amides nitrified in the pattern of urea. As the incubation period increased, the amount of NO_3^- also increased. In the first week, the amount of NO_3^- recovered from acetamide (45%) was more than that of urea (31%). The recoveries from other amides were lower than from urea. The amounts of NO_3^- at the end of first week for other amides ranged from 0% of dimethyl formamide and N, N dimethyl acetamide to 25% of $CaCN_2$. As from the second, NO_3^- recovery in succinamide was higher but other amides were lower than urea. However NO_3^- recovery at the end of 8 week incubation from acetamide (87%) and succinamide (88%) were higher than urea (80%).

Ammonification in Mokwa Soils: Ammonification of the amides in Mokwa soil was similar to that in Samaru soil (Figure 2) but rate of ammonification was slower. In the first week, NH_4^+ recovered from acetamide, phenyl acetamide and N, N dimethyl acetamide was higher than in urea. NH_4^+ accumulation at the end of the first week was in the order; phenyl acetamide > N, N dimethyl acetamide > acetamide > urea > succinamide > $CaCN_2$ > dimethyl formamide. At the end of 8 weeks of incubation there was no NH_4^+ left in acetamide, succinamide and urea.

Nitrification in Mokwa Soil: Accumulated NH_4^+ of most of the amide started nitrifying within the first week (Figure 2). Phenyl acetamide and N, N dimethyl acetamide started within the second week while dimethyl formamide did not nitrify at all. The rate of nitrification for all the amides was lower than for urea upto the 4th week. However, nitrate recovered from succinamide in the 4th week and afterwards was similar to urea. At the end of the 8th week incubation NO_3^- accumulation was in the range 47% (Phenyl acetamide) to 86% succinamide.

Ammonification of amide in Bakura soil: The order of ammonification of the amides in Bakura soil is shown in Figure 3. Mineralization was rapid and NH_4^+ accumulation was more in acetamide. At the end of first week, the order of ammonification was acetamide > Phenyl acetamide > urea > succinamide > N, N dimethyl acetamide > $CaCN_2$ > Dimethyl formamide. The rate of disappearance of the accumulated NH_4^+ was higher for urea. NH_4^+ concentration from dimethyl formamide increased with incubation time whereas in others it decreased.

Nitrification in Bakura soil: The rate of nitrification of accumulated NH_4^+ was slowest in comparison to Mokwa and Samaru soil (Figure 3). Nitrification started generally in the second week of incubation and the amount

of nitrate was higher in acetamide (66%) than urea (62%). The amounts of NO_3^- were lower than in urea in other amides. In the following weeks, the amounts of NO_3^- were higher in urea than other amides. At the end of incubation (8 weeks) NO_3^- accumulation was in the order. Urea > acetamide > succinamide > N, N dimethyl acetamide > Phenyl acetamide > $CaCN_2$. As in other soils dimethyl formamide did not nitrify.

4.2.3 Mineralization in the Control Soils

Ammonification in the three soils was similar. At the end of the first week of incubation, NH_4^+ was 14.0µgN in Samaru and Mokwa soils, and 18.7 µgN in Bakura soil. The nitrification of untreated Samaru soil was higher than that of Mokwa and Bakura soils. Nitrate recovered at the end of incubation was highest in Samaru soil (44.3 µgN) than in Mokwa soil (16.3 µgN) and Bakura soil (14 µgN). The higher recovery of N observed in Samaru soil maybe due to the higher amount of organic matter and total N content. Mokwa soil is sandier and has low organic matter, hence the low nitrification rate while Bakura soil has a finer texture but has low organic matter.

4.2.4 Structural relationship of the amides to N recovery:

The rate of amide decomposition seem to be related to its molecular configuration. Bray et al (1950) found that the rate of hydrolysis of an amide was related to

the number of carbon atoms in the amide molecule. Frankenberger and Tabatabai (1982) reported that as the chain length of carbon atoms increased, the total recovery of amide N as inorganic N decreased. However, there was no relationship between the amide's molecular weight and the rate of hydrolysis.

From the analysis of the total inorganic N recovered at the end of incubation, it is clear that similar molecules gave similar N recovery. Where there was a marked difference between related molecules, it could be accounted for by the nature of their hydrolysis. Similar N recoveries (averaged over the three soils) were obtained from succinamide (81.3%) and urea (82.2%). They are both diamide aliphatic compounds, (Table 4.3) hence they should undergo similar type of reaction. They had higher N recovery than the mono-amides. The recoveries of the mono-amides are acetamide 80.37%, N, N dimethyl acetamide 70.25%, phenyl acetamide 53.56% and dimethyl formamide 51.76%. $CaCN_2$ (46.94%) is also a diamide compound but has a lower recovery of N compared to urea. This could be attributed to the several steps in the process of hydrolysis. It first get converted to urea then NH_3^-. It can be deduced that the hydrolysis of $CaCN_2$ to urea is the rate limiting step as urea hydrolysed readily in the soil. The rate limiting step determines the rate of reaction hence the recovery from $CaCN_2$ was lower than urea.

Table 4.3

Molecular Structure of the Amides

Urea $H_2N - \overset{O}{\overset{\|}{C}} - NH_2$

Succinamide $H_2N - \overset{O}{\overset{\|}{C}} - CH_2 - CH_2 - \overset{O}{\overset{\|}{C}} - NH_2$

$CaCN_2$ $Ca = N - C \equiv N$

Acetamide $CH_3 - \overset{O}{\overset{\|}{C}} - NH_2$

Phenyl acetamide  $- \overset{O}{\overset{\|}{C}} - NH_2$

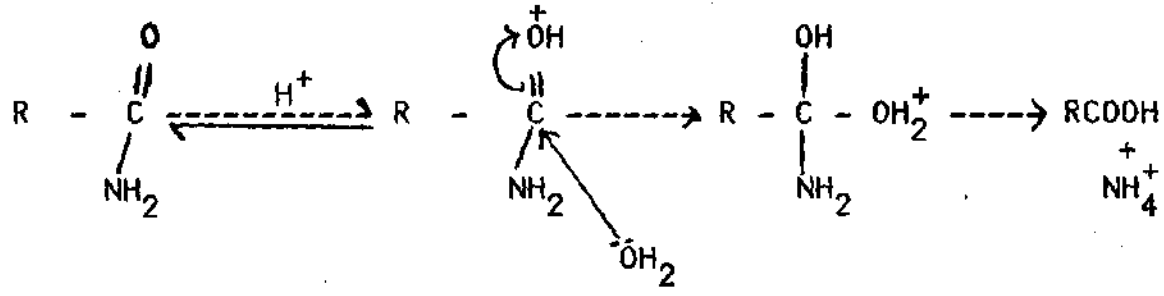
N, N-dimethyl acetamide $CH_3 - \overset{O}{\overset{\|}{C}} - N(CH_3)(CH_3)$

Dimethyl formamide $H - \overset{O}{\overset{\|}{C}} - N(CH_3)(CH_3)$

Acetamide has N recovery comparable to urea but acetamide derivatives (phenyl acetamide and N, N dimethyl acetamide) had lower recovery. The difference could be attributed to the different radicals attached to the amide group ($CONH_2$). Alkyl group decrease the rate of hydrolysis. The decrease is caused by its inductive effect (+ I) which depends on the number of alkyl substitents either

on C or N. The alkyl group is electron donating (electronic factor), making the carbonyl carbon less susceptible to nucleophilic attack. Alkaline medium provides OH^- ion, which acts as a strongly necleophilic reagent and acid solutions provide H^+ ion which attaches itself to carbonyl oxygen and thus render the malecula vulnerable to attack by the weakly necleophilic reagent water. Water alone is not sufficient to hydrolyze most amides since NH_2 is a poor leaving group (Solomons, 1976). These conditions are met in the soil for amide hydrolysis.

Acidic hydrolysis.



In acetamide molecule, there is only one CH_3 attached to the carbonyl carbon compared to N, N-dimethyl acetamide where there are two more CH_3 attached to N and in phenyl acetamide, there is a benzyl group () group instead of the CH_3. Considering the electronic factor and resonance, phenyl acetamide should be more reactive. Since this was not so, another possible explanation could be the steric factor. Because the benzyl group is bulkier than methyl group, the shielding of the reactive centre will be

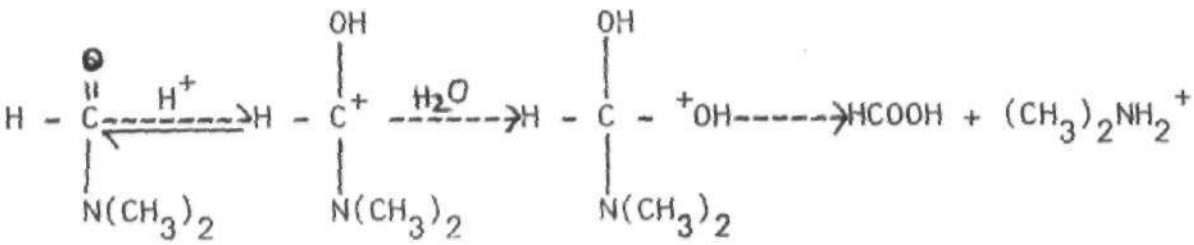
hither in phenyl acetamide and this accounts for the lower N recovery.

There is inductive effect on N, N dimethyl acetamide, in addition to steric hinderance caused by overcrowding of the molecule. In a reaction, the two factors can hinder a reaction simultaneously or either can take precedence in controlling the rate of reaction. However, all these factors contributed to the lower rate of reaction and lower recovery of inorganic N.

The difference in the N recovered from N, N dimethyl acetamide and dimethyl formamide can be explained in terms of the inductive effect and degree of steric hinderance in each molecule. The difference in the two molecular structures is the extra CH_3 in N, N-dimethyl acetamide instead of H in dimethyl formamide. Considering the two factors, dimethyl formamide is expected to be more reactive than N, N-dimethyl acetamide leading to a higher N recovery. But the results of present experiment suggest otherwise. The lower recovery of N from dimethyl formamide may be explained as follows:-

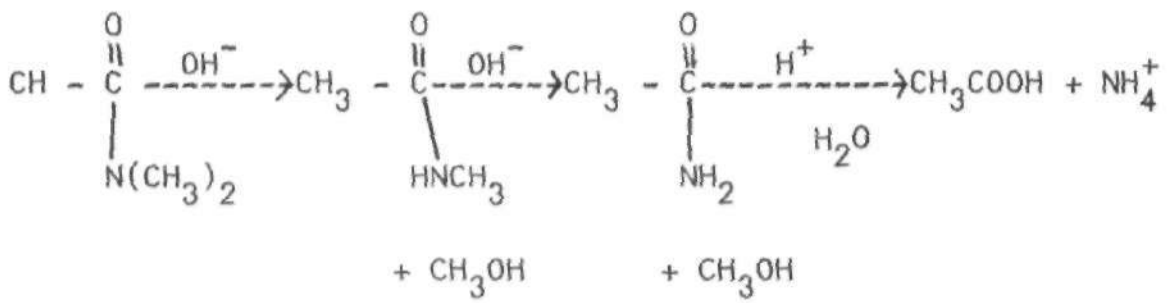
N, N - disubstituted amides undergo normal amide hydrolysis to yield secondary amines (HNR_2). In dimethyl formamide it is assumed that normal amide hydrolysis yielded dimethyl amine ($HN(CH_3)_2$) instead of NH_3. The reaction

may not have gone to completion unlike the unsubstituted amides, because of the inductive effect and steric hinderance.



It is probable that the amine in this case is not liable to nitrification hence NO_3^- was not recovered. Moreover being a gas it can also be lost from the system. So the recovery is low and all of it was in NH_4^+ form.

N, N dimethyl acetamide may have undergone an indirect route of hydrolysis since it is not readily hydrolyzable ordinarily (March, 1967) as shown below).



(N, N disubstituted) amide , (unsubstituted amide

The unsubstituted amide can then undergo the normal amide hydrolysis yielding NH_3 followed by nitrification. The fact that the above reaction took place was supported by the better recovery in Mokwa soil which was less acidic. This is because the soil solution furnished more OH^- ions for the reaction to proceed. The better recovery here may be due to the ease with which the reaction proceeded after the formation of the unsubstituted amide.

In general, most of the amides studied accumulated as NO_3^- at the end of incubation. Acetamide and succinamide nitrified rapidly in the soils in the order of urea while phenyl acetamide, N, N dimethyl acetamide and dimethyl formamide were not readily hydrolyzed. $CaCN_2$ had the lowest recovery of about 47% and rapid nitrification. Frankenberger and Tabatabai (1982) reported 10% recovery from cyanamide which is the first product of $CaCN_2$ hydrolysis. However, higher recovery between 60 and 100% N from $CaCN_2$ (Pleysier et al, 1982 ; Vilsmeier and Amberger, 1978) and delayed nitrification has been reported. (Arora et al, 1987).

Considering the fact that the recovery of N varied with soils, it may be advisable to test the efficiency of amide with a particular soil before usage. And since some amides had low rate of nitrification, they may be useful in area where leaching loss is high. Those which accumulated as NH_4^+ can be used with crops that utilize this form of N.

4.3 Residual effect of amides on soil pH

There was change in pH of the treated soils during incubation (Table 4.4). The soil pH could be related to mineralization. In all the three soils, there was a positive correlation between NH_4^+ and soil pH while NO_3^- and soil pH showed negative correlation i.e. as the amount of NO_3^- increased, the pH value decreased.

In all the soils, the pH value increased above the control in the first week of incubation. This period conformed with that of ammonification. There was a gradual increase in pH of soils treated with dimethyl formamide throughout the incubation period. This may be due to the gradual increase in amount of NH_4^+. $CaCN_2$ and urea increased the pH most at the end of first week of incubation. The pH started decreasing generally at end of second week probably due to nitrification. There was an exception to this general trend in Mokwa soil, where phenyl acetanide and N, N dimethyl acetamide increased the pH till the end of second week. The nitrification of these sources was delayed and the accumulation of NH_4^+ raised the pH. Moreover Mokwa soil is sandy in nature and has poor buffering capacity.

Table 4.4 pH of soils (soil : water, 1:2) at different incubation intervals of the three Soils

(a) Samaru

Treatments	Zerotime	Week 1	Week 2	Week 3	Week 4	Week 8
Acetamide	5.9	4.9	4.5	4.2	4.2	4.2
$CaCN_2$	6.1	5.3	4.8	4.8	4.6	4.6
D-formamide	5.6	5.9	5.7	5.8	5.8	6.0
P-acetamide	5.6	5.1	4.5	4.4	4.3	4.4
N, N-D-Acetamide	5.6	5.3	5.0	4.4	4.3	4.2
Succinamide	5.7	5.1	4.4	4.3	4.2	4.3
Urea	6.3	5.1	4.4	4.2	4.1	4.2
Control	5.5	5.0	4.8	4.7	4.6	4.6
L.S.D.			0.12			

(b) Mokwa

Acetamide	6.1	6.1	5.1	4.8	4.5	4.6
$CaCN_2$	6.6	6.6	5.6	5.6	5.4	5.5
D-formamide	6.0	6.2	6.6	6.5	6.4	6.7
P-acetamide	6.1	7.7	7.6	6.9	6.2	4.9
N,N-D-acetamide	6.0	7.0	5.9	4.9	4.4	4.5
Succinamide	6.1	5.8	5.1	4.8	4.5	4.5
Urea	6.7	5.9	5.1	4.9	5.6	5.5
Control	6.2	5.8	5.6	5.8	5.6	5.5
L.S.D.			0.15			

(c) Bakura

Treatment	Zerotime	Week 1	Week 2	Week 3	Week 4	Week 8
Acetamide	6.6	6.1	4.8	4.7	4.4	4.4
$CaCN_2$	7.4	6.2	5.6	5.1	5.0	4.9
Dimethyl formamide	6.8	5.8	5.6	5.9	5.8	6.1
Phenyl acetamide	6.5	6.3	5.5	5.1	4.8	4.8
N,N-Dimethyl acetamide	6.5	5.5	5.7	5.8	4.6	4.6
Succinamide	6.6	6.0	4.8	4.8	4.8	4.7
Urea	7.5	6.0	4.9	4.8	4.5	4.7
Control	5.7	5.7	5.7	5.6	5.5	5.3
L.S.D.			0.10			

The process of nitrification generates H^+ which is the cause of low pH accompanied with it.

$$NH_4^+ + 2O_2 \longrightarrow NO_3^- + H_2O + 2H^+$$

From the equation, for every mole of nitrate generated, there are two corresponding H^+ ions.

At end of incubation, all the amides decreased the soils pH to around 4.5 on the average with the exception of dimethyl formamide. In general difference between control and treated soils was significant. Acetamide, N,N-dimethyl acetamide, succinamide and urea significantly reduced the soil pH below control while other amides increased soil pH significantly. Acetamide and succinamide were statistically the same as urea in decreasing soil pH while other treated soils had significantly higher pH than urea at the end of incubation. It was observed that amides with high rate of nitrification lowered soil pH as much as urea did. The acidification varied with the soils. Bakura soil with lower rate of nitrification was less acidified.

The average decrease in pH value during incubation with various amides in Samaru soil was 0.9, Mokwa soil 0.7 and Bakura soil 0.4. Hence Samaru soil was the most acidified by the amides followed by Mokwa and Bakura soils in that order. The decrease in soil pH due to the addition of N sources has been reported by many workers (Jones, 1976; Bache and Heathcote, 1969).

4.4 Greenhouse Study

The amides used for greenhouse experiments were acetamide, succinamide, phenyl acetamide and urea as standard for comparison. A control treatment ie no N-source was also included. These amides were selected on the basis

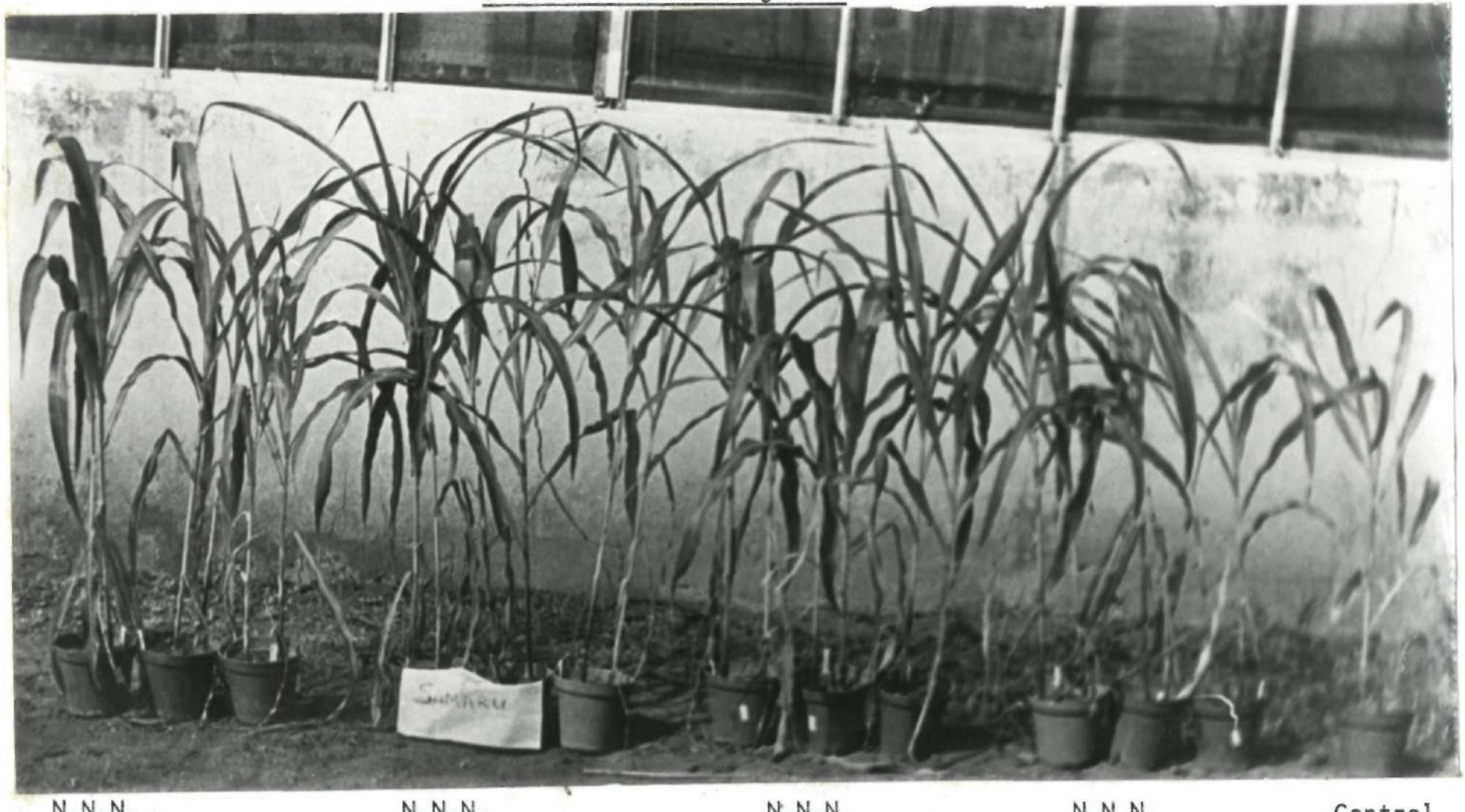
of inorganic N recovery in the incubation experiment. Acetamide and succinamide had very high recovery and rapid hydrolysis in all the soils comparable to urea, while phenyl acetamide has low recovery. This was included to find out if there was difference in their recovery in the incubation and by plant.

There were three rates of N application, which were 60kgN/ha (N_1), 120kgN/ha (N_2) and 180kgN/ha (N_3). The recommended rate of N application for maize in savanna region is 120kgN/ha. For each treatment and rate, a representative of the plants at 6 weeks growth in Samaru, Mokwa and Bakura soils is shown in plates I, II and III respectively. It was observed that all the control pots had thinner, and shorter plants with more yellowish leaves than other plants.

4.4.1 Dry Matter Yield

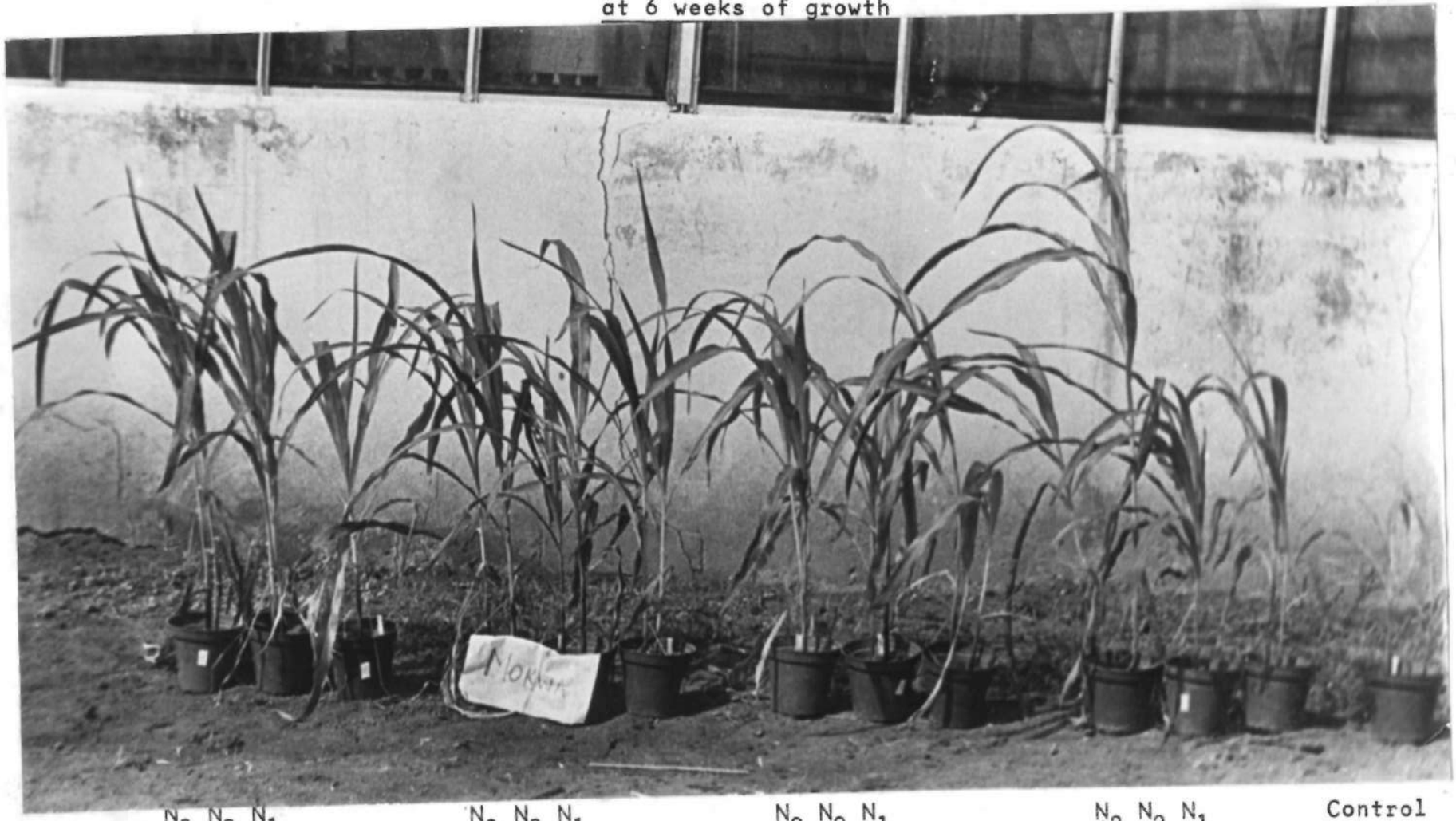
The dry matter yields (DMY) of maize (Zea Mays L.) plants grown at each application rate of all N-sources on Samaru, Mokwa and Bakura soils are shown in figures 4.4a, b &C respectively. The plants responded to the N application but the response to various amide was different. However, the response of the crop to the N-sources followed the same pattern in the three soils.

Plate i. Representative of Maize Plants in the greenhouse for each treatment and N rate at 6 weeks of growth



$N_3N_2N_1$	$N_3N_2N_1$	$N_3N_2N_1$	$N_3N_2N_1$	Control
Succinamide	Urea	Acetamide	Phenyl acetamide	

Plate ii. Representative of Maize Plants in the greenhouse for each treatment and N rate at 6 weeks of growth



N_3 N_2 N_1 Succinamide | N_3 N_2 N_1 Urea | N_3 N_2 N_1 Acetamide | N_3 N_2 N_1 Phenyl acetamide | Control

Plate iii. Representative of Maize Plants in the greenhouse for each treatment and N rate at 6 weeks of growth



N_3 N_2 N_1 Succinamide | N_3 N_2 N_1 Urea | N_3 N_2 N_1 Acetamide | N_3 N_2 N_1 Phenyl Acetamide | Control

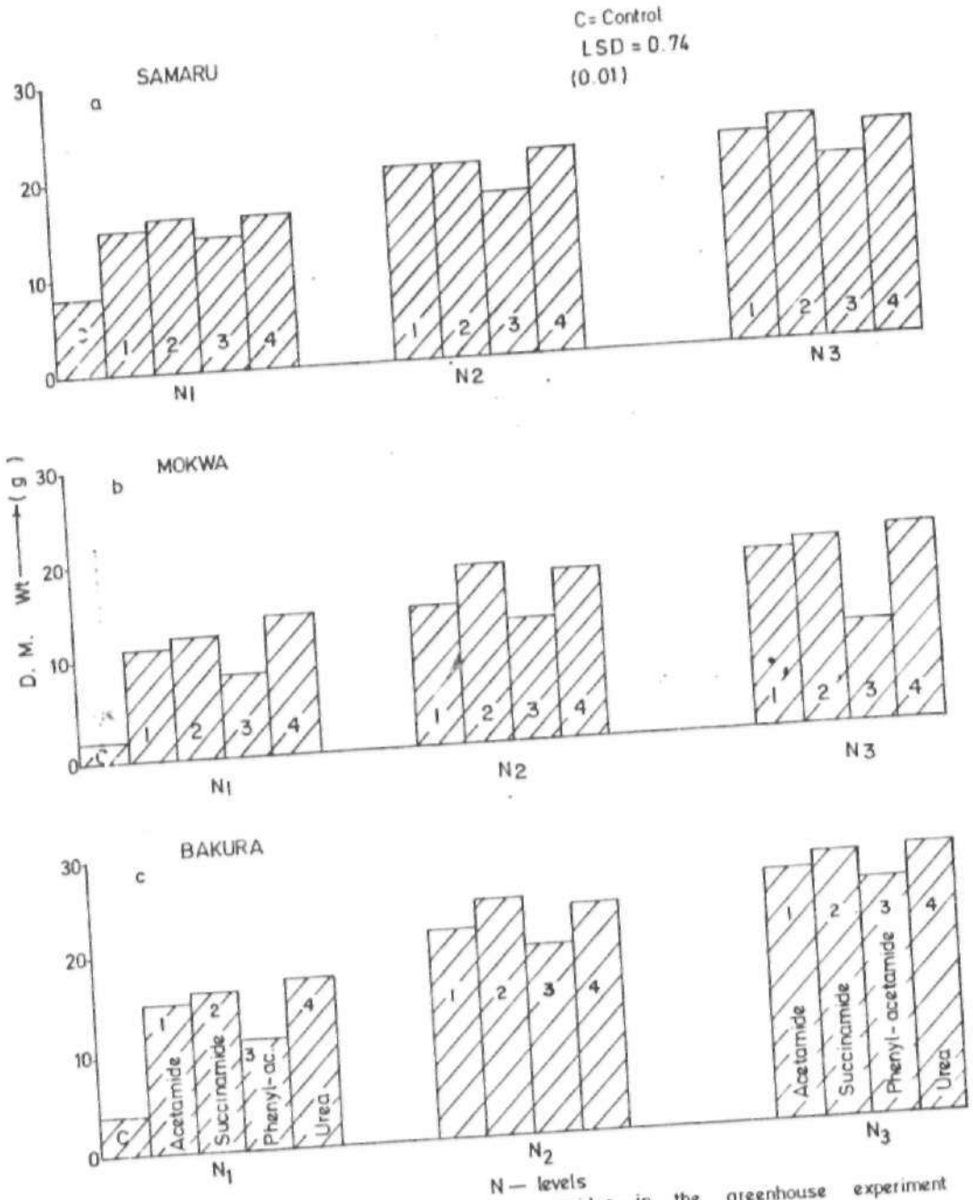


Fig 4. The response of maize to various amides in the greenhouse experiment

1 = Acetamide
2 = Succinamide
3 = Phenyl acetamide
4 = Urea

Samaru Soil: Phenyl acetamide produced significantly lower DMY than other amides which produced DMY that were not significantly different among themselves. This concurred with the low recovery of N in the incubation experiment, where N recovered from the three sources (acetamide, succinamide and urea) were similar but the DMY tended to be low relatively with acetamide.

At N_1 rate, urea gave the highest yield followed by succinamide, acetamide and phenyl acetamide in that order. With increase in N level to N_2 there was significant increase in yield but further increase to N_3 (180kgN/ha) gave a much less increase in DMY. At the highest level of N application the yield from acetamide, succinamide and urea were similar. Yield was highest at N_3 level generally. It was observed that the thickness of all plants and their heights increased with rate of N application. Plants grown on phenyl acetamide treated soil lacked the initial take off.

Mokwa Soil: The response was similar to that obtained with the Samaru soil. Phenyl acetamide performed poorly compared to other amides. The yield from Mokwa soil was generally lower than in other soils. This may be associated with the lower levels of total N and organic matter in the soil. From the incubation study, higher pH were observed from the treated soil, up to pH 7,7 in some cases. The soil high pH could encourage volatilization of NH_3

as well. Frankenberger and Tabatabai (1982) reported that significant amount of NH_3 were volatilized on from such soils.

Bakura Soil: The DMY was better than the yield in Samaru and Mokwa soils but the response to amides was similar to those in the two soils. The performance of phenyl acetamide was better here and the yield compared favourably with that of other amides. It is interesting to note that the recovery of inorganic N from various amides in the incubation experiement was also highest in Bakura soil. Acidification of the soil by the amides was also low compared to the other two soils.

4.4.2 Plant Nitrogen Uptake

Nitrogen uptake from various amides by maize plants in the three soils is shown in Table 4.5. The average N uptake was highest in Bakura soil and least in Mokwa soil, while Samaru soil was in between. The N uptake in each soil, from various amides followed the same pattern as that of DMY. But the % N in the plant material in general was higher amount of total N present in Samaru soil. There was an increase in N uptake with increasing N application but each increment resulted in lower increase in N uptake.

Table 4.5 N Uptake (mgN) by the dry matter in the greenhouse experiment

Treatment	N-rate	Samaru	Mokwa	Bakura
1. Control		73.99	18.29	26.04
2. Acetamide	N_1	104.63	105.36	93.57
3. "	N_2	210.35	143.99	179.75
4. "	N_3	285.03	194.79	396.10
5. Succinamide	N_1	120.81	98.53	110.70
6. "	N_2	225.41	154.09	251.37
7. "	N_3	298.95	207.29	350.28
8. P-acetamide	N_1	93.96	56.51	123.27
9. "	N_2	167.79	97.55	198.39
10. "	N_3	163.79	101.27	222.18
11. Urea	N_1	117.19	97.21	107.86
12. "	N_2	224.77	134.08	217.88
13. "	N_3	278.35	189.72	302.88
L.S.D.		16.15		

N_1 = 60 KgN/ha

N_2 = 120 KgN/ha

N_3 = 180 KgN/ha

Generally, N uptake from acetamide and succinamide were not significantly different from that of urea. The uptake from phenyl acetamide was significantly lower than other N sources. The results conformed with the incubation study, where phenyl acetamide gave lower recovery of N. There is a positive correlation between DMY and N uptake. The relationship between the total DMY and the N uptake has always been reported to correlate positively (Cantarrella and Tabatabai, 1983; Steggerda, 1962; DeMent et al, 1961).

4.4.3 Apparent Nitrogen recovery

The percentage recovery of the N from various amides by maize plant (Table 4.6) was determined by the difference method; calculated by the equation, (A-B)/C x 100, where A is N mg taken up by the plants from control pots, and C is N (mg) applied.

With the exception of phenyl acetamide that performed poorly in Mokwa soil, the recoveries ranged from 52 to 103%. The recoveries were similar to those of other readily available N sources, (Gasser and Jephcott, 1964; Terman et al, 1986).

The total amount of the applied N recovered by the plant averaged over the three rates, form all N sources

Table 4.6 % N Recovered by the Plants from the various Amides at different rates of N application in the greenhouse.

Treatment	N-rate	Samaru	Mokwa	Bakura
1. Acetamide	N_1	87.2	87.8	77.98
2. "	N_2	87.7	59.99	74.9
3. "	N_3	79.2	54.11	100
4. Succinamide	N_1	100.0	82.11	92.25
5. "	N_2	93.92	64.2	103.7
6. "	N_3	83.04	57.58	97.3
7. P-acetamide	N_1	78.3	47.09	102.73
8. "	N_2	69.9	40.65	82.66
9. "	N_3	45.49	28.13	61.72
10. Urea	N_1	97.66	81.01	89.88
11. "	N_2	93.65	55.87	90.66
12. "	N_3	77.32	52.7	84.13

N_1 = 60 KgN/ha

N_2 = 120 KgN/ha

N_3 = 180 KgN/ha

was 82.78% for Mokwa and 89.08% for Bakura. For all treatments, the highest recovery was obtained from the lowest rate and least from the highest rate ie the efficiency of N decreased with increase in N application rated.

The recovery from succinamide was more than from urea in the three soils. Urea was better than other amides in Samaru and Bakura soils while acetamide was better than urea in Mokwa soil. Generally, the efficiency of amides as N sources to maize was best in Bakura soil.

4.5 Field Experiment

The amides used in the field were succinamide, acetamide, urea and $CaCN_2$. They were all applied at one rate (120KgN/ha). Phenyl acetamide was not included in the field study because both incubation and greenhouse studies gave low N recovery from this source in Samaru soil.

4.5.1 Dry Matter Yield (DMY)

The grain yield, stover yield and nitrogen uptake by maize plant are shown in Table 4.7. All treatments gave higher yield of grain and stover than control. Succinamide gave the highest grain yield followed by urea,

Table 4.7 Effect of application of different amides in soil on the yield N content, N uptake, and N recovery in a field trial at Samaru

Treatments	DMY(KgHa)		% N'		N uptake(KgN/ha)		Total N uptake KgN/ha	% N Recover
	Grain yield	Stover	Grain	Stover	Grain	Stover		
1. Control (no nitrogen)	1700	2300	1.33	0.63	22.61	14.49	37.10	-
2. Acetamide	3600	5900	1.26	0.70	45.36	41.30	86.66	41.3
3. Calcium (cyanamide)	2500	4600	1.33	0.67	33.25	30.82	64.07	22.48
4. Succinamide	5400	6100	1.40	0.70	75.70	42.70	118.30	67.67
5. Urea	4500	7500	1.40	0.63	63.00	47.25	110.25	60.96

acetamide and $CaCN_2$ in that order. But the trend of total DMY was urea > succinamide > acetamide > $CaCN_2$. The yield from $CaCN_2$ was very low compared to urea. This might be due to damage to the seedlings. The application of $CaCN_2$ is normally done a week before planting to ensure proper decomposition of the toxic compounds (Tisdale and Nelson, 1975) but in the present experiment, it is was applied at the time of planting. It has been reported that $CaCN_2$ applied a week before planting is as efficient as urea (Arora and Nnadi, 1987). The total N uptake followed the trend of DMY.

4.5.2 Total N recovered

N recovered by the maize crop from various amides (Table 4.7) used ranged from 23% ($CaCN_2$) to 68% (Succinamide). The recovery from urea (61%) closely followed the recovery from succinamide. Acetamide had low recovery of 41%. The recovery from $CaCN_2$ was the lowest probably in % N in the grain and stover yield from $CaCN_2$ and other amides.

In the greenhouse study, acetamide and succinamide were similar to urea as sources of N to maize. However, the field study showed marked differences between these two sources. This may be due to the different methods

of N application in the greenhouse and the field. The amides were mixed thoroughly with the soils before potting whereas in the field they were applied by brodcasting. This can lead to some difference in the volatilization losses from the various sources. The better response of plants to succinamide compared to urea could be due to the formers insolubility in water which might have led to reduced leaching losses.

CHAPTER FIVE

SUMMARY AND CONCLUSION

The rate of mineralization of amides in tropical soils, their efficiency as N fertilizers and their residual effect on the soils were studied. A laboratory incubation experiment was conducted with soils from Samaru, Mokwa and Bakura to study the rate of mineralization and nitrification of seven amides (Acetamide, Calcium cyanamide, Dimethyl formamide, Phenyl acetamide, N, N dimethyl acetamide, Succinamide and Urea) The amides were added at the rate of 60 µgN/g of soil and incubated under aerobic condition at field capacity moisture content and at 30°C for 8 weeks. The pattern of mineralization of the amides were similar to urea in all the soils.

Nitrogen recovered (as NH_4^+, NO_2^- + NO_3^-) at the end of incubation (average of all amides) varied from soil to soil and was highest in Bakura soil. The range of total N recovered at the end of incubation were 39% ($CaCN_2$) to 88% (Succinamide) in Samaru soil, 35% (Dimethyl formamide) to 86% (Succinamide) in Mokwa soil and 45% (Dimethyl formamide) to 93% (Urea) in Bakura soil. The various

amides had different rates of hydrolysis. Urea, Succinamide and Acetamide were readily hydrolyzed in the soils. Ammonification of the amides in the soils started within the first week of incubation. The recovery of NH_4^+ was also highest during this period. Nitrification of accumulated NH_4^+ started in the first week of incubation in Samaru and Mokwa soils. The rate of nitrification was generally slower in Bakura soil. In all the soils, Dimethyl formamide did not nitrify but accumulated as NH_4^+. The pH value of the soils decreased as incubation progressed.

A greenhouse experiment was also conducted with the same soils and four amides (Acetamide, Phenyl acetamide, Succinamide and Urea) which gave high recoveries in the incubation study. Two kilograms of the soils were used in a plastic pot, into which all nutrients except N were added. There were three rates of N application (60 mgN/kg, 120mgN/kg and 180 mgN/kg of soil) and maize as the test crop. The N recoveries by maize plant at 6 weeks growth ranged from 52% to 103% with the exception of pyenyl acetamide which performed poorly in Mokwa soil. The recovery from Succinamide was more than Urea in the three soils.

In Mokwa soil, acetamide gave higher N recovery than urea. The efficiency of the amides as N fertilizer to maize decreased with increase in N application.

Succinamide, acetamide and $CaCN_2$ were also compared with urea in a field study at Samaru using maize as the test crop. The rate of N application was 120 kgN/ha. Calcium cyanamide was applied all at the time of planting while the other sources were split applied. The DMY of grain and stover obtained from field experiment was in the order of urea ≈ succinamide > acetamide > $CaCN_2$. The recovery of N by the maize crop from various amides used ranged from 23% ($CaCN_2$) to 68% (Succinamide).

The following conclusions can be drawn from the results of the three experiments:

(i) All the amides undergo mineralization in soils in the patterm of urea but with varying rates of hydrolysis.

(ii) All amides except Dimethyl formamide undergo nitrification with rates of succinamide and acetamide similar to urea

(iii) The efficiency of amides as N sources for maize varies with the nature of the

soil. Their recoveries vary from 35% to 103%.

(iv) For maize crop succinamide is a better source of N than urea whereas acetamide is as good as urea.

(v) Residual acidity caused by phenyl acetamide, $CaCN_2$, N, N dimethyl acetamide and succinamide is less than urea and Dimethyl formamide did not cause any residual acidity.

REFERENCES

1. Abdelmagid, H.M. and Tabatabai, M. A. 1982. Decomposition of Acylamide in soils. J. Environ. Qual. 11:701 - 704.

2. Adetunji, S. A. and Agboola, A.A. 1973 Fertilizers in the improvement of shifting cultivation. In shifting cultivation and soil conservation in Africa. FAO/SIDA/A RCN. Soil Bulletin 24.

3. Agboola, A. A. 1968. Increaing the efficiency of applied fertilizer. Time of application of nitrogenous fertilizer. Niger. Agric. J. Agric. 5:45 - 48.

4. Agboola, A. A. and Udom, G. E. 1967. Effect of moisture on fertilizer response. The Nig. Agric. J. 11:70 - 71.

5. Alexander, M. 1965. Nitrification. In W.V. Bartholomew and F.E. Clark (ed). Soil Nitrogen. Agronomy 10:309 - 343.

6. Allen, S.E., Mays, D.A. and Terman, G.L. 1968. Low cost slow release fertilizer developed. Crops and soils. 21: 13 - 15.

7. Allen, S. E., Terman, G.L. and Hunt, C.M. 1971, Soluble and slow release Nitrogen fertilizer effects on grass forage as influenced by rate and placement. J. Agric. Sc. Camb. 77: 397 - 404.

8. Arora, Y. and Juo, A.S.R. 1982. Leaching of fertilizer ions in a Kaolinitic ultisol in the high rainfall tropics. Leaching of nitrate in field plots under cropping and bare fallow. Soil Sci. Soc. Am. J. 46: 1212 - 1218.

9. Arora, Y., Mulongoy, K. and Juo, A.S.R. 1986. Nitrication and Mineralization potentials in a Limed Ultisol in the humid tropics. Plant and soil 92, 153 - 157.

10. Arora, Y., Singh, L. and Nnadi, L.A. 1987. Transformation of Calcium cyanamide and its inhibitory effect on urea nitrification in some tropical soils. Fertilizer Research (In press).

11. Ataga, D.O. 1978. Soil phosphorus status and response of the oil palm to phosphorus on some acid soils. J. Nig. Inst. Oil Palm Res. 5: 25 - 36.

12. Ataga, D.O. and Nnadbuchi, S.E. 1978. Nitrogen in precipitation at three locations in the oil Palm belt of Nigeria. J. Nig. Inst. Oil Palm Res. 5: 21 - 24.

13. Aweto, A.O. 1981. Total Nitrogen status of soils under bush fallow in the forest zone of South Western Nigeria. J. Soil Sci. 32: 639 - 642.

14. Aganaba, A. and Kang, B.T. 1976. Urea transformation in some tropical soils. Soil Biol. and Biochem. 8: 313 - 316.

15. Bache, N.W. 1965. The Harmful effects of ammonium sulphate on fine sandy soils at Samaru. Proceedings: 2nd F.A.O. Meeting of soil fertility and fertilizer use in West Africa. 1: 15 - 20.

16. Bache, B. Wand Heathcote, R.G. 1969. Long term effects of fertilizers and manure on soil and leaves of cotton in Nigeria

17. Balasubramanian, V. and Nnadi, L.A. 1977. Crop residue management and soil productivity in Savannah areas of Nigeria. Paper presented at the "F.A.O. Workshop on Organic Recycling in Agriculture". Buea, Cameroon, Dec. 4 - 14, 1977.

18. Balasubramanian, V. and Singh, L. 1982. Efficiency of nitrogen fertilizer use under rainfed maize and irrigated wheat at Kadawa, Northern Nigeria. Fertilizer Research 3: 315 - 324.

19. Balasubramanian, V., Nnadi, L.A. and Mokwunye, A.U. 1978. Fertilizing sole crop maize for high yields. Samaru Miscellaneous paper 76, I.A.R. Zaria - Nigeria.

20. Balasubramanian, Nnadi, L.A., Lombin, L.G., and Yayock, J.Y. 1979. Fertilizer use in Nigeria. II Future prospects and problems. Samaru Conference paper 32, I.A.R., Zaria - Nigeria.

21. Bates, F.E. and Tisdale, S.L. 1957. The movement of nitrate nitrogen through columns of Coarse - texture soil materials. Soil Sci. Soc. Amer. Proc. 21: 525 - 528.

22. Beaton, J.D., Hubbard, W.A. and Spear, R.C. 1967. Coated urea, Thiourea, Urea - formaldehyde, hexamine, oxamide, glycoluril and oxidized nitrogen - enriched Coal as Slowly available sources of nitrogen for orchard grass. Agron. J. 59: 127 - 133.

23. Black, C.A. 1957. Soil - Plant Relationships. John Wiley and Sons., Inc. New York 319

24. Black, C.A. 1965. Exchangeable Ammonium, Nitrate and Nitrate by steam distillation methods. In method of soil analysis. No 9, pp. 1191 - 1206. Am. Soc. of Agron. Inc. Publ. Mad. WisConSin. U.S.A.

25. Bjalfve, G. 1957. The nitrification of $CaCN_2$ and its effect on the soil Microflora. K. Lantbrltogsk Ann. 23: 423 - 456.

26 Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59: 39 - 45.

27. Bray, H.G., James, S.P., Thorpe, W.V. and Wasdell, M.R. 1950. The fate of certain organic acids and amides in the rabbit II. Further observations on the hydrolysis of amides by tissue extracts. Biochem. J. 47: 294 - 299.

28. Bremner, J.M. 1965. Inorganic forms of nitrogen pp. 1179 - 1237. In C.A. Black (ed) Methods of soil analysis. Part 2 Amer. Soc. Agron. Madison. Wis. U.S.A.

29. Broadbent, F.E., Hill, G.W. and Tyler, K.B. 1958. Transformation and movement of urea in soils. Soil Sci. Amer. Proc. 22: 303 - 309.

30. Brown, M.A. 1965. Leaching losses of Nitrogen. Soils and fertilizer Research Branch. T.V.A. Wilson Dam Alabama.

31. Brown, B.E. and Reid, F.R. 1937. Formamide and ammonium formate as nitrogen sources for plants. Soil Sci. 43: 341 - 347.

32. Cantarella, H. and Tabatabai, M.A. 1980. Potential of some anides as nitrogen fertilizers. Agron. Abst. pp. 166.

33. Cantarella, H. and Tabatabai, M.A. 1983. Amides as sources of nitrogen for plants. Soil Sci. Soc. Am. J. 47: 599 - 603.

34. Carter, J.N., Bennett, O.L. and Pearson, R.W. 1967. Recovery of nitrogen under field conditions using nitrogen 15. Soil Sci. Soc. Amer. Proc. 31: 50 - 56.

35. Chapman, H.D. 1965. Cation exchange capacity. In C.A. Black (ed) Methods of soil analysis. Agron. Monograph. 9: 891 - 932 Am. Soc. Agron, Madison, Wisconsin.

36. Chinwuba, P.M. and Fayemi, A.A. 1970. Time and Method of N application. Annual Report Fed. Dept. Agric. Res. Ibadan. 6.

37. Cummings, R.W. and Gleason, R.N. 1973. The role of fertilizer in Agricultural Development. In Olson, R.A. (ed) Fertilizer Technology and use. Second edition (ed) SSSA.

38. Dancer, W.S., Peterson, L.A. and Chester, G. 1973. Ammonification and Nitrification of N as influenced by soil pH and previous N treatments. Soil Sci. Soc. Am. Proc. 37: 67 - 69.

39. Day, P.R. 1965. Hydrometer Method of particle size analysis. In C.A. Black (ed). Methods of soil analysis. Agron. Monograph 9, 545 - 566. Am. Soc. Agron. Madison, Wis.

40. DeMent, J.D., Hunt, C.M. and Stanford, G. 1961. Hydrolysis nitrification, and nitrogen availability of oxamide as influenced by the granule size J. Agric. Food Chem. 9: 453 - 456.

41. Davis, J. and Freitals, F. 1970. Physical and Chemical Methods of Soil and Water analysis F.A.O. soil bulletin 10: 57 - 70.

42. Diamond, R.B. and Myers, F.J. 1972. Crop response and related benefits from coated urea. Sulphur Institute J. 8: 9 - 11.

43. Enyi, B.A.C. 1964. The effect of soil moisture and nutrient availability on leaf death of rice plants during tillerging periods. The Nig. Agric. J. 1: 32 - 33.

44. Enyi, B.A.C. 1967. Effect of N and P on two varieties of swampa rice. The Nig. Agric. J. 1: 49 - 57.

45. Fagi, A.M. and DeDatta, S.K. 1981. Environmental factors affecting nitrogen efficiency in flooded tropical rice. Fert. Res. J. 2: 53 - 68.

46. Fayemi, A.A. 1966. Effect of time of nitrogen application on yield of maize in the tropics. Expl. Agric. 2: 2.

47. FranKenberger, W.T. Jr., and Tabatabai, M.A. 1980. Amidase activity in soils. I Method of assay. Soil Sci. Soc. Am. J. 44: 282 - 287.

48. Frankenberger, W.T.Jr., and Tabatabai, M.A. 1980b. Amidase activity in soils. II Kinetic parameters. Soil Sci. Soc. Am. J. 44: 532 - 536.

49. FranKenberger, W.T.Jr. and Tabatabai, M.A. 1981. Amidase activity in soils. III stability and distribution. Soil Sci. Soc. Am. J. 45: 333 - 338.

50. FranKenberger, W.T.Jr. and Tabatabai, M.A. 1982. Transformation of amide nitrogen in soils. Soil Sci. Soc. Am. J. 46: 280 - 284.

51. Gasser, J.K.R. and JephCott, R.M. 1964. Insoluble nitrogen fertilizers. Rothamsted Exp. Sto. Rep. 1963: 45 - 46.

52. Godlsworthy, P.R. 1967. Responses of Cereals to fertilizers in Northern Nigeria. Expl. Agric. 3: 263 - 273.

53. Goldsworthy, P.R. and Palmer, J.L. 1971. Fertilizer trials with sprayed and unsprayed cotton in Nigeria. Expl. Agric. 7: 281 - 287.

54. Halne, H.C., Wybe, K. and Lutz, J.A. 1977. Nitrogen fertilization. I. Nitrate accumulation and losses under continuous corn cropping. Soil Sci. Soc. Am. J. 41: 562 - 567.

55. Haucks, R.D. 1964. New nitrogen fertilizers. Commer. Fert. Plant Food Ind. 108: 23 - 66.

56. Hignett, T.P. 1971. Paper presented at 2nd Interregional fertilizer symposium Tennesse Valley Authority Muscle Shoals. Alabama 235660. U.S.A.

57. Hunter, A.S. 1974. Field Comparisons of formamide, urea, ammonium nitrate solution and ammonium nitrate as nitrogen sources for grasses and wheat. Agron. J. 66: 540 - 543.

58. Jones, E. 1960. Contribution of rainwater to the nutrient economy of soil in Northern Nigeria. Nature. 186 (4748). 432.

59. Jones, M.J. 1971. The maintenance of soil organic matter under continuous cultivation at Samaru, Nigeria J. Agric. Sci. Cam. 77: 473 - 478.

60. Jones, M.J. 1973. Time of application of fertilizer to maize at Samaru, Nigeria. Expl. Agric. 9: 113 - 120.

61. Jones, M.J. 1974. New recommendations for nitrogen fertilizers in Northern States. Samaru Agric. Newsl. 16: 67 - 73.

62. Jones, M.J. 1975. Leaching of nitrate under maize at Samaru - Nigeria. Tropical Agric. (Trinidad) 52: 1 - 10.

63. Jones, M.J. 1976a. Effects of three nitrogen fertilizers and lime on pH and exchangeable cation content at different depths in cropped soils at two sites in the Nigeria Savanna. Tropical Agric. (Trinidad) 53: 243 - 254.

64. Jones, M.J. 1976b. Water movement and nitrate leaching in a Nigerian Savanna soil Expl. Agric. 12: 69 - 79.

65. Jones, M.J. and Bromfield, A.R. 1970. Nitrogen in the rainfall at Samaru, Nigeria, Nature, London 227, 86.

66. Jones, M.J. and Wild, A. 1975. Soils of the Yeat African Savanna. Technical Communication. No 55 of the Commonwealth Bureau of soils. Harpenden.

67. Jones, T.M., Lewis, H.T.Jr., and Getsinger 1966. Formamide as a component of liquid fertilizers. J. Agric. Food Chem. 14: 20 - 23.

68. Kang, B.T., Doblesh, F. and Moody, K. 1977. Soil Fertility Management Investigations on altitude tropics of W. Africa. Investigations on Egbeda soil series. Agron. J. 69: 651 - 656.

69. Kapoor, J.N. and Mathur, D.P. 1983. Studies on preparation, handling and applications of polyacrylamide solutions as industrial flocculants. Fertilizer News. April. 40 - 45.

70. Kayode, G.O. and Agboola, A.A. 1982. Effect of different nitrogen levels, plant population and soil nutrient status on yield and yield components of maize (Zea Mays L.) in different ecological zones of Nigeria. Fertilizer Research 2: 177 - 191.

71. Kowal, J. 1970. The hydrology of a small catchment basin at Samaru, Nigeria. (IV) Assessment of soil erosion under varied land management and vegetation cover. The Nig. Agric. J. 7: 134 - 147.

72. Kohnke, H., Deribellis, F.R. and Davidson, J.M. 1940. A survey and discussion of Iysimeters and a bibliography on their construction and performance. USDA. Wisc. Pub. 372. 68 pp.

73. Krauter, C.F. 1974. The uptake, storage and loss of nitrogen in the field using 15 N labeled fertilizer. Univ. of California. Davis. Ph.D. Agriculture, Plant Culture.

74. Lombin, L.G. 1978. Effects of continuous fertilizer use on crop nutrition and yield in the Northern Savanna Soils of Nigeria a preliminary assessment at Samaru. In Proceedings of the Soil Science Society of Nigeria Annual Conference and 6th National Soil Correlation Conference held at Calabar, Nigeria 18 - 22 Sept. 1978.

75. Lombin, L.G. and Ogunlela, V.B. 1979. Time and rate of nitrogen application to cotton in the Savanna areas of Nigeria. Indian J. Agric. Sci. 49: 665 - 673.

76. Lunt, O.R. 1968. Modified sulphur-coated granular urea for controlled nutrient release. International congress of soil science, 9th Transaction 3: 377 - 383.

77. Malgwi, W.B. and Ibanga, I.J. 1982. The detailed soil survey of the Agricultural Research Farm at Mokwa, Niger State. I.A.R., Zaria.

78. March, J. 1967. Advanced Organic Chemistry Reactions, Mechanisms and Structure. International Student edition McGraw-Hill Book Company Tokyo.

79. Mays, D.A. 1970. Sulphur - coated urea, a slow - release nitrogen source for grass land congress. Queensland, Australia, pp. 428 - 430.

80. Nelson, D.W. and Sommers, L.E. 1973. Determination of total nitrogen in plant material. Agron. J. 65: 109 - 112.

81. Nnadi, L.A. 1975. Comparison of Leaching Losses of Nitrogen from soluble and slow-release fertilizers. Samaru Agric. Newsl. 171: 82 - 85.

82. Nnadi, L.A. and Abed, S. N. 1983a. Evaluation of Sulphur coated urea fertilizers in Savanna soils. I. Response of Cotton and Sorghum. J. Agric. Sci. Camb. 101: 119 - 121.

83. Nnadi, L.A. and Abed, S.N. 1983b. Evaluation of Sulphur coated urea fertilizers in Savanna soils. II. Effect of on soil pH and residual nitrogen. J. Agric. Sci. Camb. 101: 121 - 123.

84. Nnadi, L.A. and Arora, Y. 1986. Effect of Nitrogen sources on crop yield and soil properties in the Savanna (In press). A.B.U., Zaria.

85. Nnadi, L.A. and Stockinger, K.R. 1980. Leaching losses of N from lysimeter plots at Samaru, Nigeria. Proceedings of the 1st International Soil Science Congress, Accra, Ghana.

86. Nommik, H. 1958. On decomposition of $CaCN_2$ and dicyanadiamide in the soil. Acta. Agric. Scand. 8: 404 - 440.

87. Nye, P.H. and Greenland, P.H. 1960. The soil under shifting cultivation. Common, Bur. Soils. Tech. Commun. 51: 43 - 47.

88. Obakin, F.O. 1978. Effect of N fertilizer on Sugar-cane juice quantity. In proc. of the Int. Symposium on Sugar-cane in Nigeria. National Cereals Res. Inst. 1978, Ibadan.

89. Odunze, A.C. 1987. Characterization of soils in various Geomorphic Units of the Bakolori Area in Sokoto State, Nigeria. M.Sc. Thesis, A.B.U., Zaria.

90. Ojeniyi, S.O. 1980. Nutrient status of NPK - treated Coffee plots. Plant and soil 56: 175 - 179.

91. Ojeniyi, S.O., Egbe, N. and Omotosho, T. 1982. Effects of nitrogen and phosphorus fertilizers on unshaded amazon Cocoa in Nigeria. Fertilizer Research. 3: 13 - 16.

92. Okeagu, M.U. 1981. Evaluation of nitrogen fertilised signal grass (Brachiaria decembens stapf.) pastures under Cattle grazing. M.Sc. Thesis, A.B.U., Zaria.

93. Ologunde, O.O. and Ogunlela, V.B. 1982. Relationship of plant density and nitrogen fertilization to maize performance in Southern Guinea Savanna of Nigeria. Samaru J. Agric. Res. 2: 99 - 109.

94. Olsen, R.J. Hensler, F.F., Attoe, J.O., Witzel, S.A. and Peterson, I.A. 1970. Fertilizer nitrogen and crop rotation in relation to movement of nitrate N Through soil profiles. Soil Sci. Soc. Am. Proc. 34: 448 - 452.

95. Omeje, M.U. 1981. Nitrogen - supplying power of soils from Lake Chad Basin. M.Sc. Thesis, A.B.U., Zaria.

96. Oyedokun, J.B. 1976. Effect of time of Nitrogen application on upland rice (Oryza Sativa L.) grown as rainfed rice. Niger. Agric. J. 13: 11 - 23.

97. Pleysier, J.L., Arora, Y., Juo, A.S.R. and Lawson, T.L. 1982. Calcium cyanamide as a nitrogen fertilizer for the high rainfall tropic. I.I.T.A. Res. Briefs. 3: 1 - 3.

98. Raney, W.A. 1960. The dominant role of nitrogen in leaching losses from soils in humid regions. Agron. J. 52: 563.

99. Rathsack, K. 1970. The liming value of $CaCN_2$. Landw. Fursch 23: 129 - 134.

100. Rehling, C.J., and Taylor, J.R. Jr. 1937. Formamide as a nitrogenous fertilizer. J. Am. Soc. Agron. 29: 134 - 144.

101. Richards, H. Fox. 1972. Nitrogen fertilization in the humid tropics Agronomy Mimeo. 72 - 17 Dept. of Agron. Cornell University, Ithaca, New York: 14850.

102. Rotimi, C.T., Soldatini, G.E. and Grovanni G. 1971. Transformation of $CaCN_2$ in submerged soils. Agrochemia. 15: 523 - 530.

103. Sandhu, M. 1974. Plant N uptake and soil N transformations as influenced by soil Temp. and plant residue. North Dakota State Univ. Ph.D. Agronomy.

104. Sauchelli, V. 1964. Fertilizer nitrogen: its chemistry and technology (A.C.S. Monograph No 161) Reinhold, pp. 432.

105. Stockinger, K.R. 1966. Soils. In 3rd Annual report of the AID - ARS. projects on major Cereals of Africa. pp. 23 - 35.

106. Temme, T. 1946. The transformation of $CaCN_2$ in the soil. Plant and soil. 1: 145 - 166.

107. Terman, G.L., Parr, J.F. and Allen, S.E. 1968. Recovery of nitrogen by corn from solid fertilizers and solutions. J. Agric. Food Chem. 16: 685 - 690.

108. Terry, D.L. and McCants, C.B. 1968. The leaching of ions in soils (Technical bulletin No 184) Raleigh, pp. 16.

109. Tisdale, S. and Nelson, W. 1975. Soil fertility and fertilizer. 3rd Edition. The Macmillan Company, New York.

110. Tyler, K.B. and Broadbent, F.E. 1958. Nitrogen uptake by ryegrass from three tagged ammonium fertilizers. Soil Sci. Soc. Amer. Proc. 22: 231 - 234.

111. Valette, J. and Ibanga, I.J. 1983. The detailed soil survey of the Experimental Farm of the I.A.R., Samaru, Zaria, Kaduna State, Nigeria. Soil Survey Bul. IAR,ABU, Zaria.

112. Van Gordan, T.D. and Gilbert, S.G. 1976. Bioconversion of Barex 210 (an acrylonitrite Copolymer) nitrogen for plant utilization. J. Agric. Food Chem. 24: 823 - 824.

113. Van Raiji, E. and Peech, M. 1972. Electro - chemical properties of some oxisols and alfisols of the tropics. Soil Sci. Soc. Am. Proc. 36: 587 - 591.

114. Vilsmeier, K. and Amberger, A. 1978. Model studies on the breakdown of powered and granular $CaCN_2$ as affected by soil moisture and application method. Zeitschrift fur Acker-und Pflanzenban 147: 68 - 77.

115. Volk, G.M. and Sweat, A.W. 1955. Mobility of urea nitrogen applied to Florida soils. Soil Sci. Soc. Pls. Proc. 25: 117 - 123.

116. Wetsarlaar, R. 1961. Nitrate distribution in tropical soils. II. Extent of Capillary accumulation of nitrate during load dry period. Pl. Soil, 15: 121 - 133.

117. Westerman, R.L., Kurtz, L.T. and Hauck, R.D. 1972. Recovery of 15_N labeled fertilizers in field experiments. Soil Sci. Soc. Amer. Proc. 36: 83 - 86.

118. Walkley, A. and Black, C.A. 1934. An examination of Degtjareff method for determining soil organic matters and proposed modification of the chromic acid titration method. Soil Sci. 29: 38 - 45.

119. Wild, A. 1972. Nitrate leaching under bare fallow at a site in Northern Nigeria. J. Soil Sci. 33: 315 - 324.

120. Worthy, W. 1980. TVA Shows off new fertilizer technology. Chem. Eng. News 58: 32 - 33.

121. Yahuza, U. and Mokwunye, U. 1976. Occurrence and distribution of nitrogen in Savanna soils of Nigeria review. Samaru Agric. Newsl. 18: 72 - 76.

Appendix 1 Ammonification and Nitrification of the amides during incubation studies in Samaru soil.

μgN/g of soil

Treatment No.	Week 1		Week 2		Week 3		Week 4		Week 8	
	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
1	22.2	26.9	12.8	38.5	5.9	46.7	0.0	32.7	0.0	51.4
2	4.7	15.2	8.7	19.8	0.0	19.9	0.0	17.0	0.0	23.4
3	0.0	0.00	36.2	0.00	44.0	0.00	39.7	0.0	45.5	0.0
4	7.0	9.4	2.3	26.8	0.0	32.7	0.0	35.0	0.0	32.7
5	29.2	0.0	24.5	9.3	14.0	37.4	2.3	33.8	1.2	39.7
6	34.7	24.0	11.7	49.0	2.4	61.9	0.0	44.5	0.0	52.5
7	31.5	18.7	10.5	44.3	1.2	57.2	0.0	40.8	0.0	47.9

L.S.D. NH_4^+ is 6.80, NO_3^- is 4.54

Appendix 2 Ammonification and Nitrification of the amides during incubation studies in Mokwa soil.

μgN/g of soil

Treatment No.	Week 1		Week 2		Week 3		Week 4		Week 8	
	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
1	35	17.5	12.8	29.2	8.1	39.7	2.3	37.3	0.0	47.9
2	21	1.1	3.5	19.8	2.3	19.9	1.1	28.0	3.3	31.0
3	0.0	0.0	12.8	0.0	10.8	0.0	12.8	0.0	21.0	0.0
4	51.4	0.0	42.0	15.2	28.0	8.2	15.1	11.6	1.2	28.0
5	47.9	0.0	33.8	18.7	21.0	42.0	4.6	50.1	1.2	45.5
6	29.2	21	15.2	25.7	9.3	39.7	2.3	59.5	0.0	51.4
7	30.4	15.1	17.5	35.0	7.0	40.9	11.6	61.8	0.0	50.0

L.S.D.	NH_4^+	NO_3
	3.3	4.73

Appendix 3 Ammonification and Nitrification of the amides during incubation studies in Bakura Soil.

µgN/g of Soil

Treatment No.	Week 1		Week 2		Week 3		Week 4		Week 8	
	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
1	50.2	4.7	22.2	39.7	12.8	32.7	0.0	47.9	0.00	52.5
2	28.0	2.4	17.5	3.5	14.1	15.2	2.3	23.4	0.00	28.0
3	21.0	0.0	18.7	3.7	21.3	0.00	23.3	0.00	26.8	0.0
4	49.0	5.9	21.0	10.5	30.5	7.0	5.8	22.0	2.3	32.7
5	30.3	3.5	32.7	1.2	46.8	8.2	12.8	31.5	0.00	39.8
6	42.0	0.0	17.0	25.0	14.1	43.2	5.8	42.7	2.3	49.7
7	46.7	8.2	26.8	37.0	11.8	59.5	2.0	52.5	0.00	56.0

L.S.D. NH_4^+ is 8.16 NO_3^- is 5.84

Appendix 4 Dry Matter Weight (g/pot) of maize from greenhouse experiment using various amides at 3 rates.

Treatment			Samaru	Mokwa	Bakura
1	Control		7.55	2.01	3.72
2	Acetamide	N_1	15.01	11.04	15.14
3	Acetamide	N_2	20.31	13.99	20.58
4	"	N_3	21.37	17.61	25.43
5	Succinamide	N_1	15.46	11.92	15.9
6	"	N_2	19.96	17.59	23.71
7	"	N_3	22.74	19.28	26.88
8	P-acetamide	N_1	13.88	7.48	11.85
9	"	N_2	17.27	11.82	18.86
10	"	N_3	18.87	9.72	23.64
11	Urea	N_1	15.80	13.75	17.39
12	"	N_2	21.34	17.12	23.23
13	"	N_3	22.16	19.81	27.41
	L.S.D.		0.74		

Appendix 5 % N in the Dry Matter of the Greenhouse Experiment.

	Treatment		Samaru	Mokwa	Bakura
1	Control		0.98	0.91	0.70
2	Acetamide	N_1	1.19	1.12	0.79
3	"	N_2	1.40	1.16	1.00
4	"	N_3	1.68	1.21	1.66
5	Succinamide	N_1	1.26	0.98	0.86
6	"	N_2	1.50	0.98	1.17
7	"	N_3	1.64	1.17	1.40
8	P-acetamide	N_1	1.21	1.00	1.26
9	"	N_2	1.40	0.98	1.19
10	"	N_3	1.26	1.23	1.05
11	Urea	N_1	1.21	0.84	0.77
12	"	N_2	1.40	0.89	1.05
13	"	N_3	1.59	1.05	1.20
	L.S.D.		0.08		