# MINERALIZATION OF NITROGEN AND PHOSPHOROUS FROM COMMONLY USED ANIMAL MANURE IN TANZANIA

**BY**

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# ABSTRACT

A study was conducted at Sokoine University of Agriculture (SUA), Morogoro, Tanzania during 2007/08. The objective of the study was to evaluate extent of mineralization of N and P from four commonly used animal manure in Tanzania namely; poultry, pig, goat and cattle. The study involved a ten week incubation experiment and a glass house experiment in which okra was used as a test crop .The experimental design for the two experiments was split plot with manure types as the main plots and application rates as sub-plots. Results of the incubation experiment indicated that application of the four manure types significantly ($p<0.01$) increased N and P levels. Generally, Poultry manure resulted in highest levels of net N and P followed by pig, goat and cattle manure. The trend of N mineralization from the four manure types resembled that of P mineralization. Similar trends were observed for the attributes evaluated in the pot experiment .Okra shoot dry weight and root dry weight were highest in poultry manure amended pots and lowest in cattle manure amended pots. Poultry manure had the highest levels of N and P and narrowest ratios of C/N and C/P suggesting superior mineralization of N and P. Based on the fertilizer recommendation of N and P for maize in Southern Highlands of Tanzania (N=80kg N/ha and 20kgP/ha) and the highest application rate of 300kgN/ha used in this study, applications of 10.75tons/ha of poultry manure 12.84tons/ha of pig manure 18.47tons/ha of goat manure and 21.27tons/ha of cattle manure will meet the recommendation of 80kgN/ha. The above application rates will also provide 12.43kgP/ha, kgP/ha,11.54kgP/ha,13.76 kgP/ha and 10.97kgP/ha for poultry, pig, goat and cattle manure respectively which will not meet P recommendation. Based on the above the following are recommended: (1) Efforts should be directed towards

improvement of animal manure quality in order to reduce amounts required to meet N and P recommendations. (2) Manures should be supplemented with inorganic P or other sources such as rock phosphate. (3)Training programmes should be designed for farmers and extension staff to sensitize them on manure use and management practices.

# DECLARATION

I, Mlowe Chrispin Fredrick, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been nor concurrently being submitted for a higher degree award in any other University.

…………………………………… …………………………

Mlowe Fredrick Chrispin Date

( MSc candidate )

The above declaration is confirmed

…………………………………… …………………………

Prof. Kimbi, G.G. Date

(Supervisor)

## COPYRIGHT

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I am indebted to many individuals for their support and encouragement for the success of my program. I would like to express my sincere thanks to my Supervisor Prof. G. G. Kimbi for his wise guidance, constructive criticism and sincere encouragement in carrying out this study.

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My wife Restuta and my daughter Dorothea, who constantly prayed for me and accepted to miss me for most of the time of this study, deserve special appreciation; may God grant them more endurance.

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Lastly, but not least, I thank all who helped me in one way or another to make this work fruitful.

# DEDICATION

This work is dedicated to my father, Chrispin Mlowe, to my Mother, the late Dorothea Mponda for without their awareness in education, this achievement would not have been possible.

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# LIST OF ABBREVIATIONS AND ACRONONYMS

| | |
|---|---|
| % | Percentage |
| < | Less than |
| > | Greater than |
| $^{o}C$ | Degrees centigrade |
| AAS | Atomic absorption spectrometer |
| ANOVA | Analysis of variance |
| C | Carbon |
| Ca | Calcium |
| CEC | Cation exchange capacity |
| cm | Centimetre |
| Cmol (+) kg $^{-1}$ | Centimole (+) per kilogram |
| C/N | Carbon to nitrogen ratio |
| Cu | Copper |
| CV | Coefficient of variation |
| *et al.* | And others |
| FYM | Farmyard manure |
| Fig. | Figure |
| g | Gram |
| g pot $^{-1}$ | Gram per pot |
| ha | Hectare |
| kg | Kilogram |
| L | Litre |

| | |
|---|---|
| LSD | Least significance difference |
| $m^2$ | Meter square |
| MAC | Ministry of agriculture and cooperatives |
| MAFS | Ministry of agriculture and food security |
| Mg | Magnesium |
| mg | Milligram |
| MSTATC | Program for data analysis |
| Na | Sodium |
| $NH_4OAc$ | Ammonium acetate |
| ns | Not significant |
| OC | Organic carbon |
| OM | Organic matter |
| P=0.05 | Probability level of 0.05 |
| PBS | Percentage base saturation |
| pH | Negative logarithm of hydrogen ion concentration |
| Prof. | Professor |
| PSD | Particle size distribution |
| SUA | Sokoine University of Agriculture |
| DSS | Department of soil science |
| ASDP | Agriculture sector development program |
| RDM | Root dry matter |
| SDM | Shoot dry matter |
| µ | Micro |

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Back ground information

Agriculture is the predominant sector of the Tanzanian economy. It contributes about 60% of the GDP and employs about 80% of the entire population (Europa World, 1994). The main contributors to Tanzanian economy are small-scale resource poor farmers who largely depend on simple farm inputs. Over the years, agricultural production in Tanzania has not been encouraging due to various reasons such as use of inferior seeds/planting materials, pests and diseases, unreliable rains and low soil fertility. Many African countries continue to require increasing amount of food aid because their agricultural production does not match with the population growth (World Bank, 1996).

Increased food production in developing countries will require integrated approaches that focus on increased land productivity. Soil fertility management is one of the major areas that need to be looked into. Most soils in Tanzania are generally infertile due to various reasons. Major ones include different forms of land degradation and nutrient mining that is not consistent with the rate at which nutrients are added to the soil (Bekunda *et al*., 1997). Sustainable land productivity and soil fertility improvement calls for judicial use of inputs such as fertilizers.

The use of inorganic fertilizers in Tanzania has over the years drastically decreased mainly due to removal or insignificant fertilizer subsides (Kimbi *et al*., 2004;

Swinner *et al.,* 2005). Consequently, most of the resource poor farmers cannot afford high prices of the inorganic fertilizers.

There is therefore a need to promote possible fertilizer alternatives such as animal manure, compost and crop residues (Lekasi *et al.*, 2003). Manures have a number of attributes, which are vital for crop production. Manure provides a cheap source of various essential plant nutrients. Utilization of animal manure as fertilizer will not only result in increased production but will also help in solving sanitary, environmental and soil conservation problems threatening livelihoods in both rural and urban areas (Kanyanyua *et al*., 2003). The most outstanding attributes of manure is provision of long term effect on soil fertility and improvement of structure, tilth and permeability (Pratt *et al.,* 1982).

Application of manure to agricultural land has been viewed as an excellent way to recycle nutrients and organic matter that can support crop production and maintain or improve soil quality. Management is a single key factor that to a large extent determines the extent to which nutrients contained in manure can effectively be used for crop production.

Improper storage, application methods and handling conditions of manure lead to nutrient losses resulting in low nutritive values. Efficient use of manure means supply of proper amount of plant nutrients at the correct time in a plant available form while at the same time avoiding losses as much as possible (Kimbi and Semoka, 2004).

Tanzania is endowed with abundant animal manure which if judiciously used can enormously increase crop production. Kimbi *et al*. (2001) estimated animal manure output in Tanzania and observed that available manure for agricultural use is about 14 metric tons per year .Irrespective of this potential very few farmers use animal manure for crop production, this is largely due to limited knowledge by most extension staff and farmers in qualitative aspects .For example, animal manure utilization for crop production in extensive grazing systems is less than 10% (Maerere *et al*., 2001).

Numerous studies have investigated N release, and, to a lesser extent, P release from manure in the first weeks to several months after manure application (Castellanos and Pratt, 1981; Mafongoya *et al*., 2000). However, there is limited information on how nutrient mineralization in soils is affected by long –term applications of manure. Soil chemical, physical and biological properties are altered by manure applications (Lekasi *et al.,* 1998) and it seems possible that long –term manure incubation could change nutrient release patterns significantly.

## 1.2 Justification

Most studies on decomposition of animal manure have concentrated on quantitative aspects such as crop responses. Studies done on green manures and agro forestry species show that it is possible to use the release patterns, laboratory chemical indices and textural indices to describe quality of materials and predict rates of decomposition and N release (Melilo *et al.,* 1982; Frankenberg and Albdelmagid, 1985; Handayanto *et al.,* 1997). The rate of N and P mineralization of manures and other organic materials need to be established to optimize use and predict supplementation rates of mineral fertilizers.

## 1.3 Objectives

### 1.3.1 General objective

The overall objective of the study was to assess the extent of N and P mineralization of commonly used animal manure namely cattle, goat, poultry and pig manure.

### 1.3.2 Specific objectives

(i) Determine the extent of mineralization of N and P of four animal manure types.

(ii) Compare N and P release patterns of the four animal manure types.

(iii) Evaluate growth and yield variables *of Okra* based on application rates used in the incubation experiment.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Overview

According to NBS (2003) estimates that there are 4.8 million smallholder farmers cultivating about 44 million hectares in Tanzania. Cultivation which is mostly with family-based labour and production is mainly for subsistence. Inputs such as inorganic fertilizers, pesticides and improved seeds are rarely used. Fertilizer use remains low in most areas of the country, except for regions such as Iringa, Mbeya, Ruvuma, and Kilimanjaro, where about 30% of farmers use different types of fertilizers. According to Jayne *et al.* (2003) removal of fertilizer subsidies has adversely affected the overall fertilizer consumption for crop production in Tanzania.

Africa accounted for 2.9% of world fertilizer consumption in 2001/02 (FAO, 2003). Total inorganic fertilizer consumption in Sub-Saharan African countries including Tanzania was approximately 1% of World's fertilizer consumption. Resource poor farmers in these countries must therefore be encouraged to use available organic resources as a source of nutrients. Over the past two decades the use of inorganic fertilizers in Tanzania has been decreasing largely due to removal of fertilizer subsidies (Kimbi *et al.,* 2003). Recently, the Government has introduced "Voucher farmers inputs system" aiming at subsiding agricultural inputs particularly fertilizers and improved seeds. However, the impact of this intervention to resource poor farmers is still low calling for alternative fertilizer sources such as animal manure.

## 2.2 Extent of animal manure use in Tanzania

As stated earlier inorganic fertilizers are generally not affordable to most of the resource poor farmers in Tanzania. This is largely due to unaffordable prices of the inorganic fertilizers. Potential alternative for such farmers is to use organic fertilizers such as animal manure.

Tanzania is endowed with a large number of livestock such as cattle, goats, sheep, pigs, donkeys and poultry. Tanzania has one of the largest ruminant animal populations in Africa, ranked third in terms of cattle after Ethiopia and Sudan (MOAC, 1997). On the basis of the latest estimates, Tanzania has 16.7 million cattle, 3.5 million sheep and 12.6 million goats of which about 1% are of imported breeds and their crosses (MAFS, 2002).

According to Kimbi *et al*. (2001) animal manure output in mainland Tanzania is about 14 million tons per year. Irrespective of such enormous potential, very little amount of animal manure is being utilized for crop production in most parts of the country. This is mainly due to lack of technical know-how by most farmers which largely emanates from inadequate scientific basis for advising farmers on aspects such as application rates ,storage techniques and appropriate manure application methods (Shekiangio, 2008).

The extent of manure use in Tanzania varies depending largely on grazing system and types of crops fertilized .Animal manure consumption in Tanzania is higher in areas practicing intensive grazing system compared to those practicing extensive grazing system (Kyomo and Chagula, 1983).

Intensive grazing system is practiced in areas such as Kilimanjaro, Bukoba, Ukara and some parts of Mbeya. In these areas farmers grow perennial crops such as banana and coffee and animal manure is used to fertilize the crops. In extensive grazing system such as central part of Tanzania animal manure is hardly used .Major crops in these areas are annual crops which are in most cases not fertilized.

In order to increase the extent of animal manure use efforts should be directed towards strengthening extension service. Effective methods such as use of demonstrations and farmer field schools should be used.

Dogbe (2006) observed that frequency of visits is an important factor in adoption of technologies since extension is an open system service and a two way exchange between the farmer and extension agent.

**2.3 Decomposition of organic materials**

Decomposition is a process basically mediated by microorganisms residing in the soil. Organic materials are broken down by the action of microorganisms to simpler substances that can be taken by higher plants or microbes themselves (Swift *et al*., 1979). During the process of decomposition essential elements such as N and P are released or immobilized (Brady and Weil, 2002).

The rate at which nutrients are released depends on the nature of the material and the nutrients in question. Klausner and Boulding (1983) estimated that the fraction of organic N in fresh diary cattle that is mineralized during the first year is about 40% where by 12% is mineralized in the second year. According to Brady (1990) about 50% N in most animal manures is available for plant up take during the first year of application. Poultry manure can release up to 90% of its N in the first year (Semoka and Ndunguru, 1983). Brady and Weil (2002) observed that the first crop grown after manure application may recover about 20% of P and 50% of K. Factors determining the rate of decomposition and nutrient mobilization are the same as those that determine microbial activity. The rate of decomposition of organic materials such as animal manure depends on a number of factors. Major ones include; availability of nutrients and associated nutrient proportions, soil moisture, soil temperature, organic matter content, soil pH and Oxygen supply. These factor are discussed below.

### 2.3.1 Composition of organic materials

The elemental composition of the substrate is significant in determining activity of microbes involved in the decomposition process. When all nutritionally significant element are abundant a greater population of microbes can be supported and the process will proceed more rapidly and extensively. Nitrogen is probably the most important element in the nutrition of microorganisms responsible for decomposition since it is required for the assimilation of the C substrate in organic wastes. Phosphorous is next in importance while K, Mg, Ca, S and trace quantities of several other elements have important role in the cell metabolism (Landais *et al.*, 1993). Not only most of these nutritional elements be present in the substrate but a balance between them must occur. The balance between C and N is one of the most important aspects for the decomposition process.

Organic matter rich in carbon provides a large source of energy to soil microorganisms. Consequently, it brings population expansion of microorganism and higher consumption of mineralized N. High populations of microorganisms inhabit the upper soil surface and have an access to the soil N sources. As decomposition proceeds, carbon is released as CO2 and the C/N ratio of the substrate falls. Conversion of carbon in crop residue and other organic materials applied to the soil into humus requires nutrients (Lal, 2001).

For purposes of N release, a low C: N ratio (10-15) is preferred, allowing the N to be mineralized instead of synthesized by microbial organisms. Decreasing the C: N ratio increases the N mineralization rate.

A wide range of plant and animal materials are added to soil as organic matter. Nitrogen is key nutrients substance for microbial growth and hence leading to organic matter decomposition (Brady and Weil, 2002). Microbial action can either mineralize or immobilize nitrogen, and the principle factor determining which occurs is the C/N ratio (Handanyanto *et al.,* 1997) pointed out that, a C/N ratio of approximately 20:1 is the dividing line between Immobilization and release of nitrogen, and that when organic substances with C/N ratios wider than 30:1 are added to the soil, there is immobilization of soil nitrogen during the initial decomposition process. The initial total nitrogen concentrations of between 1.5 and

1.7 % ( Tisdale *et al.*, 1995) is reported to be sufficient to minimize immobilization of soil nitrogen. Nikokwe (1992) pointed out that the application of poor and slow decomposing organic materials with C/N ratio wider than 30:1 require supplemental nitrogen so as to meet the demands of microorganisms involved in the decomposition process. The "quality" of organic matter available for microbial decomposition is an index of its palatability, its energy content and its nutrients value. Quality is determined by; the amount of fibre, the content of carbon compound which provides the energy source for organisms involved in the decomposition and the content of nutrients such as nitrogen and phosphorus (Ross, 1989).

Other important nutrient balances are between C and P and C and S.Organic matter may also have some negative effects namely the short –term fixation of nutrients such as N,P and S into micro-organisms which may create a transient deficiency particularly at wide ratios of C with these elements. Brady and Weil, (2002) noted that decomposition process may progress at 33 percent lignin 17:1 C: N ratio, 60:1 carbon-to-phosphorus ratio, and 75:1 carbon-to-sulphur ratio. It is important to keep in mind, however, that wide C: N and C: P ratios may lead to net immobilization of nutrients that otherwise could be available for the plants (Dubeux *et al.*, 2006d). Generally, the C/P ratio <100:1 leads to mineralization whereas C/P >100 :1 leads to immobilization (Janson and Person,1982).

### 2.3.2 Soil reaction (pH)

Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and/or biological environment. Soil reaction affects nutrient availability, microbial activity, and root growth. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment (Ross, 1989).

Decomposition of organic matter is optimum at the pH range of 6.5 to 7.5, where most of the nutrient elements such as N, K, Ca, and Mg are generally more available (Uriyo *et al.,* 1979). This range of pH favors growth and activities of most of soil microorganisms responsible for the decomposition process. Many authors have noted that nitrogen release rates from organic matter are greatly reduced below pH 6.0 and microbial activity is at optimal rate when pH is about 7.5 (Ross, 1989).

Mineralization of soil organic matter is an acidifying process (Nahm, 2005). Fern *et al*. (1990) observed a decrease in soil pH from 7 to 4.5 after adding very large amounts (715mg $Nkg^{-1}$ soil ) of $NH_4^+$-N to a loamy soil, about six times the maximum amount of $NH_4^+$-N formed by N-mineralization. . Soil reaction is the main factor regulating the equilibrium between $NH_4^+$ ions and $NH_3$ gas in the manure solution. Burnett and Dondero (1969) observed that degradation of uric acid and undigested protein in the poultry manure increases their breakdown rates at pH 5.5 or higher, with an optimum pH of 9 for uricase.

Mineralization of freshly added organic material usually decrease with increasing sodicity (Van Faassen *et al.,* 2001). Nelson *et al.* (1996) noted that sodicity decreased mineralization of crops straw in clay, where as Pathak (1998) observed significant decrease in N mineralization when soil pH was increased from 8.1 to 10.

**2.3.3 Moisture content**

Decomposition process requires adequate moisture for microbial growth. Ideal moisture content is between 40% and 60% of WHC. Excessive moisture displaces the air that is necessary for microorganisms. The upper limit somewhat depends upon the material being decomposed. If the material contains straw, it may be possible to operate successfully well above 60% of WHC, because straw retains its strength at higher moisture contents and still allows air to freely move through (Nahm, 2005).

Several physical processes that can affect microbial activity vary with soil water content, particularly water movement and gas and solute diffusion. As a consequence, the relationship between soil water content and microbial processes in soils is complex because this relationship varies between soils, depending on the soil moisture-retention curve, porosity, concentration of organic matter, pH and soil depth (Palm *et al*., 2001; Sørensen *et al*., 2003). Estimation of a least limiting water content range may be a useful measure of water stress on decomposition in soils (Palm *et al*., 2004).

The more easily decomposable the substrate is, the more sensitive decomposition is likely to be to temperature and moisture (Palm *et al*., 2001).

Differences in substrate quality may explain why microbial activity in the litter layer and soil are not similarly affected by temperature and moisture (Quemada and Cabrera, 1997) and why the effects of temperature and water on microbial activity is greater in the soil surface layer than in the underlying mineral soil layers (Strong *et al*., 1999b).

Soil moisture and temperature are the major environmental factors affecting N availability from organic N sources. Soil moisture regulates oxygen diffusion in soil with maximum aerobic microbial activity occurring at soil moisture levels between 50 and 70% of water holding capacity (Frankenberger *et al.,* 1985). On the other hand, low soil moisture inhibits microbial activity by reducing diffusion of soluble substrates (Griffin, 1981), microbial mobility and intracellular water potential (Kirchmann *et al.,* 1993).

Mafongoya and Dzowela (2000) reported that net mineralized N from fresh carrot leaves increased with increasing soil moisture from 18 to 45% of WHC, but was constant up to 60% of WHC after 98 days of incubation. Water logging conditions tends to build up of an acidic and toxic condition for the microorganisms.

**2.3.4 Temperature**

Soil temperature markedly influences soil nutrient mineralization by controlling the rate of microbial activity. Different microorganism species require different soil temperatures to act efficiently. Most incubation studies suggest that the optimum temperature for organic matter decomposition and nitrogen mineralization is in the range of 25-35ºC (Ross, 1989).This range of temperature influences growth and activities of most decomposers such as bacteria, fungi and actinomycetes.

Temperatures that are below or above this range will slow down decomposition process (Troel and Thompson, 1993). The N mineralization rate constants developed from one approach reportedly varied by approximately two fold for each $10^{O}$ C change in temperature (Nahm, 2005). Mungwira and Mukurumbira (1997) reported that the N content of agricultural processing wastes and other cellulosic materials can be significantly increased by ammoniation under elevated temperatures and pressure. Studies conducted in temperate regions indicated high rates of decomposition during summer and in fall compared to winter (Knoepp and Swank, 1998). However, the temporal responses can vary due to other climatic influences. For example, Diaz-Ravina *et al*. (1993) studied soil microbial populations in Spain, a Mediterranean climate. They found that populations were lowest in the summer and winter, presumably due to limiting moisture in summer and limiting temperature in winter. In tropical forest soils, where temperature is not limiting, Wong and Nortcliff, (1995) observed that soil moisture fluctuations between wet and dry seasons largely regulate N mineralization rates.

A wide range of plant and animal materials are added to soil as organic matter. Nitrogen is key nutrients substance for microbial growth and hence leading to organic matter decomposition (Brady and Weil, 2002). Microbial action can either mineralize or immobilize nitrogen, and the principle factor determining which occurs is the C/N ratio (Thompson and Troeh, 1979). Frankenberger and Abdelmagid

(1985) and Handanyanto *et al.* (1994) pointed out that, a C/N ratio of approximately 20:1 is the dividing line between Immobilization and release of nitrogen, and that when organic substances with C/N ratios wider than 30:1 are added to soil, there is immobilization of soil nitrogen during the initial decomposition process. The initial total nitrogen concentrations of between 1.5 and 1.7 % (Tisdale *et al.,* 1990) is reported to be sufficient to minimize immobilization of soil nitrogen. Nikokwe (1992) pointed out that the application of poor and slow decomposing organic materials with C/N ratio wider than 30:1 require supplemental nitrogen so as to meet the demands of microorganisms involved in the decomposition process. The "quality" of organic matter available for microbial decomposition is really an index of its palatability, its energy content and its nutrients value.  Quality is determined by; the amount of fibre, the content of carbon compound which provides the energy source for decomposer organisms, and the content of nutrients such as nitrogen and phosphorus (Ross, 1989).

### 2.3.5 Leaching

Leaching is usually considered to be the process whereby readily soluble soil components, organic and inorganic, are removed in percolating water.  The balance between removal and replacement of nutrients ions in soil depends on the rate of leaching and occasionally volatilization, compared to input from organic matter decomposition, the weathering of soil minerals and atmospheric precipitation. The main factors influencing leaching process are; pore distribution; the amount and distribution of precipitation; topography; surface vegetation, the depth and duration hence affecting decomposition process (Ross, 1989).

## 2.4 Mineralization of N from organic materials

Mineralization is the biological conversion of organic nitrogen to inorganic forms, dominantly $N0_3$ and $NH_4$. Soil organic matter provides a substantial pool of nitrogen for mineralization. Long term mineralization of soil organic nitrogen will result in continuous depletion unless this nitrogen is replaced in the soil organic pool by external sources such as manure. Soil N mineralization potentials has been defined as the fraction of the organic N pool that is susceptible to mineralization (Stanford and Smith, 1972).

As the consequences of mineralization, ammonium and nitrates are generated and organic nitrogen disappears. These products demarcate into two distinct microbial processes; ammonification process where ammonium is formed from organic compounds and nitrification process where ammonium is oxidized to nitrates (Liang and Mackenzie, 1994).

The process in which inorganic N is transformed into organic N is refered to as N immobilization (Jansson and Persson, 1982). The aim of agricultural N management is to enhance net N mineralization at times when plants need N and to synchronize soil N mineralization (N releases) with uptake by the plant (Campbell *et al.,* 1995; Murwira *et al.,* 1995).

According to Pratt *et al.* (1973) about 50% of N in manure is in the form of simple organic compounds such as urea and uric acids which decompose in ammonium compounds when exposed to favourable environment for decomposition .The remaining N is in the form of more resistant organic compounds which decompose much more slowly by the microbial activities.

The organic N mineralizes over a period of several years at the rate which decreases with increasing time. Bouldin (1983) estimates that under New York conditions the fraction of residues which decompose each year are 40%for the first year,20% for the second year, 5% for the third year and 3% for the fourth year and all years beyond.

Pratt *et al*. (1973) have proposed that the rate of decomposition will depend on nitrogen content of material. Mineralization of organic N will vary depending on a number of factors.

As the microbes die and decay, some of the biomass N is released as $NH_4$ through the process of mineralization. Therefore, the net result of immobilization – mineralization is a decrease in the availability of the N added to soil as fertilizer, and also the partial conversion of this N to a form that is not subject to loss from the soil except by erosion. Castellanos and Pratt (1981) showed that both the organic material and soil type determine nitrogen availability. Available nitrogen varied from about 5% in very old composted dairy manure to 65% in chicken manure. They also indicated that the rate of nitrogen release over a 10-week period of each material showed that fresh chicken manure was decomposed at the fastest rate while old dairy manure was decomposed at the lowest rate because the presence of uric acids in chicken manure aggravated the fast decomposition. Data from both field and green house trials indicate that nitrogen availability from manures depends on the type of animal, the nitrogen content, and the stability of the nitrogen or the ease with which it is mineralized. In studies of the mineralization of N from various manures, Delve *et al*. (2001) encountered situations where there was an initial immobilization of N, despite the fact that the overall C: N ratio of the material was such that it would be expected to result in net mineralization.

**2.5 Mineralization of phosphorus from organic materials**

As with many soil nutrients, P is in a continuous cycle in relation to the soil and is in either inorganic or organic form. Inorganic and organic P sources contribute to the soil solution P. Organic forms include P found in humus and organic materials. Inorganic P refers to P additions from sources such as P fertilizers, naturally occurring inorganic P minerals, and mineralization of organic P. Inorganic P is added to the soil via P containing fertilizers and animal manures but can also naturally occur in soils as rock phosphates such as apatitie. However, rock phosphates are slow dissolving and contribute only a small amount of plant available P

Organic P is present in soils in the tissues and residues of plants, inositol phosphates, phospholipids, nucleic acids, nucleotides, and sugar phosphates (Tisdale *et al.*, 1990). Through mineralization, organic P is released in an available form to plants. Organic P can comprise 30 to 65 % of the Total P in soil (Harrison, 1987) with inositol phosphates representing 50% of the total organic P fraction, while phospholipids and nucleic acids represent about 1% (Anderson, 1967). The amount of P in solution at a given time is based on dissolution/precipitation of P minerals, hydrolysis of organic matter and sorption/desorption of P to Al/Fe oxides and soil surfaces (Bhatti *et al.*, 1998; Hinsinger, 2001).

Microorganisms play an important role for biochemical reactions and the release of organic P in an available form (Preusch *et al.,* 2002). Microbes immobilize P by combining orthophosphates, adenosine diphosphate (ADP) and an energy source to create adenosine triphosphate (ATP).

Manure contains significant amount of P that can be utilized for crop production. To provide P needs of a crop, the amount of P mineralized following manure application needs to be determined. Mineralization of organic P in the soil is catalyzed by various enzymes, including phytase. (He and Honeycutt, 2001).

Phosphorus availability in soils depends on phosphorus pool size, rate of geochemical P dynamics and rate of biologically P transformation (Hedley *et al*., 1982). In order to sustain plant growth phosphorus has to be added to the soil organic and inorganic forms. Soils differ significantly in phosphorus adsorption capacities and their tendency to release both native and applied phosphate to growing crops (Mugwira and Mukurumbira, 1997). Soil organic P makes up to 20-80% of total P and the P in soil solution, 20-70% may exist in organically bound forms (Subba, 1988).

Mechanisms responsible for organic P mineralization are complex. Inorganic materials released during the process are the essential plant nutrients. Mechanisms for organic P mineralization are complex to measure, because the product of mineralization is readily subject to fixation reactions in soil (Iyamurenye and Dick, 1996).

For mineralization to occur soil organic amendment must contain at least 0.2% total P otherwise net immobilization may occur (Tisdale *et al*., 1995). Generally, the C: P ratio less than 100 leads to mineralization whereas C: P ratio greater than 300 leads to immobilization (Iyamurenye and Dick, 1996).

Singh and Jones (1976) observed that when the C:P ratio was greater than 130, organic manures did not decrease P sorption, while materials low in total P such as saw dust, wheat and corn increased P sorption in the soil. Poultry manure decreased P sorption in soils compared to cattle and goat manure due to variation in carbon contents. Incubation studies conducted in four soils of Venezuela, indicated that mineralization of the most decomposable forms of organic P took 45 days under temperature range of $20^{o}C$ and $40^{o}C$ incubation. It was also observed that increasing temperature had a marked effect on the process. Moisture content does not appear to affect the process significantly, except in the most anaerobic condition, in which a slight tendency towards reduction in the percentage of mineralized P was observed (Hartz *et al.*, 2002). Mineralization trend of P is essentially similar to that of N with organic P mineralizing at the rate which decrease with time.

**2.6 Quality of Manure**

Manure quality may simply be defined as the value of manure in improving soil properties and enhancing crop yields. The fertilizer value of animal manure depends on, among other factors, animal breeds, age of dung, handling and storage practices (Murwira *et al*., 1995).

Scientists have used laboratory analysis for nutrient contents as a measure of quality. More recently the use of nutrient release patterns, using laboratory incubations of manures, and how the nutrient release can be synchronized with crop uptake has been considered a better measure of manure quality (Wanjekeche *et al*., 1999).
Western Africa samples of manure analysed show the variation in the nutrient concentration of manure samples from different locations, indicating that even on the same soil type and with the same rainfall, the response to manure application will greatly depend on the source of manure. Like wise nutrient concentration contents of manure collected from extensive and intensive grazing system obeys the same order.

Manure quality varies widely and clear indices of quality determination are sometimes difficult to apply widely. Past research has focused on evaluating different ways of managing manure to improve its quality. Preliminary studies suggest that feeding of concentrates, zero-grazing rather than traditional kraaling, manure stored under cover instead of in the open, and on concrete rather than soil floors results in higher quality manure (Lekasi *et al*., 1998).

The quality of manure varies with types of animals and feeds, collection and storage methods (Kihanda, 1996). Study conducted by Lekasi *et al.* (1998) indicated that the nutrient contents (especially N and P) of manure were in the order of poultry > pig > rabbit >goat > cattle, with manure mixed with urine having a higher quality than dung alone. Nevertheless, current characterization studies (Lekasi *et al.* 2003) indicate that manure quality is very variable, e.g. 0.23–1.76 (N %); 0.08–1.0 (P %); 0.2–1.46 (K %); 0.2–1.3 (Ca %) and 0.1–0.5 (Mg %). High-quality manure has been defined as the one with >1.6% N or C: N ratios of <10; while low-quality manure has <0.6% and C: N.

Irrespective of animal type, the quality of manure can be enhanced through feed manipulation and is more favourable in intensive grazing systems (stall or zero-grazing units) than in extensive grazing systems (communal or range grazing). In a study carried out in Eastern Africa on cattle, it was reported that manure-N concentration increased by more than two-fold when the basal diet of barley straw was supplemented with poultry waste and high-quality forage shrubs, e.g. *Calliandra* and *Macrotylama spp*. In another study, the P content in manure from cattle that received P supplements of Busumbu rock phosphate (0.70% P) and Minjingu rock phosphate (0.45% P) increased by two to four-fold above the basal diet of Napier grass (0.24% P) and bone meal (0.50% P). However, feeding animals with ‘’Unga’’ commercial feed resulted in much higher values of P in manure (0.95% P) (Kihanda and Gichuru, 2000).

## 2.7 Crop response following manure application

Most studies have shown that manure have positive long-term effects on crops. In a study by Griffin (1981), long-term effects that manure applications have on soil characteristics and subsequently N availability from recently added N were examined. Results showed that when no new N was added, net mineralization in soils with a history of organic management was twice that of soils with a history of industrial fertilizer management. When N was added, results showed a strong interaction between the type of N added and the historical management of the soil.

Soils that were historically organic amended showed larger soil C and N stocks, C and N pools that were more readily available and more microbial biomass and activity as compared to soils that were not historically organic amended.

Studies by Kihanda *et al*. (2006) showed that when manure was applied from seven consecutive years, crop yields increased and then stabilized. When manure was only applied for four consecutive years, yields remained high for seven or eight years before decreasing. Results concluded that residual effect from manure application of cattle, goat and swine could sustain crop yields for at least seven years. This implies that if a field is treated annually with an organic material, the application rate needed will become progressively smaller because, after the first year, the amount of nitrogen released from material applied in previous years must be subtracted from the total to be applied a fresh.

Schlegel (1992) observed significant sorghum grain yield increase when cattle manure was used. When a combination of cattle manure and inorganic N fertilizer was applied, greater response was obtained compared to either of the sources applied alone. Application of sheep manure to the sandy loam soil gave significantly higher yields of barley compared to where the soil was not amended .Yields were higher in the second year than during the year of application. This was attributed to increased levels of nutrients in the soil from mineralized organic components of the manure applied (Mugwira *et al.*,1997).

Liu *et al*. (1997) observed a significant increase in total dry matter yield and a general increase in plant tissue N and P concentrations in forage.

The decision on the rate of manure application needs to be based on soil N status as indicated by soil testing (Perrot *et al.*, 1993), and the expected rate availability to plants. The amount of P applied to maintain sufficient level of P in soil solution would depend on P fixing capacity of the soil. Soil with high P retention capacities will require greater rate of P fertilizer application than soils of lower retention.

**2.8 Nutrient uptake**

The amount of nutrients taken up by okra crop depends on the number of root density and the amount of dry matter produced, which in turn is influenced by a number of genetic and environmental variables. Lin *et al.,* (2007) found that, soil structure, moisture content and drainage, high soil temperature increases the mobility and absorption of nutrients, although there is reduction in K and Ca absorption during high temperature. Varieties which takes long time to mature require more nutrients than short-duration ones, mainly because of their higher production of dry matter (Marschner, 1995).

Acquisition of mineral nutrients by soil-grown plants requires two complementary processes: (a) the growth of roots to reach the nutrients; and (b) the transport of nutrients from the bulk soil to the root (Jungk and Claassen, 1997). Therefore, nutrient uptake is governed by the interactions at the soil–root interface, including (a) root morphology and growth rate; (b) nutrient absorption kinetics of the root and (c) soil nutrient supply.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Soil collection and characterization

A bulk soil sample was collected from the plough layer (0-20 cm) from Magadu farm at Sokoine University of Agriculture (SUA) farm. The farm is located at $6^{0}$51’S and $37^{0}$39’E, at an altitude of approximately 550m above sea level. The collected soil lies in the middle part of the Magadu plain with slope of about 1 % ( Kaaya, 1989).

The collected soils were used in the laboratory analysis, incubation and pot experiments. Soil characterization was carried in the Department of Soil Science Laboratory, SUA, Morogoro, Tanzania. The 2mm sieved composite soil sample was analyzed for soil pH, particle size distribution, organic carbon, cation exchange capacity (CEC), total N, available P and exchangeable bases namely K, Ca, Na and Mg.

Soil pH was determined electrometrically in 1:2.5 soil-water suspensions as described by McLean (1982). The available P was determined by the Bray and Kurtz method (Juo, 1987). Organic carbon was determined by the Walkley and Black wet combustion method (Nelson and Sommers, 1996) whereas total N was determined by the micro-Kjeldahl digestion –distillation method (Bremner and Mulvaney, 1982). Cation exchange capacity (CEC) was determined by the buffered ammonium acetate saturation method described by Okalebo *et al.* (1993). The quantities of exchangeable bases were determined following the procedure described by Thomas

(1984). Particle size distribution was determined by method described by Okalebo *et al.* (1993).and textural classes by using the USDA textural triangle.

**3.2 Manure collection and characterization**

Four animal manure samples namely poultry, pig, goat and dairy cattle manure were collected prior to the onset of rains in September 2007 from selected extensive grazing areas at Kilosa District. Sampling of manure was carried out according to Zhang (2001) in which manure sub samples were scooped from four random spots on the open kraals. The four samples were then mixed together to constitute a composite sample. The manure samples were air dried, grinded, sieved and analyzed for pH, N, P, K and OC using procedures outlined in section 3.1

**3.3 Incubation**

The soil was mixed with each of the manure types at the rates of 100mg $Nkg^{-1}$, 200mg $Nkg^{-1}$ and 300mg $Nkg^{-1}$. Using 250g of soil for each treatment, the mixture was put into 360 plastic containers with covers of Aluminium –foil and incubated in laboratory at 80% of the soil's field capacity for 10 weeks. Watering was regularly done using distilled water to avoid additional minerals nutrients. The container sizes were 80mm length with diameter of 40mm and thickness of 1mm. The average temperature of the incubation was 25° C. The free soil was also set parallel for each treatment in the same study as a control where no manure was applied. The treatments were replicated three times in a split plot design in which manure types constituted main plots whereas subplots were manure application rates. Destructive samples were taken from each container from week zero, week 1, week 2, week 3, week 4, week 5, week 6, week 7, week 8, week 9 and week 10 and analysed for available levels of N and P. Available N was extracted using 2N KCl and determined by MgO - Dervada Aloy method (Bremner, 1965) while extractable P was determined by Bray and Kurtz No.1 method (Bray and Kurtz, 1945).

**3.4 Pot experiment**

The glasshouse pot experiment was conducted with the objective of assessing the effects of different rates of animal manure on Okra growth and root- shoot dry matter yield. Four kilogram air-dried, soil was ground and passed through 6mm sieve and mixed with the animal manures. The treatments were the same as those applied in the incubation study namely; control (no manure applied), Poultry, Pig, Goat and Cattle manure each at the rate of 100kgN/ha, 200kgN/ha and 300kgN/ha. The treatments were replicated three times in split plot design as it was for the incubation experiment. The treatments were thoroughly mixed with the soil. Okra seeds were sown in the pots by direct sowing 4 seeds/pot. The plastic pots were perforated at the bottom and so the holes were plugged with cotton wool. The pots were then watered using tap water to approximately field capacity. Harvesting was done after 8 weeks of plant growth by cutting the plants 2cm above the soil level.

**Shoot and root dry matter analysis**

Okra plants were harvested by cutting at the ground level, placed in the paper bag and dried in oven at 70 $^{o}$C to constant weight. The dry matter was determined by weighing the plant material on the electronic balance.

The pots were soaked in water for several minutes to loosen the soil; the soil was removed slowly with care by aspirating water into the soil when the pot was at the slanting position. After removing all the soil, the roots were washed carefully placed in the paper bag and dried in oven at 70 ºC to constant weight. The root-shoot ratio was obtained by dividing the root dry weight over shoot dry weight, Root/shoot = Rw/Sw (Arnold and Hunt, 1978).

### 3.5 Statistical analysis

Data from incubation experiment were analyzed using the MSTAT-C program. A standard ANOVA procedure was employed according to procedures outlined by Snedcor and Cochran (1993). Duncan's New Multiple Range Test (DNMRT) was used to compare differences between treatment means.

**Net available N:**

The net available N formula used was derived by Amanullah and Mohamed, (2006) is indicated below;

Net available N= $(N_t\text{-}S_t) – (N_i\text{-}S_i)$

Where

$N_{min}$ = N mineralization in animal manures

$N_t$ = Animal manures and soil mixture total (mg $NH_4$ – N +$NO_3$-Nkg$^{-1}$ Soil) at final sampling date.

$N_i$ = Animal manure and soil mixture total mg $NH_4$ – N $NO_3$- N kg$^{-1}$ Soil) at initial sampling date.

$S_t$ = Control soil total (mg $NH_4$- N + $NO_3$ – Nkg$^{-1}$ soil) at final Sampling date.

$S_i$ = Control soil total (mg NH4+ - N + $NO_3$ N kg$^{-1}$ soil) at initial Sampling date.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 Some of physical and chemical properties of the soil used in the study

Some of the physical and chemical properties of the soil used in this study are presented in Table 1. Based on the percentage sand, silt and clay content of the soil, the textual class was designated as clay (FAO, 1990). The clay textural class of the soil would have some influence on the moisture and nutrient retention capacity of the soil hence plant nutrient availability (Brady, 1984). However, the magnitude of the influence of the texture on the soil properties would depend on the type of clay minerals and their mineralogical composition. The soil used in this study was highly weathered tropical soil namely *Oxic Haplustults* which is largely dominated by 1:1 clay minerals and some considerable amounts of aluminium oxides hence a possibility of having low ability to retain plant nutrients particularly P due to high P fixation.

**Table 1: Some of physical and chemical properties of soil used in the study**

| **Parameter** | **Unit** |
|---|---|
| pH (water) | 4.70 |
| Bray 1 extractable phosphorous (mg $Pkg^{-1}$ soil) | 3.40 |
| OC (%) | 1.08 |
| Total (N %) | 0.08 |
| CEC (cmol (+) $kg^{-1}$ soil) | 9.30 |
| Exchangeable bases (Cmol (+) $kg^{-1}$) | |
| - $Na^+$ | 0.09 |
| - $Mg^{2+}$ | 1.43 |
| - $Ca^{2+}$ | 1.84 |
| - $K^+$ | 0.49 |
| BS(%) | 40.32 |
| Bray 1 P (mg P $kg^{-1}$) | 6.30 |
| Exchangeable acidity (C mol (+) $kg^{-1}$soil) | 1.63 |
| - Al | |
| - H | 0.22 |
| Particle size distribution | |
| Sand (%) | |
| Silt (%) | 35.00 |
| Clay (%) | 8.20 |
| Textural class | 56.80 |
| | CLAY |

Results in Table 1 indicate that pH of the soil used in this study was 4.7. According to Landon (1991) this can be categorized as very low pH. This could be attributed to extensive weathering and leaching of basic cations and predominance of exchangeable $Al^{3+}$ and $H^+$ on the exchange sites and in the solution (Thomas and Hargrove, 1984). Total N and OC of the experimental soil were quite low according to the categorization by Landon (1991). This could be attributed to the high rates of decomposition and oxidation of the organic compounds and residues added to the soil, which is common in soils under tropical conditions (Uehara and Gillman, 1981).

The CEC of the *oxic Hapluslults* soil was low (Landon, 1991). This is in conformity with the soil's low pH and low organic matter content. CEC depends on the type and proportion of clay minerals and organic matter present in the soil. Soils rich in organic matter have higher CEC than those with low organic matter. Different cations are held on to the exchange sites with differing adsorption affinity or bonding strength (Woomer *et al*., 2002).

Generally, CEC ranges from less than 10 cmol/kg for sandy soils to more than 30 cmol/kg for clay loam soils. For average mineral soils, an ideal ratio of cations on the exchange complex would be 75:15:5-3 of Ca: Mg: K.

Bray extractable P of the soil was 3.40mg $kg^{-1}$ soil. According to the categorization by Landon (1991) P is rated as low. The low level of P in the soil could be due to inherently low phosphorus content in the parent material from which the soil was formed and /or high P fixation. Except for K, the amounts of exchangeable bases were generally low .Most tropical soils have no K problems. The low levels of these bases particularly Ca, Mg, and Na indicate that the soil is extensively weathered calling for amendment with fertilizers. Base saturation was 40.32 % indicating low fertility status of the soil according to the categorization by Landon (1991). This corresponds to the low values of pH, total N, OC, P and exchangeable bases observed for this soil (Table 1). Exchangeable acidity was also quite high (1.85 Cmo (+) $kg^{-1}$ soil) consistent with the low pH value suggesting accumulation of oxides of $Al^{3+}$ and $H^{+}$.

### 4.1.1 Chemical properties of the animal manure used in the study

Results in Table 2 indicate variation in terms of nutrient contents of the four manure types. On average the analyzed nutrient contents were highest in poultry manure and lowest in cattle manure. The trend was poultry>pig>goat>cattle manure. N content ranged from 1.02% (cattle manure) to 1.78% (poultry manure) where as that of P ranged from 0.32% to 0.69%. Results for N and P were similar to those reported for a similar management system which indicate that N ranges from 0.53 to 0.85% and P from 0.16 to 0.42% for cattle manure (Semoka *et al.*,1983).

**Table 2: Chemical properties of different types of manures**

| Categories of manures | -- - - - - - - - - - % - - - - - - - - - - - - - - - - - - - - - - - - | | | | | | | | Ratios | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **OC** | **N** | **P** | **Ca** | **Mg** | **K** | **Na** | **pH** | **C:N** | **C:P** |
| Poultry | 17.59 | 1.78 | 0.69 | 1.543 | 0.339 | 0.715 | 0.118 | 8.12 | 10:1 | 25:1 |
| Swine | 16.49 | 1.61 | 0.57 | 0.382 | 0.608 | 1.089 | 0.057 | 7.19 | 11:1 | 28:1 |
| Goat | 16.93 | 1.21 | 0.46 | 1.104 | 0.372 | 1.204 | 0.085 | 8.55 | 13:1 | 28:1 |
| Cattle | 16.85 | 1.02 | 0.32 | 0.19 | 0.21 | 0.50 | 0.508 | 8.45 | 17:1 | 37:1 |

The variation indicated on Table 2 could largely be due to differences in animal types since the samples were collected from the same grazing system (extensive). Results in Table 2 also indicate C/N and C/P ratios for the four manure types. These ratios followed a trend similar to that observed for nutrient contents with poultry manure having narrowest ratios compared to the rest of the manures.

The C/N and C/P ratios are measures of quality rather than quantity of the organic materials (Smith *et al.,* 1993). They are useful indicators for the extent of mineralization of organic materials. The results therefore suggest that given conducive conditions mineralization in the four manure types will adequately take place.

**4.1.2 Effect of incubation on net mineralized N**

Results of available levels of N are presented in Fig. 1, 2 and 3 and ANOVA details are provided in Table 3. There was a significant ($P<0.01$) manure type x application rate interaction during incubation suggesting variation in extent of mineralization in the four manure types. Net mineralized N of the four manure types significantly ($P<0.01$) differed from the control suggesting increased nutrition for the decomposing microorganisms.

Analysis of the results of the control over the ten week period (Fig. 1,2 and 3) indicated that net N increased gradually for the first six weeks and then decreased for the remaining incubation period. This trend can be explained on the basis of the decomposition of the soil's native organic matter. Although the control treatment was not amended with the manure, decomposition of the organic matter would usually proceed as long as conducive conditions are provided. The decrease in net N after the six week incubation period was probably due to decreased C and other nutrients required by the decomposing microorganisms.

**Table 3: Effects of rate type and time of the animal manures on the net available N**

| Rate (mg N kg$^{-1}$ ) | Manure type | Net available N (µg N /g ) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| **Control** | | 6.11h | 7.21g | 9.11f | 9.32f | 10.23f | 13.67f | 14.74g | 13.77h | 12.64g | 12.65h | 12.67h |
| 100 | Poultry | 13.52e | 15.91cd | 17.43b | 19.33b | 22.36a | 23.97b | 26.51b | 27.11c | 28.54d | 32.17bc | 32.31b |
| | Pig | 12.00f | 14.04e | 16.66c | 17.97c | 19.33c | 21.09cd | 23.18d | 24.53d | 25.97e | 27.13d | 25.67e |
| | Goat | 11.35d | 12.88f | 14.68d | 15.81cd | 16.94de | 19.48de | 19.6ef | 18.67g | 20.72g | 20.16fg | 19.75fg |
| | Cattle | 10.92g | 12.35f | 13.22de | 14.41e | 15.87e | 18.18d | 19.11ef | 17.53gh | 20.11g | 21.22h | 20.1fg |
| 200 | Poultry | 14.85d | 16.79b | 18.94bc | 19.92b | 21.48bc | 24.77b | 27.8a | 28.73b | 31.59b | 33.88b | 32.11b |
| | Pig | 14.00b | 15.73c | 18.48bc | 18.62bc | 19.24c | 20.11c | 22.65c | 23.05c | 25.11e | 27.56d | 28.11d |
| | Goat | 12.38f | 15.62cd | 16.39c | 17.81c | 19.6c | 20.97c | 21.39cd | 22.52e | 23.17de | 24.65e | 24.54f |
| | Cattle | 12.81f | 14.69e | 14.64d | 16.68cd | 17.89d | 20.11c | 20.22e | 21.76ef | 22.00ef | 23.48gh | 22.67g |
| 300 | Poultry | 16.46a | 17.73a | 20.25a | 22.58a | 22.24a | 26.55a | 27.76a | 35.19a | 36.51a | 36.08a | 37.39a |
| | Pig | 15.43c | 16.67b | 19.43a | 20.77b | 22.75a | 23.7b | 25.99b | 28.5b | 30.43c | 31.49c | 30.82c |
| | Goat | 14.54d | 15.95c | 17.53b | 19.32bc | 20.02bc | 20.11c | 22.75c | 23.34cd | 23.95de | 25.78ef | 22.38f |
| | Cattle | 14.26d | 15.26c | 16.57c | 17.2c | 19.03c | 18.52d | 20.59e | 22.65e | 22.84ef | 22.45gh | 23.85 |
| **CV %** | | 13.09 | 12.14 | 10.73 | 9.42 | 10.37 | 11.91 | 11.43 | 11.34 | 10.99 | 10.81 | 8.59 |
| **LSD** | | 1.371 | 1.090 | 1.071 | 1.071 | 1.015 | 1.202 | 1.579 | 1.643 | 1.683 | 1.492 | 1.510 |
| **$s_{\bar{x}}$** | | 0.4204 | 0.3815 | 0.3746 | 0.3746 | 0.3551 | 0.4207 | 0.5523 | 0.5749 | 0.5889 | 0.5622 | 0.5282 |

*0.1,2,3,4,5,6,7,8,9 and 10 = Incubation period (weeks) Means in the column followed by the same letter(s) within columns do not differ Significantly (P < 0.05) according to DNMRT.*

Irrespective of the type of animal manure, net soil available levels of N significantly ($P<0.01$) increased with rates of application during the entire incubation period. The highest rate of application resulted in highest levels of N for all manure types. The trend for the effect of application rate on available levels of N was 300mgNkg$^{-1}$ >200mg Nkg$^{-1}$ >100mgNkg$^{-1}$ **.**

The increase in soil available levels of N with application rates could be attributed to increased microbial activities as a result of increased concentration of nutrients. This could have resulted in enhanced decomposition of organic forms of N hence increased availability of N. Similar results were reported by Maerere *et al.* (2001) who observed that applications of higher rates of animal manure resulted into increased levels of net available N.

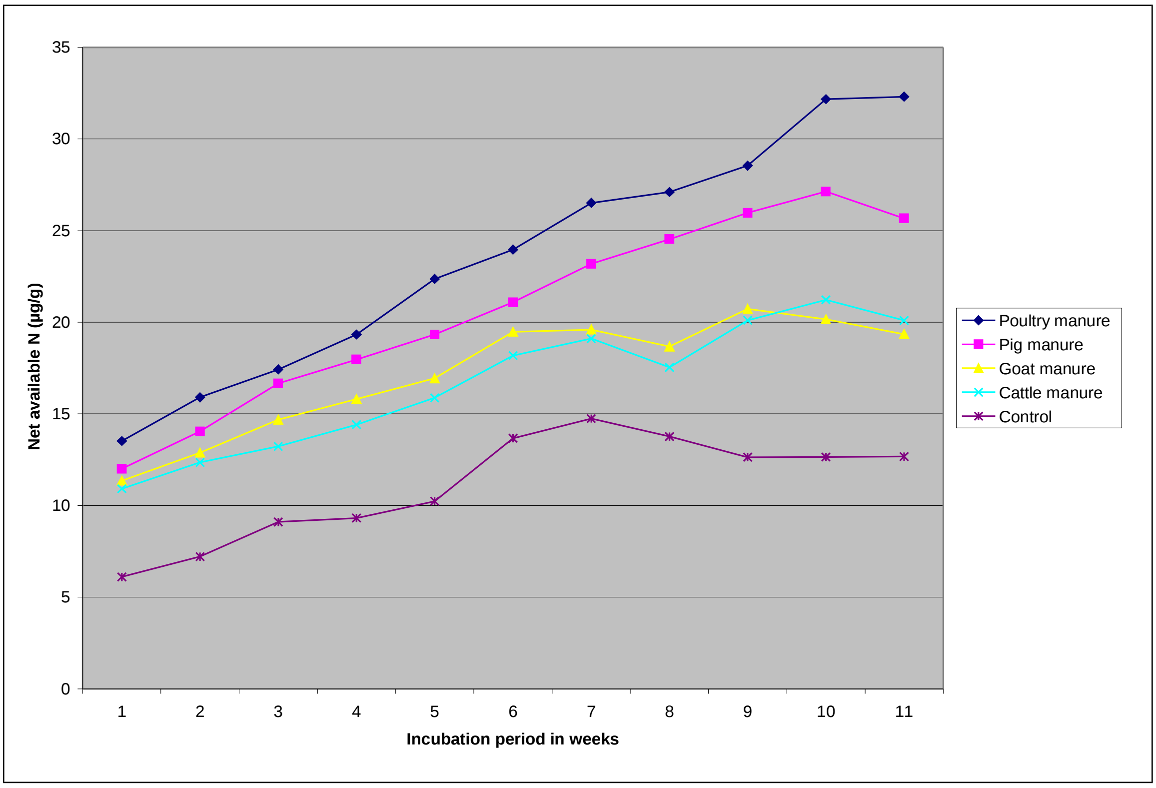


**Figure 1: .Mineralization trends of N at the rate of 100mgNkg$^{-1}$**

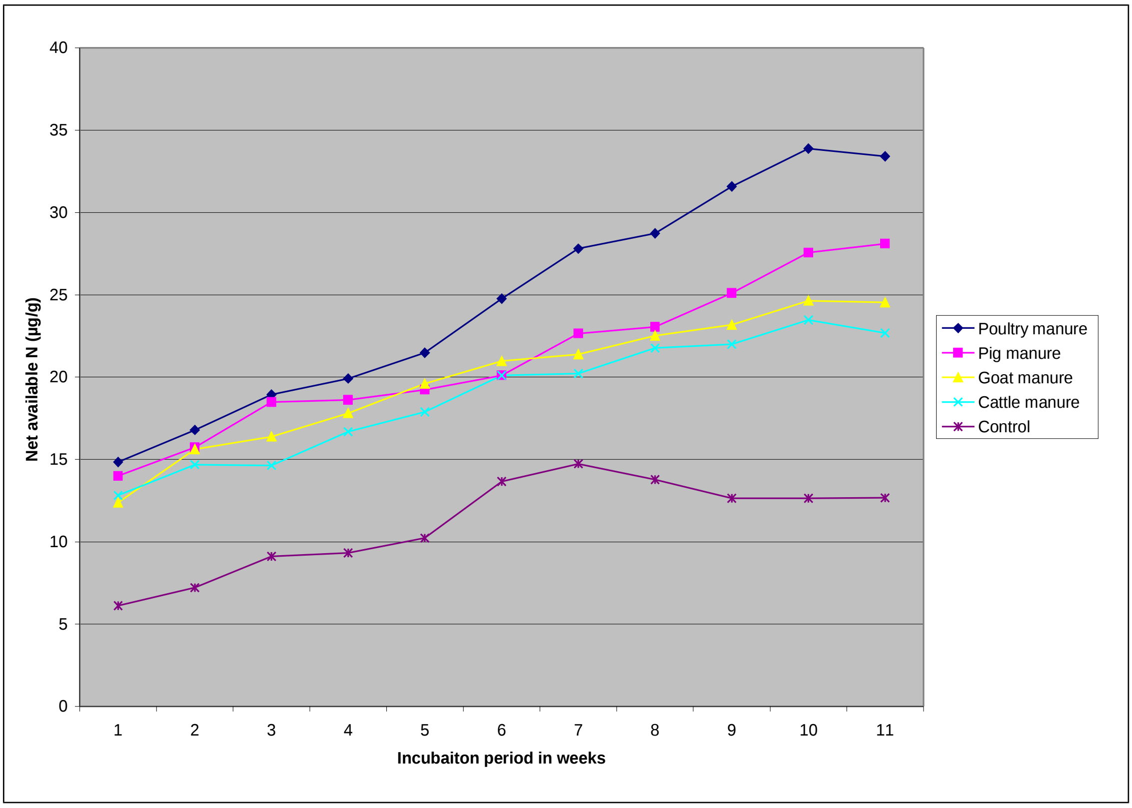


**Figure 2: Mineralization trends of N at the rate of 200mgNkg$^{-1}$**

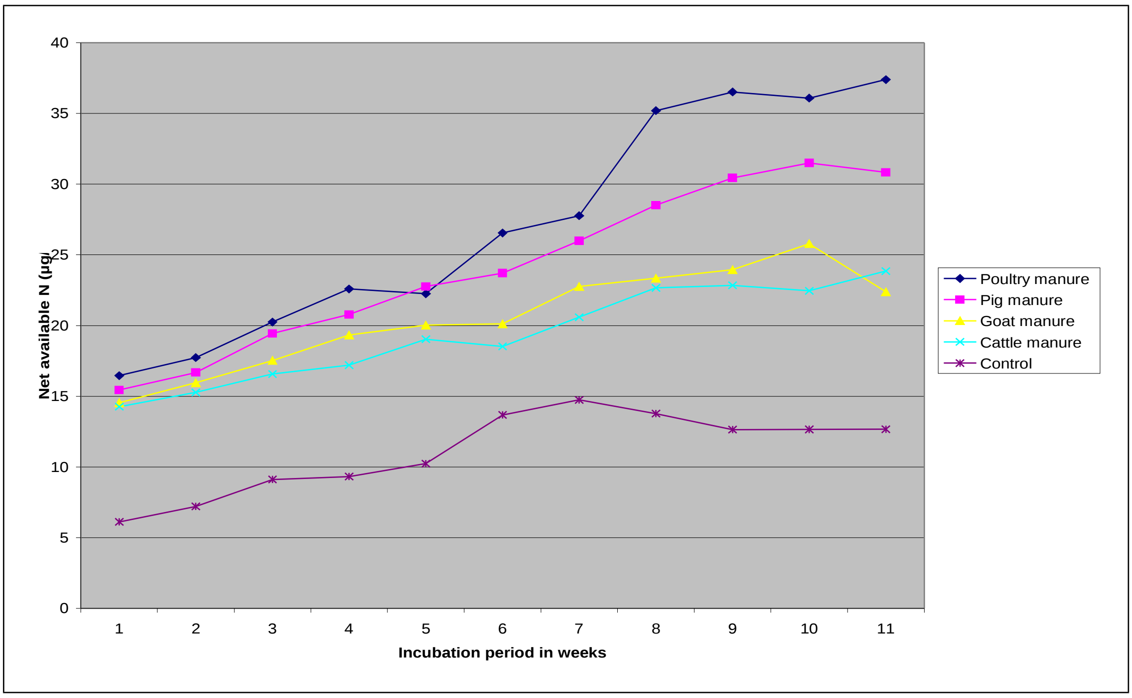


**Figure 3:.Mineralization trends of N at the rate of 300mgNkg$^{-1}$**

Results in Fig. 1, 2 and 3 also indicate that net available levels of N significantly ($P<0.01$) differed among the four manure types. At any application rate, available levels of N were highest in poultry manure followed by pig, goat and cattle manure, respectively. These results are consistent with those on Table 2 which indicate that on average, poultry manure had highest levels of the analyzed nutrients and narrowest ratios of C/N and C/P compared to the rest of the manures. These results therefore suggest that N mineralization was superior in poultry manure and inferior in the cattle manure.

Klausner and Bouldin (1983) observed that approximately 50% of the total N in poultry manure is in the form of simple organic compounds such as urea and uric acid which decompose very easily during the fist few days after application in the soil. This is also consistent with the findings by Gale and Gilmour (2005) who observed higher available N when poultry manure was applied compared to farm yard manure.

In most cases net available N increased with the increasing incubation period suggesting that microbial activity, hence decomposition rate increased with time. Additions of organic materials can increase microbial pool sizes and activity, C and N mineralization rates and enzyme activities. Given conducive conditions this will increase with time (Smith *et al.*, 1993).

Bouldin (1983) observed that under the New York conditions the fraction of residues which decompose each year are 40% for the first year, 20% for the second year, 5% for the third year and 3% for the fourth year and all years after.

**4.1.3 Effect of animal manures incubation on trends of net available P.**

Results of net available P are presented in Fig. 4, 5 and 6 and details on ANOVA provided in Table 4. There was a significant ($P<0.01$) manure type x application rate interaction during incubation suggesting variation in extent of mineralization of the four manures types.

As it was the case for N mineralization, incubation of the four manure types significantly ($P<0.01$) differed from the control. Net P for the control treatment increased with incubation period for the first seven weeks and then decreased for the remaining period. Irrespective of the low organic matter of the soil (Table 1) and the fact that the control was not amended with manure, decomposition of the native organic matter would still be expected given conducive conditions. The decrease in net available P after the seventh week is most likely due to shrinking C pool and other nutrients required by the decomposing microorganisms.

Generally, net P for the four manure types increased with increasing incubation period suggesting that decomposition of organic materials is among other factors, a function of time. Van Faassen *et al*. (2001) also observed that mineralization of P increased with time for the entire eight weeks period.

Analysis of the effect of application rates on net available P (Table 4) indicate that there was a significant ($P<0.01$) variation for all manure types. The trend was 300mgNkg$^{-1}$ >200mg Nkg$^{-1}$ >100mgNkg$^{-1}$ Suggesting increased nutrient concentration with increasing rate of application.

These results are consistent with those in Table 2 which indicate that poultry manure had the highest P content and the narrowest C/P ratio followed by pig, goat and cattle manure. Net P mineralization patterns are determined primarily by P concentration. The rate at which P mineralizes will largely depend on the C to P ratio. Materials with C/P ratio >200 are likely to undergo immobilization (Mulegeta, 2004). Larney and Janzen (1996) also observed significant effect on soil P concentration which increased with increasing rates of application of poultry and cattle manure.

**Table 4: Effects of type rates and time of incubation the animal manures on the net available P**

| Rate (mg N kg $^{-1}$) | Manure type | Net available P (µg P /g) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| **Control** | | 2.38g | 2.41h | 2.58d | 3.23e | 3.41g | 3.91h | 4.11h | 3.21h | 3.00h | 4.31h | 3.38h |
| 100 | Poultry | 7.12d | 8.73f | 10.75a | 11.26ab | 12.42a | 13.77a | 11.4e | 12.52cd | 11.37fg | 12.67e | 12.49e |
| | Pig | 6.6e | 7.79g | 9.68b | 12.29a | 12.28ab | 13.14bc | 12.32b | 11.54g | 11.57f | 12.49f | 11.89f |
| | Goat | 6.02e | 7.77g | 8.68c | 9.75d | 11.83d | 12.42e | 12.13c | 12.76b | 11.62e | 10.33g | 11.85f |
| | Cattle | 5.77f | 7.28fg | 8.38c | 9.45d | 10.56e | 11.25g | 11.4e | 12.59de | 10.21 | 12.08 | 10.52g |
| 200 | Poultry | 8.4c | 9.61c | 10.72a | 10.22b | 12.12ab | 11.93fg | 11.72cd | 12.64cd | 12.88c | 13.48cd | 12.78cd |
| | Pig | 8.15c | 9.00e | 11.24ab | 10.21bc | 11.65d | 12.22f | 11.63de | 12.13e | 12.78cd | 13.25de | 12.43de |
| | Goat | 7.63d | 8.72f | 10.74a | 11.79ab | 12.54a | 12.41e | 11.56d | 11.89f | 12.67de | 12.21g | 13.04c |
| | Cattle | 7.06d | 7.77g | 10.47a | 10c | 11.13cd | 11.25g | 11.77cd | 11.13ef | 11.81f | 12.66e | 12.20bc |
| 300 | Poultry | 10.47a | 10.25b | 10.44a | 11.41ab | 12.07b | 13.41ab | 13.43a | 13.85a | 14.78a | 14.89a | 14.67a |
| | Pig | 9.37ab | 10.46a | 10.32a | 10.93cd | 11.83d | 12.63cd | 12.86b | 13.55ab | 13.28b | 13.9b | 13.65b |
| | Goat | 8.56c | 9.57cd | 10.76a | 12.15a | 11.92c | 12.43de | 11.28f | 12.58b | 13.28b | 12.25g | 12.13g |
| | Cattle | 7.8d | 9.15de | 9.98b | 10.18f | 12.71d | 13.22ab | 10.71g | 13.92c | 12.22e | 13.54 | 12.67e |
| **CV %** | | 13.09 | 12.14 | 10.73 | 9.42 | 10. | 11.91 | 11.43 | 11.34 | 10.99 | 10.81 | 8.59 |
| **LSD** | | 1.159 | 1.140 | 0.7973 | 1.230 | 1.572 | 2.398 | 2.413 | 2.371 | 2.234 | 1.845 | 1.546 |
| **$s_{\bar{x}}$** | | 0.3554 | 0.3497 | 0.2445 | 0.3773 | 0.4819 | 0.7354 | 0.823 | 0.724 | 0.718 | 0.542 | 0.4740 |

0.1,2,3,4,5,6,7,8,9 and 10 = Incubation period in weeks.

Means in the column followed by the same letter(s) within columns do not differ Significantly P < 0.05 according to DNMRT.

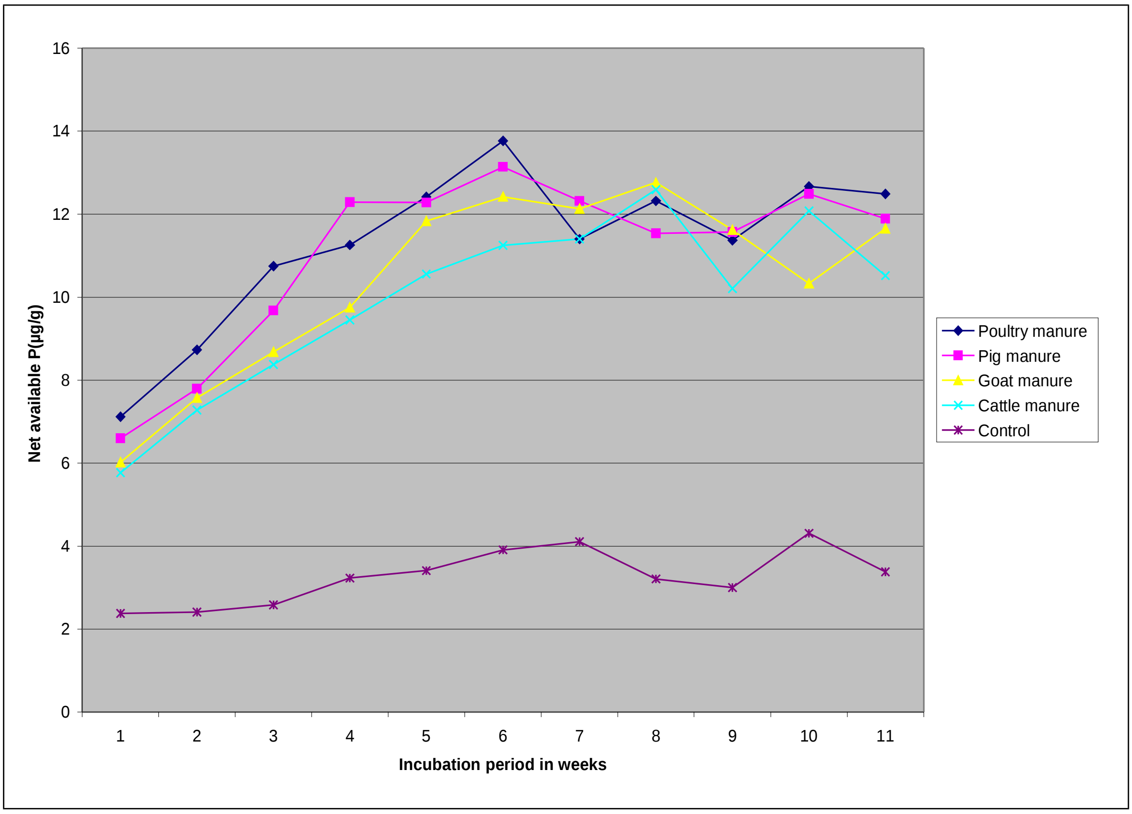


**Figure 4:.Mineralization trends of P at the rate of 100mgNkg$^{-1}$**

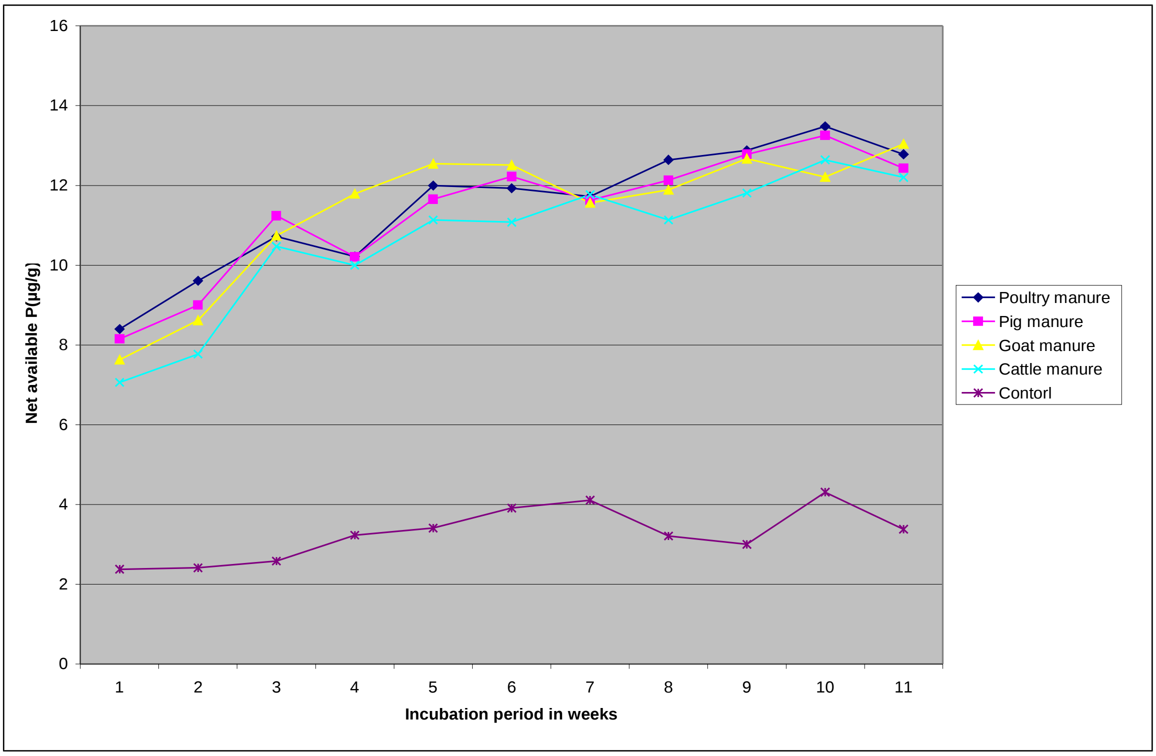


**Figure 5: Mineralization trends of P at the rate of 200mgNkg$^{-1}$**

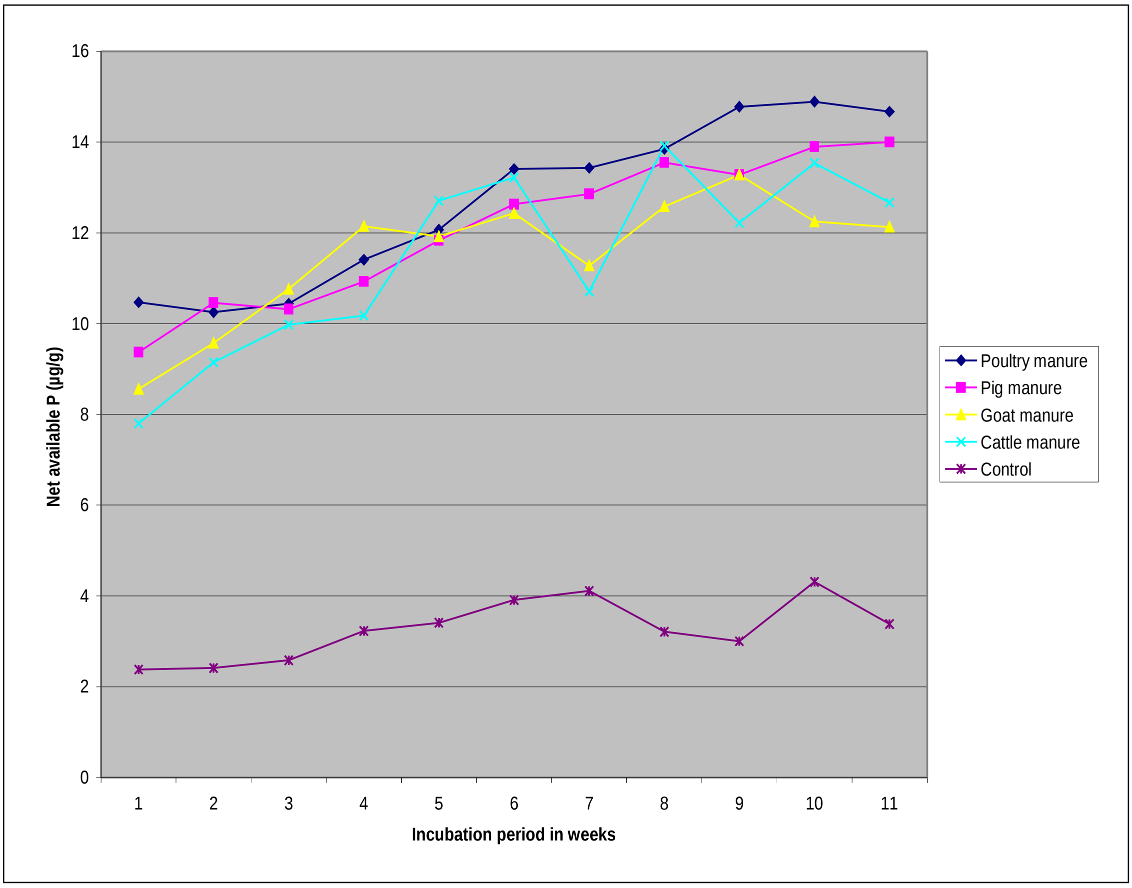


**Figure 6: Mineralization trends of P at the rate of 300mgNkg$^{-1}$**

Organic additions to soil can cause a shift in the distribution of nutrients in the organic or inorganic soil fractions caused by microbial activity. This redistribution of nutrient might affect nutrient availability patterns depending on the quality of the organic addition (McDonagh *et al.*, 2001).

Results in Fig. 4, 5 and 6 indicate significant ($P<0.01$) variation among the four manure types. As it was the case for N mineralization, poultry manure was significantly superior for all application rates. The trend was poultry >pig>goat>cattle manure.

Irrespective of the type of animal manure, net P significantly ($P<0.01$) increased with rates of application during the incubation period. The trend was $300mgNkg^{-1}$ $>200mg\ Nkg^{-1}$ $>100mgNkg^{-1}$**.** This could be attributed to increased microbial activity following increased concentration of nutrients.

### 4.1.4 Comparison of trends of N and P

Comparing N and P mineralization it is evident that the trends are similar (Fig. 1 to 6). This similarity is based on the increased mineralization rate with incubation time for all manure types. Other levels of comparison are effects of application rates and manure types which indicated similar effects to N and P mineralization. However, it should be emphasized that P release patterns are not necessarily correlated to N release. Some materials showing net N mineralization can result in net P immobilization and vice versa (Zengore *et al*., 2003).

### 4.1.5 Net available N and P and implications on manure recommendations.

Fig. 1, 2, 3, 4, 5 and 6 show net available values of N and P after incubation .The maximum net available N achieved after 10 weeks at the highest rate of 300kgN/ha was 37.39mgN/kg. Based on recommended rates of N and P for Southern Highlands of Tanzania for most field crops (80kgN/ha and 20kgP/ha) (MAC, 1996), applications of poultry, swine, goat and cattle manures at the rates of 10.75tons/ha,12.84tons/ha,18.47tons/ha and 21.27tons/ha respectively, will meet the recommendation of 80kgN/ha.

The above application rates will also provide 12.43kg P/ha,11.54kgP/ha,13.76kgP/ha and 10.97kgP/ha for the respective manures. These will not suffice the P recommendation calling for supplementation through application of inorganic P or other sources such as rock phosphate.

### 4.1.6 Glasshouse pot experiment

#### 4.1.6.1 Effects of the animal manures on okra shoot and root dry matter yield

Results of shoot and root dry weight are summarized in Table 5. There was a significant manure types x rate of application interaction (P<0.01) suggesting that the two parameters were differentially affected by the application of the manure types at different application rates.

The results indicate that the effects of the application of the four manure types differed significantly (P <0.01) from the control (Table 5) suggesting increased response following manure application. The observed response is in line with the results in Table 4 which indicated the experimental soil had low levels of nutrients. Minja *et al*. (2008 ) indicated that applications of compost and other types of manures significantly increased yield and quality of amaranthus. They attributed the response to enhanced levels of soil nutrients following manure application.

Irrespective of the manure type the evaluated parameters significantly (P<0.01) increased with increasing application rate.

**Table 5: Effects of Manure Types and Different application Rate on Shoot and Root Dry Matter Yield**

Means in the column followed by the same letter(s) within columns do not differ

| **Rate of manure (mgN/kg $^{-1}$ )** | **Type of manure** | **Shoot dry matter yield (g/pot)** | **Root dry matter yield (g/pot)** |
|---|---|---|---|
| **Control** | | 12.96h | 10.24h |
| 100 | Poultry | 31.21e | 19.92d |
| | Pig | 28.36ef | 19.83d |
| | Goat | 24.01fg | 16.33ef |
| | Cattle | 23.34g | 13.57g |
| 200 | Poultry | 49.68b | 22.66c |
| | Pig | 38.37d | 20.59d |
| | Goat | 30.36e | 19.92d |
| | Cattle | 28.73e | 15.04fg |
| 300 | Poultry | 69.57a | 36.07a |
| | Swine | 49.43b | 29.00b |
| | Goat | 44.75c | 24.18c |
| | Cattle | 41.44cd | 17.18e |
| LSD value | | 4.380 | 1.813 |
| **s_ x** | | 1.532 | 0.6344 |
| **CV%** | | 9.81 | 7.31 |
| **F-test** | | 0.000*** | 0.000*** |

significantly P < 0.05 according to DNMRT.

As it was in the incubation experiment, the highest rate of application (300kgN/ha) resulted in highest effect on DM yield for all manure types. The trend was 100 mgNkg$^{-1}$ <200 mgNkg$^{-1}$ <300 mgNkg$^{-1}$**.** Fenn *et al.,* (1987) observed the increased in dry matter yield of corn caused by higher doses of nutrient in the solution. They related this to a synergistic effect in the uptake of nutrients. Similar results were reported by Marschner (1995) who observed an increase of root growth of corn when grown in soils amended with organic residues. Similarly, Smalley and Wood (1995) observed an increase in root density of corn in sandy and clay soils when amended with organic amendments at higher rates. Working with various animal manures Turner and Thompson (1983) observed increased silage corn dry matter yields in the first and second year of application indicating substantial mineralization of organically bound nutrients.

Results in Table 5 also indicate that he effects of the four manure types on the shoot and root DM yields differed significantly ($P<0.01$). As it was for the incubation experiment application of poultry manure resulted in highest shoot and DM yields compared to the other manure types. The trend was poultry manure>pig manure>goat manure>cattle manure.

The above variations can be related to those observed in the incubation experiment which indicated that poultry manure resulted into enhanced mineralization of N and P compared to the rest of the manures. This is also related to the highest levels of other nutrients in poultry manure (Table 2) compared to the other types of manure.

Approximately 50% of the total N in poultry manure is in the form of simple organic compounds such as urea and uric acid which decompose very easily during the fist few days after application in the soil (Klausner and Bouldin, 1973).

Working with six types of animal manures, Larney and Janzen (1996) observed significant dry matter yield increase of wheat. Results in Table 8 are also in agreement with those reported by Wright *et al*. (1987) who observed that maximum root growth and rooting depth of barley crop were observed in soils that received animal manures compared to where manures were not applied.

The observed increase in root dry matter yield (Table 5) could also be attributed to reduction in bulk density of the soil hence easy root penetration and development. The incorporation of organic matter and other soil amendments into soil help to improve soil physical properties, thereby positively influencing root development (Rose *et al.*, 1995).

# CHAPTER FIVE

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

The objective of this study was to evaluate the extent of mineralization of N and P from commonly used animal manures in Tanzania and its effect on crop performance. The study involved incubation experiment and a glasshouse experiment using okra as a test crop.

Results of the incubation experiment indicated that application of the four manure types significantly ($p<0.01$) influenced net N and P levels. Irrespective of the manure type, net available levels of N and P increased with increasing rates of manure application. The results also indicated significant ($p<0.01$) variations among the four manure types. The trend of the responses was; poultry manure>pig manure>goat manure>cattle manure. Similar trends were also observed for other attributes evaluated in pot experiment. As it was for the incubation experiment, highest responses of shoot and root dry matter yields were obtained from poultry manure followed by pig, goat and cattle manure. Okra shoot and root dry matter yield were highly related to net available levels of N and P. These responses could largely be due to differences in total N, P, C/N and C/P ratios of the four manures. Poultry manure had the highest levels of total N and P and narrowest C/N and C/P ratios, suggesting superior mineralization of organic forms of N and P compared to pig, goat and cattle manures.

## 5.2 Recommendations

Based on the fertilizer recommendations of N and P for Southern Highlands of Tanzania (80kgN/ha and 20kgP/ha) and the highest application rate of 300kgN/ha used in this study, corresponding to application of 10.75tons/ha of poultry manure,12.84tons/ha of pig manure,18.84tons/ha of goat manure and 21.27tons/ha of cattle manure will meet the recommendation of 80kgN/ha.The above application rates will also provide 12.43kgP/ha, 11.54kgP/ha, 13.76.kgP/ha and 10.97kgP/ha for the respective manures, which would not suffice P recommendation rate of 20kg P/ha.

Based on the above the following recommendations are pertinent;

1) Efforts should be made to increase quality of animal manure in order to decrease the amounts required to meet N and P recommendations. Emphasis should be on improved storage and supplementation of the animal feeds.
2) Given the low P content of the manures, supplementation with inorganic P and other sources such as rock phosphate is necessary in order to meet P recommendation.
3) Farmers and extension staff in the study area and others with similar characteristics should be sensitized /trained on manure management practices.
4) Long term studies about 6 month- 12 month on mineralization trends of N and P should be conducted in order to ascertain the responses observed in this study.

5) Plant up take of nutrients N and P should be determined as one of the indicators of the effectiveness of the different types of manure in supplying N and P to the crop.

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