RESPONSE OF MAIZE TO NITROGEN, PHOSPHORUS AND FILTERMUD APPLIED TO A *DYSTRIC NITOSOLS*

BY

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ABSTRACT

A glasshouse pot experiment to study the response of maize (*Zea mays*) to nitrogen, phosphorus and filtermud applied to a *Dystric nitosols* was carried out at the Sokoine University of Agriculture (SUA) Morogoro, Tanzania. The *Dystric nitosols* was collected from the central part of SUA farm while the filtermud was obtained from Mtibwa Sugar Factory, Turiani Morogoro, Tanzania. The *Dystric nitosols* was characterized by low total organic carbon, nitrogen, exchangeable Ca and Mg, CEC, plant available P and a very strongly acid reaction. The filtermud contained low amounts of the essential nutrients elements and had a very mild alkaline reaction. Fifty four, 12 kg soil sample portions of the *Dystric nitosols* were weighed into 10 litre capacity plastic buckets and thoroughly mixed with nitrogen as $(NH_4)_2SO_4$ at the rates of 0, 50 and 100 kgNha^{-1}, P as KH_2PO_4 at the rates of 0, 75 and 150 kg P ha^{-1} and filtermud at the rates of 0, 15 and 30 tonsfiltermudha^{-1} in a 3^3 factorial experiment in a completely randomized block design with two replicates. The soil-N-P-filtermud treatments were incubated at field capacity for 3 weeks after which five maize seeds were planted in each pot and allowed to grow for 6 weeks. The whole maize plants above the soil levels in the plastic buckets were harvested according to treatments at the end of the 6th week of growth and dried at 70 °C to constant weights for dry matter determination. The oven dried maize plants were chopped into small pieces and ground into fine powder for the determination of N, P and K contents. The application of N, P alone and in combination and N-P-filtermud combinations significantly increased the dry matter yields and percent N, P and K in the maize plants. The increases in the N, P and K contents in the maize plants were attributed to increased availability of N, P and K added to the soil as N and P fertilizers and the N, P and K released from the filtermud through decomposition and mineralization. Further, improvement of the physical, chemical and biological properties of the soil by the filtemud could have contributed to increased uptake of N, P and K. However, application of filtermud alone decreased the N, P and K contents of the maize plants and this was attributed to the immobilization of these nutrients in the soil. Filtermud could be used as an organic soil amendment when applied together with inorganic fertilizers for the enhancement and sustainability of soil fertility. Application of inorganic fertilizers and filtermud would improve soil productivity without detrimental effect to the environment.

DECLARATION

I, NESSIE LUAMBANO, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has never been submitted for a degree award in any other University.

Signature.......................................

Date.....19/3/2003.....

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DEDICATION

This work is dedicated to my beloved parents; father Dietrich Mahavanga Luambano and mother Editha Luambano who took trouble to send me to school and taught me the value of education. **'May God bless them so that their dreams come true'.**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVIATIONS

AAS	atomic adsorption spectrophotometer
Al	aluminium
AN	ammonium nitrate
AS	ammonium sulphate
C/N	carbon to nitrogen ratio
Ca	calcium
$CaCO_3$	calcium carbonate
CAN	calcium ammonium and nitrogen
CEC	cation exchange capacity
Cmol(+)/kg	centimole per kilogram
CMP	carbon pressmud
Cu	copper
DTPA	diethylenetriaminepentacetic acid
EC	electrical conductivity
ESP	exchangeable sodium percentage
et al	and others
FAO	Food and Agriculture Organisation
Fe	iron
FM	filtermud
g/pot	gram per pot
H^+	hydrogen ion
H_2O	water
H_2O_2	hydrogen peroxide

HCl	hydrochloric acid
HNO_3	nitric acid
K	potassium
kg	kilogram
$kgha^{-1}$	kilogram per hectare
KH_2PO_4	monopotassium phosphate
Mg	magnesium
Mn	manganese
N	nitrogen
N_2	dinitrogen
Na	sodium
NaOH	sodium hydroxide
NH^+_4	ammonium ion
NH^-_2	amide
NH_4Cl	ammonium chloride
NH_4Oac	ammonium acetate
NO^-_2	nitrite ion
NO^-_3	nitrate ion
NORAD	Norwegian Agency for Development Co-operation
nm	nanometre
OC	organic carbon
OM	organic matter
P	phosphorus
pH	negative logarithim of hydrogen ion activity

PM	pressmud
S	sulphur
SPM	sulphitation pressmud
SUA	Sokoine University of Agriculture
tha^{-1}	tonnes per hectare
TN	total nitrogen
Zn	zinc
%	percentage
$(NH_4)_2SO_4$	ammonium sulphate
<	less than
>	greater than
µg	microgram

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays*) production ranks second among the cereal production levels world-wide with an average yield of 4.0 tha^{-1} (Tumuhairwa and Rwakaikara, 1999). Although maize is a major food crop in East Africa, the average yield is 1.5 tha^{-1}, which is categorized as being very low (FAO, 1997). One of the factors contributing to the very low yields of maize in East Africa is the low fertility status of the soils under maize cultivation (CIMMYT, 1992). The fertility status of the soils has been attributed to the extensive weathering of the soils, low organic matter contents in the soils, continuous crop removal of the nutrients from the soils without replenishment and extensive loss of nutrient through soil erosion and improper management of the soils (Kamidi *et al.*, 1999).

The fertility status of the soils can be increased and sustained through the application of fertilizers and manures. However, maize cultivation in East Africa is mostly undertaken by small scale farmers whose income status is very low. The small scale farmers cannot purchase the very expensive inorganic fertilizers. Further, these farmers cannot meet the cost of preparation, transportation and application of the manures and crop residues. Furthermore, the small scale farmers have very little knowledge and awareness of the benefits of using fertilizers and manures in maize production. The above problems faced by the small scale farmers and the continuous cultivation of the same pieces of land for extensive periods have compounded the problems of low soil fertility for maize production (Giller and Wilson, 1991).

Nitrogen (N) and phosphorus (P) are the major essential plant nutrients limiting maize production in East Africa due to the very low contents of the available forms of these nutrients in the soils (Tumuhairwe and Rwakaikara, 1999). The main causes of low N contents in soils include loss of N through leaching, low organic matter contents in soils and gaseous loss of N (Stevenson, 1982). On the other hand, the phosphorus problem in crop production is attributed to low P contents in the parent materials of most soils and the phosphorus occurring in soils in forms not available to plants. Further, phosphorus added to soils as fertilisers and manures is subsequently converted to forms not available to plants. The problems of N and P in maize production in East Africa could be overcome by judicious application of fertilizers, manures and crop residues and other appropriate organic soil amendments.

The last half of the 20th century has been characterised as the chemical era of production agriculture (green revolution) under which extensive and massive use of inorganic fertilizers were used in crop production (Napier and Tucker, 2001). The extensive use of inorganic fertilisers resulted into increased crop yields and farm income. However, the benefits of the use of inorganic fertilizers in various farming systems were only realized by the large scale farmers with high income (Haru, 1996). To the poor peasants in the developing countries, the green revolution was a dream. Under the green revolution very little consideration and attention was given to the adverse environmental consequences of the use of very high amounts of inorganic fertilizers. Some of the adverse environmental consequences included contamination of the groundwater, lakes, springs, rivers and water reservoirs. These consequently culminated in health problems for human as well as other animals and living creatures (Napier and Tucker, 2001).

It has been observed that soil fertility can be sustained and enhanced through the use of organic soil amendments, like farmyard manure, compost, factory ash, crop residues, sewage sludge, and sugar factory filtermud. Use of manures, factory wastes and crop residues increase the fertility status of the soils by supplying the essential plant nutrients, cation exchange capacity, controlling the pH and improving soil physical properties like structure and soil moisture retention (Greenland, 1980). However, the plant nutrients in manure and crop residues are very low as compared to those in chemical fertilisers and not immediately available to plants. Therefore, high amounts of manures and crop residues have to be added to soils so as to supply the amounts of nutrients, which will be sufficient to the crops after decomposition and mineralization.

Application of very high levels of manures might contribute to environmental pollution and health hazards to human being and detrimental effect to the crops. In order to reduce the application of high rates of manure, combination of inorganic fertilizers and manures, will significantly reduce the amounts of manure and inorganic fertilizers to be applied without adverse effects on the fertility status of the soil and with very little or no environmental pollution (Amolo *et al.*, 1996). Filtermud from sugarcane factories can be used as an organic soil amendment to supply plant nutrients and/or as soil conditioners. Well weathered filtermud or filtercake, is one of the widely used soil conditioners in sugarcane producing/ growing areas, near the sugar factories (Yadav, 1995). Filtermud wastes contain valuable nutrients like nitrogen, phosphorus and potassium that could improve soil fertility. These filtermud wastes further contribute to soil fertility by improving soil tilth, crusting and organic matter (Amolo *et al.*, 1996).

Information on the effect of filtermud as organic soil amendment on soil properties and crop yields in Tanzania is very scanty. Therefore, a study to characterise and evaluate the usefulness of filtermud as an organic soil amendment for sustainable soil fertility and productivity would be in the right direction. The overall objective of the study was to assess the response of maize to nitrogen, phosphorus and filtermud when applied to a *Dystric nitosols.*

The specific objectives of the study were:

(i) To determine fertility status of the *Dystric nitosols* and the nutrients contents of filtermud.

(ii) To assess the response of maize to N, P and filtermud in terms of N, P and K uptake and dry matter yields.

(iii) To determine/establish the optimal N, P and filtermud levels for optimal maize performance/yields.

CHAPTER TWO

2.0 LITERATURE REVIEW

Nitrogen and phosphorus are the primary essential macro nutrients that must be supplied in sufficient quantities for optimal plant growth and development. This can be achieved through either organic or inorganic fertiliser application or a combination of the two (Tumuhairwe and Rwakaikara, 1999). Nitrogen for plant growth is obtained from many sources and its transformation in soils is very dynamic, hence significant losses of nitrogen from the soil through various chemical and biological processes are common. Though maize can effectively use both NO_3^- and NH_4^+-nitrogen, nearly all N required by maize for growth is absorbed in the form of NO_3^- which is very prone to leaching and can be converted to nitrogen gas. This may be mainly because conditions that favour maize growth also favour the conversion of N compounds to NO_3^-.

Currently, nitrogen is the most deficient essential nutrient element in tropical soils, limiting crop production. Tropical conditions favour high activities of microorganism and high rainfall which favour denitrification and leaching of soil nitrogen. The amount of P in the soil and in maize plants is low compared to N and K, but nevertheless P is an equally important element in the nutrition of maize. Phosphorus does not easily leach out of the soil hence in most soil P is retained close to the site of application (Aldrich *et al.*, 1975). Phosphorus occurs in soils in both mineral and organic forms and its availability to plants depends on the mineralogy and the pH of the soils.

Nitrogen and phosphorus are added to soils through decomposition of organic matter. The release of N and P from organic matter decomposition is a slow process and in some cases may cause immobilization of the soil available N and P. In such cases it may be necessary to combine both soil organic amendments and inorganic fertilizers in order to increase soil productivity (Palm *et al.*, 1997), partly through the enhanced release of N and P contained in the soil organic amendments. One of the soil organic amendments which can be used in maize production is filtermud. Filtermud contains 1.0-3.1% nitrogen, 0.6-3.6% phosphorus and 0.3-1.8% potassium (Yadav, 1995), which could be used to supplement the need for inorganic fertilizers with respect to nitrogen and phosphorus. This material is readily available from all sugar factories in Tanzania.

2.1 Nitrogen

2.1.1 Sources of nitrogen in soils

2.1.1.1 Atmospheric nitrogen sources

The atmosphere which contains about 78% N is the ultimate source of all forms of N in soils and inorganic fertilizers N (Tisdale *et al.*, 1993). The atmospheric N enters the soil through N fixation, which involves biological and non biological N fixation (Uriyo *et al.*, 1979). The biologically fixed N in the soil is from atmospheric N that has been converted by microorganisms to N- containing organic compounds. Upon death of the organisms their cell N is acted upon by several microorganisms and release N to the soil as ammonia (Brady and Weil, 1996). Fixation of the atmospheric N biologically is represented by the following chemical equation; $N_2+6H^++6e^- \longrightarrow 2NH_3$. This reaction takes place in the presence of the enzyme, nitrogenase.

The non biologically fixed N, is the N which enters the soil as a result of fixation of atmospheric N either by electrical discharge or by the Haber-Bosch process (Tisdale *et al.*, 1993). During thunderstorms there is electrical discharge whereby atmospheric N reacts with hydrogen and oxygen to form ammonium and nitrate respectively. The ammonium and nitrate or oxides of N formed may dissolve in rain water and enter the soil as ammonium hydroxide and nitric acid. However, the amount of N added to the soil from electrical discharge has been reported to be very low (Brady and Weil, 1996). Nitrogen from the Haber-Bosch process is another source of N from non-biological fixation of atmospheric N. This is the industrial production of ammonium in which hydrogen gas react with nitrogen gas to form ammonia, it is represented by the following chemical equation;

$3H_2+N_2 \xrightarrow{\qquad} 2NH_3$. This reaction takes place in the presence of a catalyst at 1200 ^0C and 500 atm. The ammonia formed can be directly used as fertilizer or used in the production of other N fertilizers (Tisdale *et al.*, 1993).

2.1.1.2 Organic Sources

Usually 95% or more of the N in surface soils is present in organic forms namely protein and humic compounds and the remainder is in mineral forms (Tisdale *et al.*, 1993) like NO^-_2, NO^-_3, exchangeable NH_4^-, non exchangeable NH_4^- and nitrous oxide (Young and Aldang, 1982). Soils differ widely in their ability to mobilise organic N and a number of environmental factors such as temperature and water affect the process of mineralization. Net mineralization of organic N is the most important component of soil N budget (Stevenson, 1982).

Manures contain appreciable amounts of nitrogen. Most of this nitrogen is in organic forms. For example cattle manure contains about 0.45 to 1.81% nitrogen. About half of this nitrogen in the manure is converted to forms available to plants during the first growing season, through the processes of biochemical decomposition and mineralization (Thompson and Troeh, 1993).The degradation of the organic material decrease with time due to reduction in number of the microorganism involved in the process (Jansson and Persson, 1982). It has been observed that organic manures are characterised by low nutrient contents due to there nature and difficulties in storage. For example one tonne of farm manure is equivalent to 2.27-9.1 kg of N (Saha *et al.*, 1995). Therefore, many tonnes of organic manures are required so as to supply enough N for plant growth (Young and Aldag, 1982).

Unlike nitrogen in commercially prepared fertilizers, nitrogen in organic materials must be mineralised to nitrate or ammonium (inorganic or mineral forms) before it becomes available to plants. This mineralization occurs as microorganisms decompose the organic materials in soil. The mineralization of N is always accompanied by the formation of new organic materials, either as new microbial cells or as by-product of microbial activities. When soil temperature and moisture are favourable, the availability of organic materials is the primary factor that determines how much microbial activity occurs in the soil (Stevenson, 1982) for the decomposition processes.

It has been observed that if the organic residues are well distributed over the field they decompose and contribute to soil organic matter (Brady and Weil, 1999).

Decomposition of organic residues is a slow process thus leading to slow release of N to succeeding crops (Stevenson, 1982). Generally, less than 5% of the organic nitrogen is converted per year by soil microorganisms to a form of nitrogen that plants can use like NH_4^- and NO_3^- (Srivastava and Singh, 1996).

The nitrogen content in crop residues relative to carbon content is a major factor that determines how decomposition of the organic materials influences N availability to the next crop. Characterisation of the nitrogen from organic materials is best achieved by the use of carbon-to-nitrogen (C/N) ratios (Jansson and Persson, 1982). Carbon to nitrogen ratio is the relationship existing between the organic carbon and the nitrogen contents of soils. It is important in controlling the rate of organic matter decay and in developing sound soil management schemes (Tisdale *et al.*, 1993). The average organic matter content of mineral soils is about 20 times that of N, although the ratio varies from > 200 (N poor) to < 10 (N rich) (Brady and Weil, 1999).

2.1.1.3 Inorganic sources

Commercial fertilizer nitrogen comes in three basic forms: gas, liquid and solid. These forms are equally effective when properly applied to soils for crop production (Stevenson, 1982). In fact there is no difference between the ammonium (NH_4^-) or nitrate (NO_3^-) that enters the plant from commercial fertiliser and that produced from natural products such as manures, crop residues or organic fertilizers (Saha *et al.*, 1995) with respect to availability and plant uptake as the preference depends on the age and type of plant, the environment and soil factors. Depending on the form of N, N-carriers are classified into four groups, which are; ammoniacal fertilizers (e.g ammonium sulphate), combined ammoniacal and nitrate fertilizers (e.g calcium ammonium nitrate), amide fertilizers (e.g urea) and nitrate fertilisers (e.g sodium nitrate) (Govil and Kaore; 1996, Tandon, 1994).

2.1.2 Processes of nitrogen transformations

2.1.2.1 Nitrogen immobilization

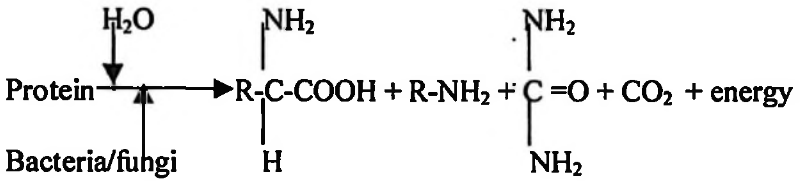
Nitrogen immobilization is the conversation of inorganic nitrogen ions (NO_3^- and NH_4^+) into organic forms of N (Jansson and Persson, 1982). When microorganisms act on the residues, they utilise inorganic N ions and convert them to organic tissues and this is how immobilization of N occurs When these microorganisms die, some of the organic N in their bodies are converted into forms that make up the humus complex and some may be released as NO_3^- and NH_4^+ (Brady and Weil, 1999).

2.1.2.2 Mineralization

Mineralization is biological release of organically bound nitrogen to inorganic mineral form of nitrogen (NH_4^+ and NO_3^-) (Tisdale *et al.*, 1993). Heterogeneous soil microorganisms decompose and hydrolyse the organic nitrogen compounds to NH_4^+ and NO_3^- that is absorbed by plants (Thompson and Troeh, 1993). It has been reported that only 2-3% of the immobilised N is mineralised annually (Brady and Weil, 1999). Mineralization involves two processes namely aminization and ammonification.

(i) Aminization

Aminization is the biological decomposition of proteins to release amine, amino acids and urea. It is represented by the following chemical equation



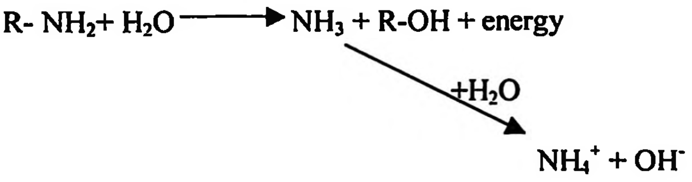
$$\text{Protein} \xrightarrow[\text{Bacteria/fungi}]{H_2O} R\text{-}\underset{H}{\overset{NH_2}{C}}\text{-COOH} + R\text{-}NH_2 + \underset{NH_2}{\overset{NH_2}{C}}{=}O + CO_2 + \text{energy}$$

(Amino acids) (Amines) (Urea) (i)

The rate of aminization is controlled by the amount of the protein and number of bacteria/fungi available during the process.

(ii) Ammonification

Ammonification is the process whereby the amines and amino acids produced by aminization of organic N are decomposed by aerobic and anaerobic bacteria, fungi and actinomycetes, with the consequent release of NH_4^+ (Tisdale and Nelson, 1975). The ammonification process is represented by the following chemical equation



$$R\text{-}NH_2 + H_2O \longrightarrow NH_3 + R\text{-}OH + \text{energy}$$

$$NH_3 \xrightarrow{+H_2O} NH_4^+ + OH^- \qquad \text{(ii)}$$

The rate of ammonification is influenced by the amount of amines and amino acids produced by aminization of organic N (protein) and the number of aerobic and anaerobic bacteria, fungi and actinomycetes in the soil.

2.1.3 Nitrogen contents in soils

Nitrogen in the soil is largely contained in the soil organic matter. Usually total N in the soil profile is highest in the surface horizon due to higher organic matter content and decreases with depth. A reverse trend may occur in peat soils or in the presence of compacted clay pan which can hold nitrate against leaching (Srivastava and Singh, 1996). The low organic matter and consequently the low N content of soils is mainly due to the tropical and subtropical climatic conditions which do not favour the accumulation of organic matter and secondly due to organic matter loss through continuous cropping (Tisdale *et al.*, 1993).

Temperature is a key deciding factor in determining the depletion and build up of soil organic matter. The total N content of soil is inversely related to temperature. At a given temperature total N content increases with increase in rainfall and also increases with altitude. Soils of arid and semiarid areas and coarse-textured soils are low in N due to intense leaching. High clay contents in soils, dominance of expandable 2:1 clay minerals and high exchangeable calcium protect N against leaching and thus maintain a higher level of N in soils (Stevenson, 1982). The 2:1 clay minerals has high isomorphic substitution capacity where cations are held tight by anions on broken edges of the 2:1 clay minerals.

2.1.4 Crop response to nitrogen fertilizers

Crop response to inorganic and organic fertilizers and soil organic amendments is controlled by time/age, method of application, type of plant, the environment and other factors. Plants absorb nitrogen whenever they are actively growing but not always at the same rate. The uptake of N per day per kg of plant weight is at maximum when the plant is young and gradually declines with age. Therefore, nitrogen constitutes a significant percentage of the dry weight in young plants than older plants (Thompson and Troeh, 1993). Plant can also absorb extra nitrogen when it is available and stores it to be used later if needed hence the mobility of N in plants (Thompson and Troeh, 1993). Carefulness on correct amount of N to be applied, timing and placement of each gram of nitrogen used by maize per year should be kept in mind (Pang and Letey, 2000) to overcome losses through leaching and immobilisation.

2.1.4.1 Time

Response to fertilizer N by plants can be affected by time of application in relation to stage of plant growth and form of fertilizer applied. For cereals, maximum use efficiency of fertilizer nitrogen is obtained during vegetative phase to grain filling stage, the stage that permit maximum utilization of fertilizer N (Tisdale *et al.*,1993). On soils with high potential for nitrogen loss (leaching or denitrification), application close to optimum crop uptake is important to minimise losses and to increase the crop response to fertilizer N (Tisdale *et al.*, 1993). Early applications, especially for fertilisers containing the nitrate form of nitrogen should be avoided so as to minimize losses through leaching (Prasad, 1996). Nitrate being negatively charged is weakly retained on the soil exchange complex at normal pH and is susceptible to leaching and denitrification (Jansson and Persson, 1982). To reduce losses due to denitrification and leaching, N fertilisers should be applied at time where crop will respond positively.

2.1.4.2 Method of application

Broadcasting and banding are the most common methods used by farmers when applying N fertilisers. Effectiveness of the method varies with cropping system and the form in which fertiliser N is applied (Uriyo *et al.*, 1979). Broadcasting is commonly used for closely spaced crops, such as small grain crops. In addition, broadcasting can be used for the fertiliser that takes long time to be converted to forms available to plants (Uriyo *et al.*, 1979). For example urea must be broadcasted prior to planting especially for short season crops for better response to fertilizer N. Banding of fertilizer N is done by applying the materials some distance below or to the side of the seed or plant. The N fertilizers are applied 5-8 cm away from the plant to avoid plant injury and fertilizer losses especially for those fertilizers with ammonium and nitrate which are susceptible to leaching and denitrification (Tisdale *et al.*, 1993). This application method is used for wide spaced grown crops like maize so as to make it easily available for crop uptake (Jansson and Persson, 1982).

2.2 Phosphorus

2.2.1 Phosphorus contents in soils

Phosphorus occurs in the soil as organic and inorganic compounds. Only about 10% of added phosphorus is immediately available to plants, the rest is rapidly converted into insoluble compounds or adsorbed on the soil particles (Mongi, 1974).

Phosphorus is the second most deficient nutrient element in cultivated soils (Jones, 1982). Low total phosphorus and high rate of fixation result in low available P in soils (Palm *et al.*, 1997). Total P in a hectare furrow slice averages about 0.18% (Jones, 1982). Some soils may contain as much as 1.25% but others may contain less than 0.075% depending on the origin of the parent materials. However, the amount of total P in a soil is not necessarily a good measure of the amount of P that is available for plant growth because a large proportion of the P may exist in forms that are not available to plants (Jones, 1982).

2.2.2 Phosphorus sources in soils

Phosphorus makes up about 0.12% of the earth crust (Cathcart, 1980). It is present in all soils and rocks, in water, in plant and animal remains and it forms complex compounds with a wide variety of elements (Cathcart, 1980). About 150 minerals are known to contain at least 0.44% phosphorus (Cathcart, 1980). The world's supply of phosphorus comes from mineral deposits, a non-renewable natural resource (Cathcart, 1980). Very small percentage is mined from secondary aluminium phosphate deposits, in which the phosphate mineral has been derived from apatite by weathering (Morgan, 1997).

The P in soils may be divided into four general categories namely P as ions and simple compounds in the soil solution, P adsorbed on the surface of inorganic soil constituents, P minerals both crystalline and amorphous and P as a component of soil organic matter (McClellan and Gremillion, 1980; Cathcat, 1980; Ussiri, 1992; Morgan, 1997). Phosphate deposits fall into three broad classes based upon their mineral assemblages, namely Fe-Al phosphates, Ca-Fe-Al phosphates and Ca phosphates. These three classes form a natural weathering sequence in which the stable Fe-Al phosphates represent the final stage of weathering (McClellan and Gremillion, 1980). The most common P minerals found in acid soils are Al and Fe-P minerals, while Ca-P minerals predominate in neutral and calcareous soils (Tisdale *et al.*, 1993). Highly weathered soils in the tropics often have low available phosphorus because of high phosphorus retention by aluminium and iron oxides and amorphous materials (Wang *et al.*, 2000).

2.2.3 Factors affecting phosphorus availability

2.2.3.1 P-adsorption capacity of the soil

Phosphorus adsorption capacity of the soils is the major factor which control available P in soils. Most soil differs in P adsorption capacities and soil properties known to influence phosphate adsorption capacities include clay minerals and hydrous oxides of Fe and Al (Thompson and Troeh, 1993). Highly weathered soils such as oxisols and ultisols are known to retain large amounts of phosphate fertilizers added to such soils. This is because oxisols and ultisols contain large amounts of 1:1 clay minerals, Al and Fe hydrous oxides which have high affinities for phosphate (Kuo, 1990).

Mankandani and Sastry (1988) reported that, phosphate adsorption increases with increase in amorphous ferri-aluminol silicates and Fe-oxides in the soil. Soils with 1:1 layer silicate clay such as kaolinite retain more P than the 2:1 layer silicate group (Singh, 1982). High capacities of 1:1 clays to retain phosphate are largely due to the high amounts of hydrated oxides of Fe and Al associated with kaolinitic clays (Rajan and Perrot, 1975). Sanchez (1976) recommended high rates of P application especially to soils with high adsorption capacities so as to saturate the P adsorption sites on the soil colloids hence rendering some of the weakly and non-adsorbed P (exchangeable P) available to plants.

2.2.3.2 Phosphate interactions in soils

The effectiveness of the P applied to the soils is better ensured when combined along with optimum N application rates. For example the interaction of 120 kgN + 60 kgP_2O_2 ha^{-1} contributed 27% to the total response to N and P (Sharma and Tandon (1992). Applications of N fertilizer often have been shown to influence the P-percentage in and total P uptake by non leguminous plants. Olson and Sander (1988) reported that, N deficiency can result in low P-contents in plants growing on soils with adequate available P.

It is reasonably well established that NH-N placed with fertilizer P in a band promotes crop uptake of the P by increasing P solubility, top growth, root growth, and altered metabolism (Engelstad and Terman, 1980). On the other hand, plant P content decreased with increasing Ca and Zn uptake (Jones, 1982). This is because Ca affects dissolution of P in the soil by the formation of insoluble calcium phosphate compounds (Adams, 1980).

2.2.3.3 Soil moisture

Phosphorus availability and uptake is strongly influenced by soil moisture since plants cannot take up P from dry soils. Maximum availability of P is associated with a soil moisture tension at around one third bar (Ussiri, 1992). Excessive moisture results in poor soil aeration and restricts P uptake by plants due to anaerobic conditions and formation of insoluble phosphate. Dry soils often results in the precipitation of orthophosphate in various forms of calcium phosphate. Therefore, during a period of dry weather the surface soil becomes dry and plants suffer from P deficiency because of insufficiency water (Ussiri, 1992). Medium to fine (clay) textured soils which have high P adsorption capacity can not adsorb P when P is applied to dry clay soil (Olson and Sander, 1988).

2.2.3.4 Soil pH

The extent of soil pH to affect the availability of P depends on acidity and alkalinity of the soil. The highest availability of P to plants in most soils is at pH range 6.0 to 6.5 (Porter and Sanchez, 1992). In moderate to strongly acid soils that contain exchangeable Al and Fe, the Fe and Al fix the available P. In soils near or above pH 7.0, most of the P is tied up in Ca compounds. With time, P in these Ca compounds is held more and more tightly (Aldrich *et al.*, 1975) hence unavailable to plants because they are not found in soil solution. When materials such as limestone are added to a soil with neutral pH, the solubility of P will be decreased because calcium carbonate causes precipitation of P (Tisdale *et al.*, 1993). When limestone is added to acid soils hydrolyse to calcium, carbonate and hydroxyl ions. The hydroxyl ions react with aluminium and iron to form aluminium/iron hydroxides. The reaction deactivates aluminium and iron to react with P resulting into increased P availability to plants (Tisdale *et al.*, 1993; Jones, 1982).

2.2.3.5 Methods of application of P fertilizers and P use efficiency by plants

There are several methods for fertilizer P application namely broadcasting, banding, foliar application, fertigation and injection. However phosphorus fertilizers are commonly applied to soils by either broadcasting or banding. Broadcasting is the application of fertilizer over the entire soil surface, either by hand or by using machinery (Uriyo *et al.*, 1979). Generally P is applied prior to planting since the growing plant needs P for growth and development (Jain and Shara, 1993).

Application of P fertilizer through broadcasting leads to low P concentration in the soil solution due to the fact that the applied P is mixed with a soil that causes P adsorption (Sanchez, 1976). For phosphates of low solubility, broadcast application is the most effective method since it encourages a higher dissolution rate as it tend to reduce the formation of reaction products of lower solubility and allows intimate mixing with the soil. Broadcast application of P fertilizers is necessary where higher rates of P are employed in an effort to build up soil P levels for future crops productions (Olson and Sander, 1988). When phosphorus materials are broadcasted on acid to neutral soils they dissolve easily (Engelstad and Terman, 1980). Neutral to slightly acid soils permit the most efficient use of phosphate fertilizers, but basic and acid soils fix phosphates in forms unavailable to plant roots (Jones, 1982). Later broadcast application to the soil surface after the emergence of the crop will not be effective, except for sands (Olson and Sander, 1988). Sandy soil have low P fixing capacity as the P fixing capacity of soil increases with increasing clay content of the soil.

Banding is the method of fertilizer placement which involves placing fertilizer either below or to the side of the seed or plant. Banding 4 to 5 cm to the side of the seed row has generally proved to be the most effective placement in deriving maximum "starter" benefit and greatest yield increase per unit of applied P in the case of maize (Engelstad and Terman, 1980). Banding is more advantageous when P fertiliser is more water soluble than insoluble P fertilizers. Banding at early planting dates increases the response of crops to fertiliser P (Aldrich *et al.*, 1975).

2.2.4 Crop response to phosphate

The rate of plant uptake of P is partly dependent on the availability of N (Sharma and Tandon, 1992; Adams, 1980). It has been found that a small amount of N included in a P fertiliser makes it more effective (Thompson and Troeh, 1993). Organic P becomes available to plants after mineralization, a process mediated by microorganism. In the tropics where mineralization rates are high, soil organic P has been found to meet a high proportion of the P requirement of crops (Ussiri, 1992). Plants uptake of P is largely governed by three major factors namely the type of plant, the stage of maturity and the competition between the plant roots and soil components for soil and fertilizer P (Jones, 1982).

Plants vary widely in their ability to obtain sufficient P from soils. For example buckwheat and alfalfa are considered strong feeders of P from soils which have low available P and from those fertilised with rock phosphate. Oat hay contains about 0.18% P and alfalfa hay 0.3% when they are both grown on soils containing ample supplies of available P (Jones, 1982). High yielding crops require high amounts of available P throughout the growing season (Jain and Shara, 1993). Generally long season crops, such as corn, outgrow early growth responses to applied P with little effect on final yield (Jones, 1982). Root development of such crops usually allow uptake of soil P adequate for later growth. Corn and sorghum are quite efficient in utilisation of P as compared with small grains (Jones, 1982).

For short-season crops, such as vegetables, growth responses to added P tend to persist until harvest. Root development is often inadequate for P uptake during the short growing period (Engelstad and Terman, 1980). Hanway and Olson (1980) reported that corn is significantly more responsive than soybeans to fertiliser P application, so in a corn-soybean rotational system it is advantageous to apply the P fertiliser recommended for the corn crop. Similarly, wheat responds to P at higher soil P levels than required for maximum yields of corn, presumably due to the fact that wheat makes most of its growth under colder soil conditions which reduce P solubility. The amounts of P taken by crops vary among the different crops species and variety, and the amounts of P fertiliser required to maintain optimum P levels in the soils also vary (Manang, 1976).

Young plants assimilate P very rapidly, and accordingly need water-soluble P forms that move to the meager root system (Reid, 1980). Later, as the roots develop into more extensive and efficient system that is in contact with more soil volume, it absorbs sufficient P from less soluble forms. Plants with more extensive root systems, like corn, absorb P from larger volumes of soils and are therefore better placed to obtain sufficient P from the soil than for example, mungbean which has limited root system (Jones, 1982).

2.3 Pressmud (Filtermud)

Pressmud (PM) or filter mud is the waste product obtained from the manufacture of sugar from sugar canes (Yadav, 1995). Pressmud is a soft, spongy, amorphous and dark brown to brownish white material containing sugar, fibre, coagulated colloids, including cane wax, albuminoids, inorganic salts and soil particles (Yadav, 1995). The composition and properties of pressmud is very variable depending upon the quality of the cane crushed and the process followed thereafter for the clarification of the cane juice in the sugar factory (Kumar and Mishra, 1991). For example sulphur pressmud (SPM) contains about 1.0-3.1% N, 0.6-3.6% P and 0.3-1.8% K and some of the micronutrients (Yadav, 1995) as compared to carbon pressmud (CMP) which contains 0.6-0.9% N, 0.3-2.4% P and 0.3-1.6% K.

2.3.1 Uses of pressmud

Pressmud has been used mainly as a source of plant nutrients, an amelioration for acidic and sodic soils when (CMP) and (SMP) are used, respectively. CMP contains 60-70% $CaCO_3$, and therefore it can be used as liming material in acid soils (Datta and Gupta 1983a, b), whereas SMP has been used in reclamation of sodic soils. It has been reported that the addition of SMP to a saline-sodic soil reduced the pH, EC and ESP (Sahi and Rai 1978). Pressmud can be used as medium for raising some seedlings due to its high P content and carrier for legume inoculants as it maintain higher population (Yadav, 1992).

It has often been argued that a year old pressmud is superior to fresh pressmud with regard to its effects on soil properties and plant growth (Yadav, 1995). However, recent studies have shown that fresh pressmud can be used without any adverse effects on soils and crops, therefore for agricultural purposes; pressmud does not require any processing prior to its application to soils (Yadav, 1995). However, Patil and Kale (1983) and Thopate *et al.* (1991) suggested that application of fresh pressmud might be harmful to plants due to its high wax content, which ranges between 8-15%. Wax is the predominant factor which retards the decomposition of pressmud and release of nutrients like the nitrogen contained in it (Yadav, 1995). It is therefore, recommended that pressmud must undergo decomposition before use for better crop response/growth.

2.3.2 Pressmud as a source of plant nutrients

Pressmud contains all the essential plant nutrients both macro and micro, though in small amounts (Yadav, 1995). The plant nutrients contained in the pressmud become available to plants after the degradation (decomposition) of the pressmud added to soils. The use of pressmud has benefited the growth of many plants through direct, residual and cumulative effects (Yadav, 1995). Application of pressmud to soil has been reported to increase the yields and quality of various crops, maize inclusive, when applied to soils. It has been argued that the effect of pressmud on the yields and quality of various agricultural crops is a net combined effect of all its chemical and physical attributes (Yadav, 1995). Application of SPM and CPM to acid soils has been reported to significantly increase the yields of various crops (Kapur and Kanwar, 1989; Yaduvanshi and Yadav, 1993; Datta and Gupta, 1983a,b). For example direct application of carbonation pressmud to an acid soil increased the grain yield of maize by 3.15 tha^{-1} (+157%) (Datta and Gupta, 1983a). Application of SPM and CPM each at the rate of 10 tha^{-1} was found to be optimal for a rice-maize rotation (Kumar and Mishra, 1991).

Besides the benefits which accrued from the direct application of pressmud to soils, their residual effects on soil fertility has been reported to significantly improve the yields of many crops (Yadav, 1995). The residual soil fertility from 10 t ha^{-1} of pressmud was found to be optimal for maize (Kumar and Mishra, 1991) and the residual effect was due to the gradual release of plant nutrients from the filtermud by the degradation (decomposition) processes. Integrated use of pressmud with fertilizer N have been reported to increase the crop recovery of fertilizer N, in addition to its positive effects on the physical, chemical and biological properties of the soils (Yadav, 1995). Yaduvanshi and Yadav (1990, 1991) obtained an increase of 4-8% of the N use-efficiency by sugar cane with the combined application of 10 tha^{-1} of SPM and 75-100 kg N ha^{-} in clay loam soil (pH 7.8). The yield increases in each year were partly due to decline in soil pH and exchangeable sodium percentage and increase in infiltration rate of the sodic soil. The higher availability of nitrogen and phosphorous and improved physical environment with pressmud treatment has contributed to the high yields of different crops (More, 1994).

2.3.3 Effect of pressmud on soil properties

Pressmud like any other organic soil amendment affects the physical, chemical and biological properties of soils. The contents of soil organic carbon, plant available N, P, K, Zn, Mn and other plant nutrients have been reported to increase with the additions/applications of increasing rates of pressmud to most soils (Yadav, 1995). Research carried out in India and elsewhere showed that SPM decreased the pH of clay loam soils (Rai *et al.*, 1980; Borde *et al.*, 1984) but had no effect on the pH of silty clay loam soils (Kumar and Mishra, 1991). It has also been reported that SPM increased the electrical conductivity of clay loam soils (Yaduvanshi and Yadav, 1990) but decreased the electrical conductivity and sodium adsorption ratio of calcareous saline sodic soils (Singh *et al.*, 1986). The SPM decreases the sodium adsorption capacity of clay loam soils and therefore make soluble salts available while in calcareous saline sodic soils the sulphate reacts with sodium to form sodium sulphate which is easily leachable.

Application of CPM to acid soils have been reported to increase the soil pH and exchangeable Ca and Mg (Datta and Gupta, 1983a,b), increase the organic carbon, and available K but decreased the availability of P in silty clay loam soils (Kumar and Mishra, 1991) because calcium carbonate enhances P fixation. CPM has been reported to decrease the electrical conductivity of soils (Yaduvanshi and Yadav, 1990), because it contains much $CaCO_3$ and act as a liming material on acid soils.

2.3.4 Effects of pressmud on nutrient uptake by plants

Application of CMP and SPM to different soils has been reported to enhance the nutrient uptake by various crops (Yadav, 1995). For example uptake of sulphur by mustard plants (Narwal *et al.*, 1991), N, P, and K uptake by greengram (Borde *et al.*, 1984), N and Zn uptake by maize (Gupta *et al.*, 1986), P and Ca uptake by maize and wheat (Datta and Gupta, 1983a) and N, P and K uptake by sugarcane (Patil and Kale, 1983; Yaduvanshi and Yadav, 1990) were increased significances. A four-fold increase in the uptake of N and Zn by maize as a result of the application of pressmud was obtained by Gupta *et al.* (1986). Increase in nutrient uptake by plant with the application of pressmud have been reported both for the direct and residual effects of pressmud (Yadav, 1995).

2.3.5 Scope of pressmud use in agriculture

Pressmud has a vast potential for practical application in agriculture as a source of plant nutrients and organic matter and as an amendment for sodic and acidic soils (Yadav, 1995). However, the bulkiness, high moisture content and thus high transport and labour costs restrict the use of pressmud to the zones/vicinities of the sugar factories. It has been reported that use of pressmud may increase the magnitude of termite infestations (Yadav, 1995) because termites use undecomposed organic materials as food. The possibilities of using pressmud as a carrier for Azotobacter

(Sanoria, 1965) and *Rhizobium japonium* (Tilak and Subba Rao, 1978) has been suggested (Yadav, 1995). In raising seedlings of sugarcane pressmud have been found to be superior to farmyard manure (Kapoor and Singh, 1954).

According to Amolo *et al.* (1996) there is an increasing demand for pressmud as a bio-fertilizer among farmers in sugarcane growing areas. However, the limited availability or supply of pressmud restricts the demand. Based on the very low prices of pressmud as compared to those of inorganic fertilizers and the nutritive value of pressmud, pressmud could significantly supplement the use of inorganic fertilizers hence increasing yields at low production costs. Further use of pressmud in crop production will sustain soil productivity by improving the physical, chemical and biological properties of the soils under cultivation.

CHAPTER THREE

3.0 MATERIALS AND METHODS

A glasshouse pot experiment to study the response of maize to nitrogen, phosphorus and filtermud applied to a *Dystric nitosols* was carried out at Sokoine University of Agriculture (SUA), Morogoro, Tanzania. The *Dystric nitosols,* was collected from the central part of SUA farm. The sources of N and P were ammonium sulphate ($(NH_4)_2SO_4$) and monopotassium phosphate (KH_2PO_4), respectively. The test crop was maize (*Zea maize* var. Staha).

3.1 Filtermud and soil sampling

3.1.1 Collection and preparation of the filtermud for analysis

The filtermud was obtained from Mtibwa Sugar Factory, Turiani, Morogoro, Tanzania. The filtermud was air dried, shredded and ground into fine material. One hundred grams were taken for laboratory analysis.

3.1.2 Soil sampling and preparation

A composite topsoil sample made of 20 sub-samples was collected from the central portion of SUA farm, from an area covering about 0.25 ha. The 20 sampling locations/ points in the 0.25 ha were selected at random and the sampling depth was 0-30 cm. About 30-40 kilograms soil samples were collected from each sampling point/ location, hence about 700 kg soil in total were gathered.

The 20 soil sub-samples were thorough mixed together, air-dried, pulverised and sieved to pass through 6 mm sieve. The 6 mm sieved soil was further mixed to homogenise the composite soil sample. A sample portion of about 200 g was taken from the homogenised composite soil sample, ground and sieved through 2 mm sieve for laboratory analysis for the characterisation of the soil. The 6 mm sieved soil was used for the glasshouse pot experiment.

3.2. Laboratory analysis

3.2.1 Analysis of the soil (*Dystric nitosols*)

The pH of soil was measured in water at 1:2.5 soil: water ratio as described by Mclean (1982). The organic carbon (OC) was determined following the Walkley - Black method (Nelson and Sommers, 1982). The cation exchange capacity (CEC) was determined by the neutral ammonium acetate (1 M NH_4, OAc) saturation method as explained by Rhoades (1982). Total N was determined using the micro -Kjeldahl digestion and distillation method (Bremner and Mulvaney, 1982). The amounts of exchangeable Ca, Mg, K and Na in the neutral 1 M NH_4OAc filtrates were determined by atomic absorption spectrophotometer (AAS). Available phosphorus was extracted by the Bray 1 procedure (Bray and Kurtz, 1945). Phosphorus in the extract was determined colorimetrically after developing the blue colour with ascorbic acid as described by Murphy and Riley (1962).

The available micronutrients Zn, Cu, Mn, and Fe were extracted by 0.005 M DTPA, following the method by Lindsay and Norvell (1978). The exchangeable Al^{3+} and H^+ were extracted with 1 M KCl and determined by titration with 0.1 N NaOH and 0.1 N

HCl as described by McLean (1982). Total exchangeable acidity was the summation of Al^{3+} and H^+ ions. The particle size distribution was determined by the Bouyoucos hydrometer method (Gee and Bauder, 1986).

3.2.2 Analysis of the filter mud

The filtermud was analysed for its plant nutrient contents and pH. The nutrients determined were total phosphorus which was determined by wet digestion method using H_2O_2-HNO_3-H_2SO_4-$HClO_4$-HF mixture and the P in the digests were measured spectrophotometrically at 882 nm (Juo, 1979). Total nitrogen was determined by the semi-macro Kjedahl method (Bremner, 1996). Total potassium, magnesium, calcium, copper, zinc, iron and manganese were determined by wet digestion using H_2O_2-HNO_3- H_2SO_4-$HClO_4$-HF mixture and the quantities of potassium, magnesium, calcium, copper, zinc, iron and manganese in the digest were measured by AAS (Juo, 1979). The pH was measured by the electrometric method using a 1:5 filtermud:water suspension (Thomas, 1996). Organic carbon was determined by the wet oxidation method of Walkley and Black (Nelson and Sommer, 1982).

3.3 Glass-house pot experiment

The filtermud N-P glasshouse pot experiment was carried out at SUA, Morogoro.

Fifty-four 12 kg composite soil sample portions previously ground and sieved through 6 mm sieve were weighed into 10 litre capacity plastic buckets with holes at the bottom loosely plugged by cotton. Accordingly, the weighed soil sample portions in the pots were thoroughly mixed with filtermud, N (as ammonium sulphate) and P (as KH_2PO_4) at the rate of 0, 15, 30 tha^{-1}, 0, 50, 100 $kgha^{-1}$ and 0, 75, 150 $kgha^{-1}$

respectively, in a 3^3 factorial experiment in a complete randomized block design (Appendix 1). After thoroughly mixing the filtermud, the inorganic N and P fertilizers with the soils in the pots, distilled water was added to the buckets to raise the soil moisture contents to field capacity and equilibrated/incubated for three weeks (21 days) to allow decomposition. After three weeks of incubation/equilibration, 5 maize seeds were planted in each pot/bucket.

The maize plants in the bucket were allowed to grow for six weeks. During the growing period the moisture content of the soil in the buckets were maintained or kept at field capacity. Field capacity is usually taken as the moisture content of a soil which has drained freely for one to two days after saturation (Landon, 1991). After the 6th week of growth the maize plants were harvested. The plant portions harvested were the portions above the soil levels in the individual buckets.

3.4 Preparation of the maize plants for laboratory analysis

The harvested maize plants were oven dried for 48 hours at 70 °C to constant weights for dry matter determination. The plant materials were then ground into fine powder using a Tecator 1093 Cyclotec sample mill and analysed for N, P, and K. Total nitrogen was determined by semi-macro Kjeldahl (Bremner and Mulvaney, 1982). Total phosphorus and K were extracted by wet digestion using H_2O_2-HNO_3-H_2SO_4-$HClO_4$-HF mixture and determined spectrophotometrically at 882 nm by AAS (Juo, 1979) respectively.

3.4.2 Statistical analysis

Analysis of variance was used to analyse the dry matter yields and nutrient uptake / contents of the maize plants. Means were separated by using the New Duncan's Multiple Range Test.

The statistical model used for data analysis was

$$X_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_{ijk} + \varepsilon_{ijk}$$

Where; X_{ijk} = response, μ= general effect, α_i = effect due to factor A,

β_j = effect due to factor B, γ_k = effect due to factor C,

δ_{ijk} = interaction effect, ε_{ijk} = error effect

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 The physical and chemical properties of the experimental soil

Some of the properties of the soil used in the current study were as presented in Table 1. Particle size analysis indicated that the *Dystric nitosols* had 66% clay, 6% silt, and 28% sand. According to the soil classification system by FAO (1977) the textural class for the *Dystric nitosols* was clay. Soils dominated by clay have properties of swelling, shrinking, plasticity and cohesion under various moisture conditions, but when dry tend to be hard and cloddy. Depending on the mineralogy of clay, such a soil permits greater adsorption and retention of water.

The soil pH as determined in 1:2.5 soil:water suspension was 4.8. Landon (1991) categorised pH values as follows; very high (> 8.5); high (7.5-8.5); medium (5.5-7.0) and low (< 5.5). According to the above categorisation the pH of the *Dystric nitosols* was rated as low that is the soil has a very strongly acidic reaction. The optimal pH range for maize production is 6 to 7 (Purseglove, 1988), but maize can be generally grown in soils with pH outside the 6-7 range if proper management practices are implemented.

The NH_4F-HCl extractable P (Bray-1-P) of the soil was found to be 3.10 mg P/kg soil. According to the categorisation by Landon (1991), Bray-1-P < 15 mg P/kg soil is rated as low.

Table 1: Some of the chemical and physical properties of the soil used in the study (*Dystric nitosols*)

Parameter	Unit
pH(water)	4.90
CEC (cmol/kg soil)	12.30
Extractable P (mg/kg soil)	3.10
OC (%)	1.08
OM (%)	1.86
TN (%)	0.09
Exchangeable bases (cmol(+)/kg soil)	
Ca	2.45
Mg	2.10
K	0.47
Na	0.31
Micronutrients (mg/kg soil)	
Mn	28.44
Fe	12.95
Cu	12.27
Zn	1.99
Exchangeable acidity (cmol(+)/kg soil)	1.82
Al	1.57
H	0.25
Partical size analysis (%)	
Sand	28.00
Silt	6.00
Clay	66.00
Textural class	clay

The low level of Bray-1-P in the *Dystric nitosols* could probably be due to low level of P in the soils parent materials and conversions of P into forms not extractable by the Bray-1-P reagents because of the strongly acidic nature of the soil (Tisdale *et al*., 1993). This is further supported by the observations that phosphorus is deficient in most agricultural soils (FAO, 2000) due to continuous P uptake by plants. A critical level of P concentrations for maize production in Morogoro region is 25 mg kg^{-1} soil (Singh *et al.,* 1977). Therefore, based on the above critical P level, the *Dystric nitosols* requires supplemental P from other sources like inorganic fertilizers and manures, for maize production.

Total nitrogen for the *Dystric nitosols* was 0.09% and rated as low according to the rating by Landon (1991). This is apparently due to low organic matter content in the soil and the fast transformations of organic matter which take place in tropical soils. According to Kaaya *et al.* (1994) total N > 0.2% is highly suitable for maize production for the soil used in the current study. The organic carbon (1.08%) and organic matter (1.86%) in the *Dystric nitosols* were ranked as low according to Landon (1991). The ranges of organic carbon and organic matter reported by Landon (1991) as being low are 0.60-1.25 and 1.0-2.0, respectively. The low organic carbon content in the soil could be due to non-return of crop residues and weeds/ grasses to the soil. Kaaya *et al.* (1994) observed that organic carbon in the range 1.0-2.0 was found to be moderately adequate for maize production for the *Dystric nitosols* at the SUA farm.

According to Landon (1991), the CEC of the *Dystric nitosols* is rated as being on the lower side. The low CEC of the soil is related to the low organic matter content in the soil and the very strong acidic nature of the soil which is a reflection of the extent of weathering of the soil. Based on the textural class of the soil and the low CEC of the soil it could be argued that the clay mineralogy of the clay fraction of the soil (66% clay) is dominated by the 1:1 clay minerals and the hydrous oxides of AL, and Fe, whose CEC are very low. Dominance of the 1:1 clay minerals, Al and Fe oxyhydroxides and low soil pH show that the *Dystric nitosols* is highly weathered. Kaaya *et al.* (1994) observed that CEC levels of 6-12 cmol/kg soil were marginally suitable for maize production for the *Dystric nitosols* at the SUA farm.

The exchangeable Ca, Mg, K, and Na values were 2.45, 2.10, 0.47, and 0.31 cmol (+)/kg soil, respectively. The values for exchangeable Ca, and Na, were rated as low while that of Mg and K were rated as medium based on the rating by Landon (1991). The low values for exchangeable Ca and Na and medium values for exchangeable Mg and K could be attributed to the Ca, Mg K and Na contents in the parent materials from which the soil was formed and to the pH of the soil.

The exchangeable acidity and aluminium values of the soil were 1.82 and 1.57 respectively. According to Landon (1991) the exchangeable acidity and exchangeable Al, could be rated as medium, hence might negatively affect plant growth. Generally maize root growth and development are restricted in soils with medium to high exchangeable Al. Aluminium tends to accumulate in the roots and impede the uptake and translocation of Ca and P to the tops. DTPA extractable Mn, Fe, Cu and Zn were

28.44, 12.95, 12.27, and 1.99 mg/kg soil, respectively. According to Lindsay and Norvell (1978) the values of DTPA extractable Mn, Fe, Cu and Zn were rated as high. The high values of the DTPA extractable micro-nutrients are related to the pH of the soil where acidic conditions enhance the dissolution of the compounds and minerals containing the micro-nutrients in question. It could also be argued that the contents of Fe, Zn Mn and Cu in the parent materials of the *Dystric nitosols* were high.

Since maize can grow in a wide variety of soils (Purseglove, 1988), the *Dystric nitosols* could also be used for maize production if the deficient nutrients are added to the soil in the form of fertilizers and manures. Better management techniques are required, for example addition of organic materials that will not only supply plant nutrient, but also maintain water retention of the soil and neutralise the exchange acidity and aluminium to the acceptable levels.

4.2 Some of the properties of the Filtermud

Some of the properties of the filtermud used in the current study were as presented in Table 2. The pH of the filtermud as determined in 1:5 FM:water suspension was 7.74, the wide ratio was used to get enough suspension as FM used has high water absorption capacity. Landon (1991) categorised pH values as follows; very high (> 8.5), high (7.5-8.5), medium (5.5-7.0) and low (< 5.5). According to the above categorisation the pH of the FM was rated as high, which is alkaline in nature.

Table 2: Some of properties of the filtermud used in the study.

Parameter	Unit
pH (water)	7.74
Phosphorus (%)	1.00
OC (%)	46.74.
OM (%)	80.58
TN (%)	1.15
C:N	41:1
Ca (%)	2.08
K (%)	0.60
Mg (%)	0.52
Na (%)	0.2
Micronutrients (mg/kg filtermud)	
Fe	8 497.50
Mn	705.20
Cu	43.45
Zn	114.05

The alkalinity of the filtermud would probably affect the pH of the soil, by raising the pH of the soil accordingly, hence improving the soil conditions for maize plant growth. For example Kumar and Mishra (1991) and Datta and Gupta (1983a, b) reported that carbonation pressmud increased the pH of silty clay loam soil and used for liming acid soils in India and proved to be quite effective.

The total P of the FM was 1.0%, according to the ranking by Tandon (1995), the P content of the FM was high. Addition of the FM to the soil could contribute to increased available P which could increase the uptake of P by the maize plants. The total N for the FM was 1.15% and rated as low according to the rating by Tandon (1995). The values of OC and OM were 46.74% and 80.58% respectively. The values were high according to ranking by Landon (1991). The ratio between OC and total N was wide (41:1) thus the filtermud could probably cause immobilisation of the available soil N. Similar observations were reported by Amolo *et al.* (1996) where the wide C:N ratio of the FM resulted to immobilisation of the available soil N.

The total Ca, K Mg and Na were 2.08%, 0.6%, 0.52% and 0.2%, respectively. The values for total K and Na were rated as low while that of Ca and Mg were rated as high based on the ratings by Tandon (1995). The high Ca and Mg in the FM could probably result into liming effect by raising the soil pH. Total micronutrient contents of the FM namely Fe, Mn, Cu and Zn were 8497.50, 705.20, 43.45 and 114.05 mg/kg respectively. According to Tandon (1995) ranking, the values for Fe, Mn, Cu and Zn were high. The high values of micronutrients in the FM could probably due to high content of available micronutrient of the soil in which the sugarcane was grown. The

FM used in the current study can be used to add nutrients in the soil and as soil conditioner for better maize plants growth.

4.3 Pot experiment

4.3.1 Visual observations on the maize plants

The effect of the different levels of N, P and FM applied to the *Dystric nitosols (Oxic haplustults) based* on visual observations made during the whole period of the growth of the maize plants were as shown in Plate 1 and 2. The maize plants in the control pots ($N_0P_0FM_0$) showed N and P deficiency symptoms from the 2nd week of plant growth. The plants were green in the first week of growth, thereafter the intensity of the green colour decreased with time from the second week up to harvest (6th week). The maize plants became chlorotic, with thin stems, light yellow colour in the lower leaves and purplish leaves. The chlorotic and light yellow colour of the leaves could be attributed to the low level of the available nitrogen in the soil. The purplish colour of the leaves was due to P deficiency caused by low available P in the soil used in the current study (Refer to Table 1). The N and P deficiency symptoms conform to the very low levels of total N and available P in the *Dystric nitosols.* The maize plants in pots treated with FM (main effect) showed negative response with increasing levels of FM applied. The maize plants showed N and P deficiency symptoms that increased with time. The maize plants were yellowish and purplish in colour, stunted growth with thin stems. The N and P deficiencies could be attributed to low available N and P in the soil, and biological immobilisation of the available soil N, P and other essential

Plate 1: Appearance of maize plants with 100 kg N/ha (pot 3), 150 kg P/ha (pot 19) and 30 t FM/ha (pot7) applications at five weeks of plant growth.

Plate 2: Appearance of maize plants without N, P and FM applied (pot 1) and 50 kg N-75 kg P-15 t FM (pot 14) and 100 kg N-150 kg P-30 t FM (pot 27) at five weeks of plant growth.

as a result of the wide C:N ratio (Table 2) of the FM used in the current study. The high P from the FM was not showed positive effects, these could probably affected by low N and immobilisation of soil P during decomposition of the FM.

Positive response was observed when the N fertilizer (main effect) was applied to the *Dystric nitosols*, with increasing rates of N. The maize plant was vigour and greenish with thick stems. The improvement in the growth performance of the maize plants might be due to addition of N to the soil for the maize plants uptake. Furthermore, increased availability and utilisation of N by maize plants increased the capacity of the plants to absorb other available nutrients from the soil.

Phosphorus use efficiency by the maize plants, increased with increasing application of the P fertilizer (main effect), where the pots treated with P showed positive response to P but showed N deficiency symptoms. The purplish colour of the maize plants caused by P deficiency decreased with increasing P levels. Decreased P deficiency probably could be due to increased availability of P in the soil when P was applied as KH_2PO_4.

Maize plants in pots treated with FM-N combination increased the maize plants vigour, greenish colour and had strong stems with increasing levels of FM-N applied. The improvement of the maize plants probably resulted from the release of the nutrients from the mineralisation of the FM after its decomposition and increased available N due to addition of $(NH_4)_2SO_4$ to the soil. Furthermore, the application of fertilizer N contributed to the narrowing of the C:N ratio and probably reduced biological immobilisation of the available soil N and also add N to the soil.

Application of N and P increased the maize plants dark green colour and vigour with increasing rates of N-P combination. The green colour of the maize plants was maintained up to the harvesting stage. This could be attributed to the addition of the available N and P in the soil, thereby improving nutrient balance between N and P in the soil and consequently enhancing the uptake of N and P by maize plants. Increased chlorotic and weak stems of the maize plants were observed in pots treated with FM and P, which increased with increasing levels of FM-P applied. These could be due to low available soil N (Table 1), imbalance of available N and P in the soil and the wide C:N: ratio of the FM which caused biological immobilisation of the soil N.

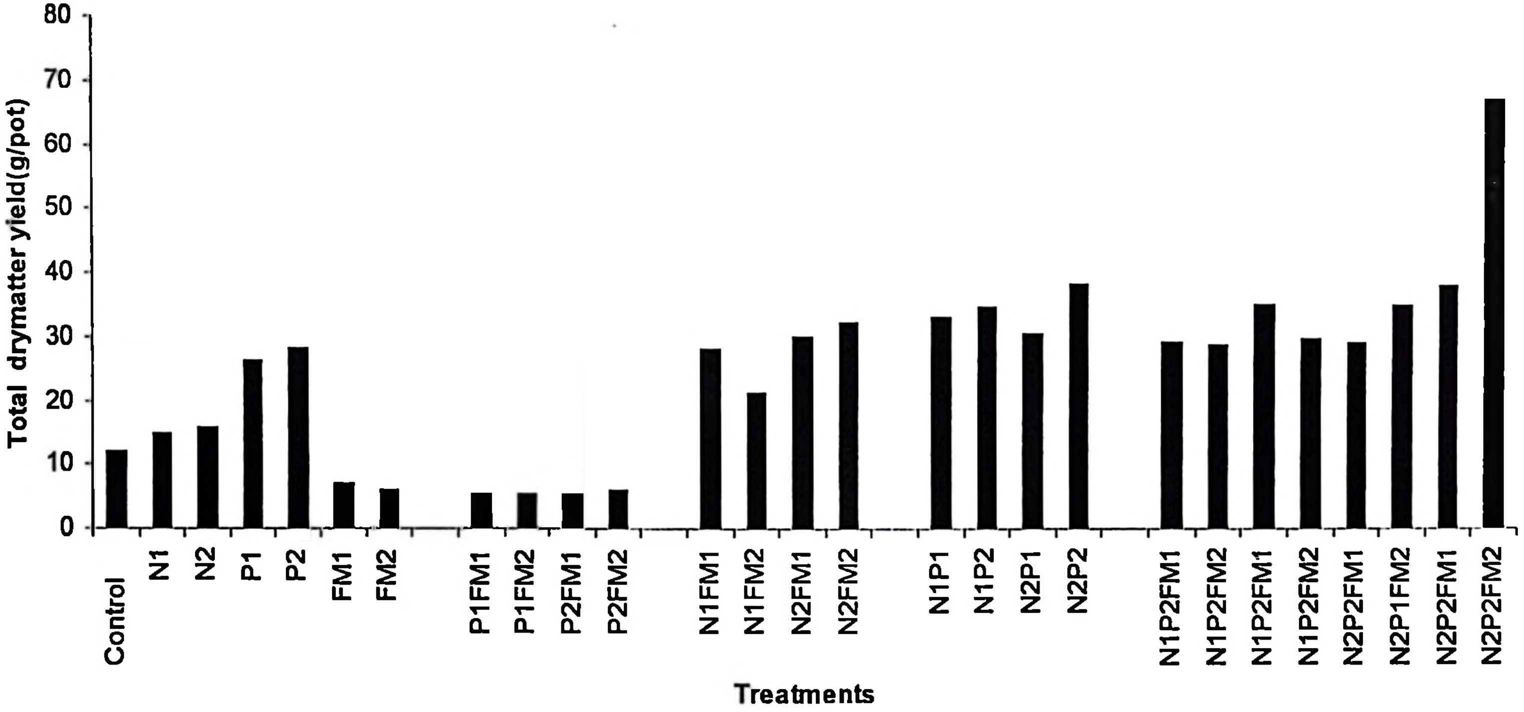
Increasing levels of N-P-FM applied to the *Dystric nitosols* increased the maize plants vigour, and green colour. The maize plants were observed to respond positively for the $N_{100}P_{150}FM_{30}$ which was the maximum combination of N, P and the FM used in the current study. The high maize plants vigour probably could be due to additions of the available soil N and P. Moreover, the available N and P in the soil might have contributed to narrowing C:N:P ratio hence increased decomposition and mineralization of the FM which released and increased availability of some of the essential nutrients in the soil.

4.3.2 The effect of N, P and FM and N-P-FM interaction on the dry matter yields, N, P and K contents of the maize plants

4.3.2.1 Effect on dry matter yields of the maize plants

The response of the maize plants in terms of dry matter yields to different rates of N, P and FM applied to the *Dystric nitosols* were as presented in Figure 1 and Appendix 2. The dry matter yields of the maize plants increased with increasing levels of N (main effect of N) and P (main effect of P) and decreased with increasing levels of FM (main effect of FM) applied to the *Dystric nitosols*. The increase in dry matter yields with increasing levels of N applied as $(NH_4)_2SO_4$ and P as KH_2PO_4 to the soil were attributed to the increased availability of the essential nutrients N, P and K. This result conform to the results obtained by Sharma and Tandon (1992) who reported that, application of N and P to soils deficient in N and P like the *Dystric nitosols* used in the current study increased dry matter yields of maize plants. Decrease in dry matter yields with increasing levels of FM applied to the soil was highly significant. The decrease could be attributed to the biological immobilisation of the essential nutrients available in the soil as a result of the wide C:N:P ratio of the FM. Similar results have been reported by Ndaki (2001). The dry matter yields of the maize plants increased with increasing levels of N-P, N-FM and N-P-FM combinations, and decreased with increasing levels of P-FM applied to the *Dystric nitosols*. Combined application of N-P as $(NH_4)_2SO_4$ and KH_2PO_4, increased the availability of N, P and K in the soil for plant uptake. The application of N, P and K in the soil increased the dry matter yields of the maize plants.

Figure 1: The effect of N, P and FM on drymatter yield of the maize plant



Where:-

Control =No nitrogen, phosphorus and filtermud applied

N1=.Nitrogen applied at 50 kg/ha

N2= Nitrogen applied at 100 kg/ha

P1= Phosphorus applied at 75 kg/ha

P2= Phosphorus applied at 150 kg/ha

FM1= Filtermud applied at 15 t/ha

FM2= Filtermud applied at 30 t/ha

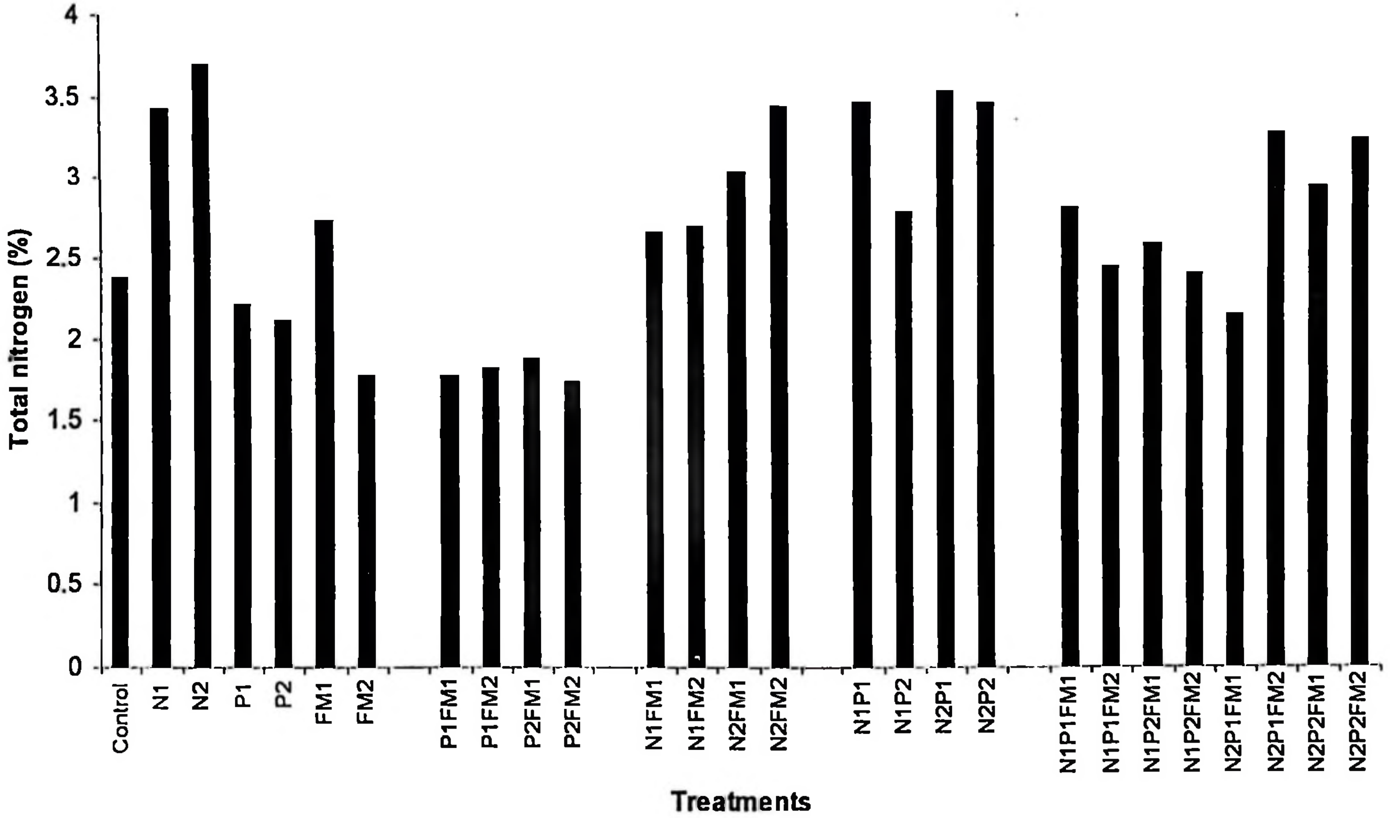
However the increase in the dry matter yields with increasing rates of N-FM added to the soil could be attributed to increased availability of N in the soil added as $(NH_4)_2SO_4$ and release of the essential nutrients from the decomposition and mineralization of the FM. Similar observation have been reported by Amolo *et al.* (1996) and Yaduvanshi and Yadav (1993) who observed significant increases in dry matter yields when FM and N are applied to soils deficient in N and P.

The increase in dry matter yields of the maize plants with increasing N-P-FM combination (Figure 1 and Appendix 2), could be attributed to the availability of N, P and K due to addition of $(NH_4)_2SO_4$ and KH_2PO_4 to the soil and the release of other essential nutrients after decomposition and mineralization of the FM. The increased in availability of the nutrients increased the uptake and consequent increase dry matter yields. These results conform to the results reported by Singh and Yadav (1992) and Tandon (1992)

4.3.2.2 Effect on the N contents of the maize plants

The response of the maize plants in terms of N accumulation by the maize plants to the different levels of N, P and FM applied to the *Dystric nitosols* was as presented in Figure 2 and Appendix 3. The percent N contents in the whole maize plants increased with increasing levels of N added to the soil (the main effect of N), decreased with increasing levels of P (main effect of P) and FM (main effect of FM) (Figure 2). The effects of the different N-P-FM combinations were more complex, that is, increased or decreased depending on the various levels of combinations of nitrogen, phosphorus

Figure 2: The effect of N, P and FM on the N contents of the maize plants



Where:-Control= No nitrogen, phosphorus and filtermud applied

N1=.Nitrogen applied at 50 kg/ha P1= Phosphorus applied at 75 kg/ha FM1= Filtermud applied at 15 t/ha

N2= Nitrogen applied at 100 kg/ha P2= Phosphorus applied at 150 kg/ha FM2= Filtermud applied at 30 t/ha

and filtermud. The significant increase in the percent N contents in the maize plants with increasing rates of N applied to the soil as $(NH_4)_2SO_4$ could be accounted for by the increased availability and absorption of N by the maize plants, hence increased accumulation of N in the maize plants. Initially, the *Dystric nitosols* was deficient in total N, hence application of N as $(NH_4)_2SO_4$ increased the levels of N in the soil and consequently increased the availability of N.

However, even at the highest level of N (100 kg N/ha) applied to the soil, the percent N contents in the maize plants were below the critical percent N content in the maize plants (young leaves) which ranges between 3.5% to 5.0% according to the rating by Landon (1991), Okalebo *et al.* (1993) and Tandon (1995).The lower percent N in the maize plants could be attributed to the fact that the percent N in the current study are based on the whole plants, while the critical levels of Landon (1991), Okalebo *et al.* (1993) and Tandon (1995) of 3.5% to 5.0% N are based on the young maize plants leaves which accumulate high N during vegetative phase of growth. Further based on the Liebig's Law of Minimum or limiting nutrients, the percent N contents in the maize plant could also have been influenced by the availability of the other essential nutrient elements. The deficient levels of most of the essential macro-nutrients in the *Dystric nitosols*, magnified the applicability of the Liebig's law of minimum with increasing level of applied N on the percent N contents in the maize plants (Tisdale *et al.*, 1993). The application of N to the *Dystric nitosols* further magnified the antagonistic effects between nutrients and imbalances of nutrients in the *Dystric nitosols* (Tisdale *et al.*, 1993). The antagonistic effect of the nutrients means the increase of one nutrient can lead to the decrease of the other nutrient.

The trend of the results of percent N in the maize plants with the application of N to the *Dystric nitosols* conform to the results reported by Nambiar (1996) who reported that application of N fertilizer alone at different rates to maize plants resulted in small increase in percent N contents. It could therefore, be argued that for the effectiveness of N applied, the deficient elements must also be applied to the soil at levels that meet the nutrient requirements by the maize plants (Tisdale *et al.*, 1993; Jain and Shara, 1993; Biswas *et al.*, 1996).

The application of P as KH_2PO_4 alone (main effect of P) to the *Dystric nitosols* decreased the percent N contents in the maize plants with increasing levels of applied P (Figure 2). The decrease in percent N contents in the maize plants with increasing levels of P applied to the soil could possibly be due to nutrient imbalances particularly between N, P and K, and the dilution effect due to increased growth (dry matter yields) of the maize plants with the application of phosphorus. Similar observations have been reported by Tandon (1996), Sharma and Tandon (1992) and Tisdale *et al.* (1993).

The decrease in the maize plants in percent N contents in the maize plants with increasing levels of filtermud (main effect of filtermud) as presented in Figure 2 could be due to the immobilization of the initial N in the *Dystric nitosols* by the soil microorganisms particularly bacteria and actinomycetes, during the biological transformations of the filtermud. The soil N microbiological immobilisation during the transformation of the filtermud added to the soil was due to the very wide C:N ratio of the filtermud (C:N= 41:1). The decrease in percent N contents with increasing amounts of filtermud added to the soil conform to the results obtained by Amolo *et al.* (1996), who argued that the decrease in percent N contents were due to the biological immobilisation of the soil N. Tandon (1992) observed that combined application of filtermud and nitrogen positively influenced the release of N in the filtermud, hence increased availability of N, and subsequently accumulation of N in the plants. Reduced availability of N to plants by the application of organic soil amendments with wide C:N ratio (above 20:1) to soil have been obtained by Ndaki (2001) who reported that application of the sawdust on maize plants showed N deficiency caused by wide C:N ratio and low soil N. Also Amolo *et al.* (1996) reported low N release from factory ash due to its wide C:N ratio (150:1).

The percent N contents in the maize plants increased with increasing levels of N-P, decreased with increasing levels of P-FM and increased with increasing levels of N-P-FM combinations though the increase with increasing N-P-FM applications were not in well defined trends (Figure 2 and Appendix 3). The increase in percent N contents with increasing levels of N-P combination levels was attributed to the increased availability of both N and P with the application of $(NH_4)_2SO_4$ and KH_2PO_4 to the *Dystric nitosols.* The increase in percent N was expected based on the very deficient levels of initial total N and available P in the soil and with a consequent synergist effect between N and P added to the soil (Tisdale *et al.*, 1993). Similar results have been reported by Tandon (1996) and Nambiar (1996) who argued that the interaction effects of N and P applied to soils on maize plants resulted into positive response of about 27% and increased the N use efficiency.

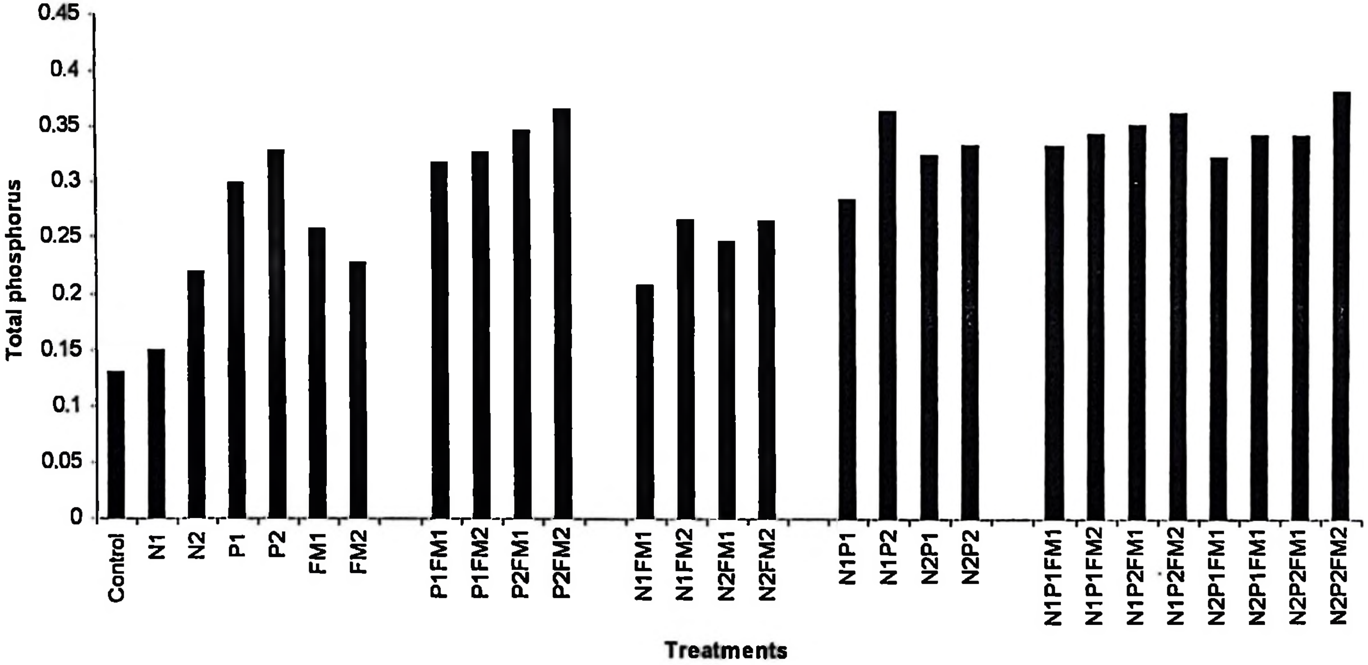
The decrease in percent N contents with increasing P-FM combinations could be attributed to nutrient imbalance in the soil and biological immobilisation of the soil N during the biological transformations of the filtermud. The increase in percent N with increasing rates of the N-P-FM combinations could be accounted for by the increase in the availability of N and P with the application of $(NH_4)_2SO_4$ and KH_2PO_4 and the consequent synergist effect between N and P and the release of N and P from the filtermud through the biological decomposition and mineralisation. Further nutrient balance in the soil resulted to the increased availability of N, P to the soil and filtermud contributed to the increase in percent N contents in the maize plants. The application of N and P positively influenced the biological transformation of the filtermud hence the release of the nutrient elements contained in complex organic compounds in the filtermud. The application of N and P narrowed the C:N:P ratio hence enhanced the biological decomposition and mineralisation of the filtermud (Tandon, 1995).

Similar results have been reported by Yadav (1995) who reported that the integrated use of FM with fertilizer N increased crop recovery of fertilizer N and enhanced the decomposition of the FM. Aldrich *et al.* (1975) reported that fertilizer N increased the rate of decomposition of the FM and consequently the release of N contained in the FM for uptake by plants. Further, Amollo *et al.* (1996) obtained superior results of percent N contents in maize plants when FM and N-fertilizers were applied together. The above increases in percent N contents in the maize plants for the N-P-FM, was attributed to the increased availabilities of N, P, K and other essential nutrients through the application of $(NH_4)_2SO_4$, KH_2PO_4 and released from the transformation of the filtermud.

4.3.2.3 Effect on the P contents of the maize plants

The response of the maize plants in terms of P uptake hence percent P contents in the maize plants at various levels of N, P and FM and N-P-FM combinations, respectively were as presented in Figure 3 and Appendix 4. The percent P in the maize plants increased with increasing levels of N, P and FM (main effect of N, P and FM) and N-P-FM combinations applied to the *Dystric nitosols*. The increase in percent P with increasing levels of N applied to the soil could have been due to the synergist relationship between N and P, where the increased level of N availability increased the ability of the plants to extract more phosphate from the soil (Adams, 1980). The increased percent P contents in the maize plants with applied P was attributed to the increased availability of P, based on the fact that the soil was deficient in plant extractable P, hence positive response to P was expected with the application of P (Tisdale *et al.*, 1993; Nambiar, 1996). The increase in percent P with increasing levels of FM added to the *Dystric nitosols*, could possibly be due to the release of P from the FM which contained 1.0% P (Table 2) rated as very high for organic residues and soil organic amendments (Landon, 1991; Tandon, 1995). The significant increase in percent P contents in the maize plants for the N-P-FM combinations (Figure 3 and Appendix 4) were attributed to the increased availability of N, P K and other essential plant nutrient resulted from application of the $(NH_4)_2SO_4$, KH_2PO_4 and decomposition and mineralization of the filtermud. The above additions and transformations in the soil could have constituted favourable nutrient balance in the soil, hence increased

Figure 3: The effect of N, P and FM on the P contents of the maize plants



Where:-

Control= No nitrogen, phosphorus and filtermud applied

N1=.Nitrogen applied at 50 kg/ha   P1= Phosphorus applied at 75 kg/ha   FM1= Filtermud applied at 15 t/ha

N2= Nitrogen applied at 100 kg/ha   P2= Phosphorus applied at 150 kg/ha   FM2= Filtermud applied at 30 t/ha

uptake of P by the maize plants. The observations made in this study are consistent with those obtained by Adams (1980), Aldrich *et al.* (1984), Olson and Sander (1988) and Borde *et al.* (1984). The increase in percent P contents in the maize plants were attributed to increased top and root growth of the maize plants, altered metabolism and increased solubility of P hence extractability of P from soil (Adams, 1980; Olson and Sander, 1988) by the maize plants.

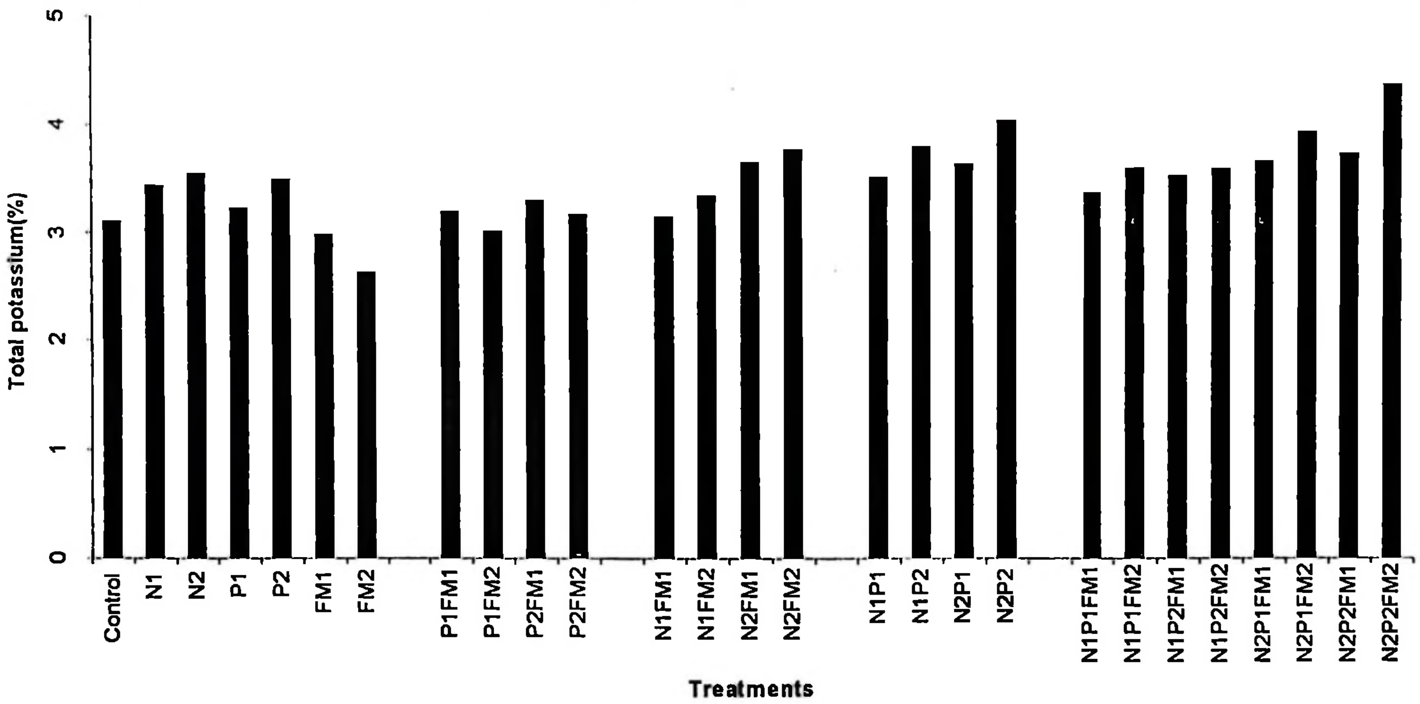
The percent P in the maize plants for P-FM, N-P and N-P-FM combinations was sufficient while for N-FM combination was low. According to Tandon (1993) ranking, the percent P of 0.3-0.5% were sufficient in the maize plants. The sufficient percent P in the maize plants could be attributed to the addition of KH_2PO_4, while the low percent P content for the N-FM combination could be attributed to the low available P in the soil used in the current study (Table 1).

4.3.2.4 Effect on the K contents of maize plants

The effect of the different levels of N, P and FM and the various combinations of N, P and FM (Appendix 1) applied to the *Dystric nitosols* on the percent K contents in the maize plants were as presented in Figure 4 and Appendix 5. The percent K in the maize plants increased with increasing levels of N, P, and with the various combinations of N-P-FM and decreased with increasing levels of FM.

The increase in percent K contents in the maize plants with the application of P as KH_2PO_4 (main effect of P) was attributed to the K applied to the soil as KH_2PO_4, hence increased availability of K for the maize plants. The increased percent K in the

Figure 4: The effect of N, P and FM on the K contents of the maize plants



Where:-Control= No nitrogen, phosphorus and filtermud applied

N1=.Nitrogen applied at 50 kg/ha P1= Phosphorus applied at 75 kg/ha FM1= Filtermud applied at 15 t/ha

N2= Nitrogen applied at 100 kg/ha P2= Phosphorus applied at 150 kg/ha FM2= Filtermud applied at 30 t/ha

maize plants with increased N-additions as $(NH_4)_2SO_4$, (main effect of N) could be accounted for by the increase maize root growth, hence increased ability of the maize plants to scavenger for more K from the soil. Further, the possibility of NH_4^- from the $(NH_4)_2SO_4$ to displaced K^- on the soil exchange sites and the interlayer K^- could have increased the activities of K^- in the soil solution, hence increased uptake of the soil solution K by the maize plants.

The decrease in percent K in the maize plants with increasing FM additions (main effect of the FM) could be associated with nutrient imbalances in the soil and both biological and chemical immobilisation of the available soil K (exchangeable K and K in the soil solution) during the processes of transformations of the filtermud in the soil. However, the effect of FM on the K uptake from the soil with medium exchangeable K levels, like the *Dystric nitosol* used in the current study needs or calls for further investigation. However, based on the low percent K in the filtermud, it could be postulated that, availability of K would accordingly decrease with increasing levels of filtermud applied to the *Dystric nitosols*.

The increase in percent K in the maize plants for the various combinations of N-P-FM (Appendix 1) could be attributed to favourable nutrient balance in the soil as a consequent of the applied N and P fertilizers and the nutrient ions released from the decomposition and mineralization of the filtermud. The results obtained in the current study concur with the results reported by Olson and Sander (1988) who argued that application of P and K together intensified the effective utilisation of K. Further Burgess (1992) and Dogo *et al.* (1994) reported increase in K uptake by various plants with the application of N fertilizers. The applications of N and P enhanced the biological and chemical decomposition of the filtermud, through their effect on the C:N ratios of the filtermud and the soil (*Dystric nitosols*).

The percentage K in the maize plants (Figure 4 and Appendix 5) for N, P and FM and N-P-FM combinations were sufficient, according to Tandon (1995) who ranked the percent K ranged 2.5-4.0% as sufficient for the growth of in maize plants. The sufficient percent K in the maize plants could be attributed to medium level of K in the soil used (Table 1), addition of K as KH_2PO_4 and mineralization of the essential nutrients after the decomposition of the FM.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of this experiment was to study the response of maize to nitrogen, phosphorus and filtermud applied to the *Dystric nitosols.* The aims of the study were to determine the nutrient content of the soil and filtermud and to observe the response of the maize plants to nutrients uptake and in terms of dry matter yields. Nitrogen and phosphorus were applied in form of inorganic fertilizers while the filtermud was the organic material from a sugar factory. The soil used in the current study was *Dystric nitosols*, characterised by low fertility status with respect to N, P, Ca and Na. The *Dysric nitosols* had pH of 4.9 which was very strongly acid soil.

The filtermud used in the current study was characterised by low N, K and Na and high P, Ca and Mg contents. The pH of the filtermud was 7.7 which could have probably raised the pH of the *Dystric nitosols.* The carbon content of the FM was high which contribute to the wide C:N ratio, moreover, the wide C:N ratio could attribute to immobilisation of the available soil nitrogen. Application of the FM decreased the dry matter yields, uptake of N, P and K. The decrease could probably be attributed due to immobilisation of the available N, P and K due to wider C:N:P ratio of the FM.

Application of N increased the dry matter yields, percent N, P and K contents of the maize plants with increasing level of application. Addition of N to the soil increased the available soil N hence improving the balance between P and K consequences its uptake by the maize plants.

When P was applied to the soil as KH_2PO_4 it resulted in increased dry matter yields and percent P and K contents of the maize plants. However, P application resulted into decreased percent N of the maize plants. The increase could be attributed to increased available soil P and K, however the decreased in N content could be attributed to imbalance of the nutrients available in the soil.

The dry matter yields, N, P and K contents increased with increasing levels of N-P, N-FM, N-P-FM combinations. However dry matter yields and percent N contents decreased with increasing levels of P-FM. These increases could be attributed to the increased availabilities of N, P, K and other nutrients released from decomposition and mineralization of the FM, moreover, the decreased in dry matter yields, N content could probably be due to imbalances of the nutrients particularly N, P and K and immobilisation of the available N to the soil.

5.2 Recommendations

1 Soil pH has to be raised to the optimum range for maize growth, through liming with appropriate liming material.

2 Nitrogen and phosphorus should be applied as fertilizers for easy uptake.

3 For the improvement of the physical, chemical and biological properties for optimal maize production N, P and FM have to be applied together.

4 The N, P and FM combinations for the highest maize yield in the current study were $N_{100}P_{150}FM_{30}$, however the yield was not optimum and rate has to be confirmed under field conditions.

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7.0 APPENDICES

Appendix 1: Experimental design of N, P and FM treatments on maize plants

$P_0FM_0N_0$	$P_0FM_0N_1$	$P_0FM_0N_2$	$P_0FM_1N_0$	$P_0FM_1N_1$	$P_0FM_1N_2$	$P_0FM_2N_0$	$P_0FM_2N_1$	$P_0FM_2N_2$
$P_1FM_0N_0$	$P_1FM_0N_1$	$P_1FM_0N_2$	$P_1FM_1N_0$	$P_1FM_1N_1$	$P_1FM_1N_2$	$P_1FM_2N_0$	$P_1FM_2N_1$	$P_1FM_2N_2$
$P_2FM_0N_0$	$P_2FM_0N_1$	$P_2FM_0N_2$	$P_2FM_1N_0$	$P_2FM_1N_1$	$P_2FM_1N_2$	$P_2FM_2N_0$	$P_2FM_2N_1$	$P_2FM_2N_2$

Where:-

N0= No nitrogen applied

N1=.Nitrogen applied at 50kg/ha

N2= Nitrogen applied at 100kg/ha

P0= No phosphorus applied

P1= Phosphorus applied at 75kg/ha

P2= Phosphorus applied at 150kg/ha

FM0= No filtermud applied

FM1= Filtermud applied at 15tonnes/ha

FM2= Filtermud applied at 30tonnes/ha

Appendix 2 : The effects of N, P and FM on the dry matter yields of the maize plants.

Treatment	FM0			FM15			FM30		
	N0	N50	N100	N0	N50	N100	N0	N50	N100
					Dry matter yields (g)				
P0	11.86j	14.85j	15.79j	7.04k	28.39gh	30.31fgh	6.07k	21.57l	32.37defg
P75	26.43h	33.28defg	35.94cd	5.20k	29.50gh	30.79efgh	5.33k	29.18gh	35.57cde
P150	28.47gh	34.83cdef	43.18b	5.33k	35.47cde	38.69c	5.87k	30.09fgh	68.44a

Means in the same column followed by the same letter(s) are not significantly different at 0.005 according to the New Duncan Multiple Range Test.

Appendix 3 : The effects of N, P and FM on the N contents of the maize plants.

Treatment	FM0			FM15			FM30		
	N0	N50	N100	N0	N50	N100	N0	N50	N100
					Percent Nitrogen				
P0	2.37fghij	3.43abcde	3.70ab	2.75cdefg	2.68defgh	3.06a	1.79j	2.72defgh	3.47abcd
P75	2.21fghij	3.49abcd	3.57abc	1.79j	2.86cdefg	2.19fghij	1.84ij	2.49fghij	3.33abcde
P150	2.12ghij	2.82cdefg	3.50abcd	1.89hij	2.63efghi	3.00bcdef	1.75j	2.45fghij	3.30abcde

Means in the same column followed by the same letter(s) are not significantly different at 0.005 according to the New Duncan Multiple Range Test

Appendix 4 : The effects of N, P and FM on the P contents of the maize plants.

Treatment	FM0			FM15			FM30		
	N0	N50	N100	N0	N50	N100	N0	N50	N100
				Percent phosphorus					
P0	0.13q	0.15p	0.22n	0.26k	0.21o	0.25l	0.23m	0.27j	o.27j
P75	0.3h	0.29i	0.33f	0.32g	0.34e	0.33f	0.33f	0.35d	0.35d
P150	0.33f	0.37b	0.34e	0.35d	0.36c	0.35d	0.37b	0.37b	0.39a

Means in the same column followed by the same letter(s) are not significantly different at 0.005 according to the New

Duncan Multiple Range Test.

Appendix 5 : The effects of N, P and FM on the K contents of the maize plants.

Treatment	FM0			FM15			FM30		
	N0	N50	N100	N0	N50	N100	N0	N50	N100
					Percent potassium				
P0	3.11def	3.43bcdef	3.54bcde	3.00ef	3.18cdefo	3.70abcde	2.65f	3.38bcdef	3.82abcde
P75.	3.24cdef	3.56bcde	3.69abcde	3.21abg	3.43bcdef	3.75abcde	3.04def	3.67abcde	4.03abc
P150	351bcde	3.86abcd	4.12ab	3.32bcdef	3.61bcde	3.82abcde	3.19cdef	3.69abcde	4.47a

Means in the same column followed by the same letter(s) are not significantly different at 0.005 according to the New

Duncan Multiple Range Test