COMPARATIVE EFFECTIVENESS OF ANIMAL MANURES ON SOIL CHEMICAL PROPERTIES, YIELD AND ROOT GROWTH OF AMARANTHUS (*Amaranthus cruentus* L.)

BY

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ABSTRACT

Pot and field experiments were conducted at Sokoine University of Agriculture (SUA), Morogoro, Tanzania during the 1997/98 cropping season. The study was carried out to comparatively evaluate the effectiveness of dairy cow, goat and poultry manures on soil available levels of N and P, amaranthus (*Amaranthus cruentus* L.) yield and root growth. In both experiments, the three amendments were applied at 100, 150 and 170 kg N/ha. The experiments were laid out in a split plot design, replicated three times with rates of application as mainplots and animal manure types as subplots. Pot experiment was conducted for a period of about one-month whereas field experiment was carried out over three crop cycles each lasting for about one month. The soil used in this study was classified as an Oxisol (*Tropeptic Entrustox*).

Results of the glasshouse experiment indicated that applications of the three animal manures significantly ($P < 0.01$) increased soil available levels of N and P, amaranthus shoot dry matter yield, tap root length, root weight and tissue concentrations of N and P. These responses increased with increasing rate of application with the highest rate of application (170 kg N/ha) resulting in highest responses. Comparison of the responses from the three manures revealed that for all the parameters evaluated the trend was; poultry manure > goat manure > dairy cow manure. This trend was mainly due to differences in total N, total P, C/N and C/P ratios of the three manures. Poultry manure had highest levels of total N and total P and narrowest C/N and C/P ratios concurring with the superior mineralization of N and P observed and consequently, the highest responses in amaranthus yield and root growth compared to the other two manures.

Results of the field experiment were essentially similar (except for the root growth which was not evaluated in this experiment) to those of the pot experiment. Soil available levels of N and P evaluated after first and third crop harvests were highest for poultry manure followed by goat and dairy cow manures and the responses were highest after the third crop harvest suggesting that mineralization of organic forms of N and P increased with time. The above responses were significantly ($P < 0.01$) and positively correlated to amaranthus yield and tissue concentrations of N and P indicating that the observed response in amaranthus yield was largely due to soil availability and uptake of N and P.

Based on the fertilizer recommendation of N and P for Southern Highlands of Tanzania (N= 40 kg N/ha and 20 kg P/ha) and the application rate of 170 kg N/ha used in this study, applications of 5.8 tons/ha of poultry manure, 9.8 tons/ha of goat manure and 13.4 tons/ha of dairy cow manure will meet the recommendation of 40 kg N/ha. The above application rates will also provide 30.5kg P/ha, 31.6 kg P/ha and 26.8 kg P/ha for the respective manures , which will suffice the P recommendation.

Results of this experiment therefore, suggest that the three types of animal manures evaluated could substantially sustain crop growth in this soil and others with similar properties. The results should however, be confirmed under different field conditions and for much longer experimental duration.

DECLARATION

I DOTTO LEONARD MHOJA NONGA, do hereby declare to the Senate of Sokoine University of Agriculture that the work presented in this dissertation has not been submitted for a degree award in any other University.

Signed: ....

Date: 25th 8-1999

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DEDICATION

This work is dedicated to my dear wife Elizabeth, my children Emmanuel, Pascal, Vincent and Theresia, my parents Mhoja and Sana and my brothers and sisters for their love, patience, encouragement and moral support.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of variance
C	carbon
cc	cubic centimeter
Ca	calcium
C. E.C	cation exchange capacity
cm	centimeter
CV	coefficient of variation
DM	dry matter
DNMRT	Duncan's New Multiple Range Test
FAO	Food and Agriculture Organization
ha	hectare
H_2O	water
K	potassium
kg	kilogram
m	metre
m^2	metre squared
m.a.s.l	metre above sea level
max.	maximum
min.	minimum
Mg	magnesium
mg	milligram
mm	millimetre

N	nitrogen
Na	sodium
NAEP II	National Agriculture Extension Programme : Phase II
OC	organic carbon
^0C	degree celcius
P	phosphorus
ppm	parts per million
RH	relative humidity
r	coefficient of correlation
S/A	sulphate of ammonia
SUA	Sokoine University of Agriculture
μg	microgram

CHAPTER ONE

1.0 INTRODUCTION

Sustainable crop production requires judicial use of inputs such as fertilizers. Inorganic fertilizers have over the last four decades dominated in agricultural production in most parts of the world (Ofori, 1993). The use of such fertilizers has however, drastically declined following the energy crisis which has immensely affected most of the developing countries (Hauck, 1982). Consequently, inorganic fertilizers are increasingly becoming unaffordable by most small-scale farmers. In Tanzania, the use of inorganic fertilizers for crop production has moreover been affected by the removal of fertilizer subsidies by the government. This has resulted in low yields of most crops due to deteriorating land productivity.

Tanzania is endowed with a large number of livestock such as cattle, goats, sheep, pigs, donkeys and poultry. Efficient use of manures from these animals could substantially alleviate the problem of declining land productivity in most parts of the country. Kyomo and Chagula (1983) reported animal manure output in Tanzania of about 11 million tons per year which could supply total nitrogen of about 77,000 tons, assuming average manure nitrogen content of about 0.7%. They further observed that this is more than three times the amount of nitrogenous fertilizers used in Tanzania in 1980. Irrespective of such enormous potential, very little amount of animal manures is being utilized for crop production in most parts of the country. Kimbi *et al.* (1992) observed that in extensive livestock grazing systems only about 1% of farmers apply animal manures on land, indicating serious under utilization of such resources. A study conducted by Gabriel (1998) revealed that one of the major reasons for under utilization of animal manures for crop production is lack of technical know-how by most farmers. This is also to a large extent due to lack of scientific basis for advising farmers on aspects such as application rates, storage techniques and appropriate manure application methods.

Animal manures have many important benefits for crop production. They supply a wide range of essential plant nutrients along with organic matter which improves soil characteristics such as water holding capacity, soil infiltration and drainage (Brady, 1984). With the increasing urban agriculture practices in Tanzania, livestock keeping under zero grazing system gives a great challenge to the management of animal manures and increased opportunity for manure use in crop production. In view of the apparent decline in soil fertility and the generally high potential of animal manure production that exists in most regions of Tanzania, deliberate efforts are required to promote utilization of animal manures for crop production.

Most of the studies on utilization of animal manures for crop production in Tanzania have largely focused on crop yield responses of various field crops with very little effort in relating such responses to availability of nutrients. Efficient utilization of animal manures requires thorough understanding of the relationship between crop responses and availability of nutrients in the soil following animal manure application. Furthermore, there is also a need of comparing different types of animal manures under similar field conditions. This is important in coming up with indications on manure recommendations. The current study was therefore carried out in order to comparatively evaluate the effect of poultry, goat and dairy cow manures at different rates of application on soil availability of N and P, amaranthus (*Amaranthus cruentus* L.) yield, and root growth. Specific objectives were to:

(i) determine soil available levels of N and P after the initial application of the manures;

(ii) assess yield and root growth of amaranthus;

(iii) determine tissue N and P concentrations in amaranthus;

(iv) derive indications on recommendations of the three manures based on the soil available levels of N and P.

Amaranthus was chosen as a test crop due to its nutritional and economic importance in most parts of Tanzania. It is the most popular vegetable crop grown in most home gardens and is a fast growing annual crop requiring intensive application of fertilizers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Perspectives

Rapid population growth in most of the developing countries coupled with different forms of land degradation has had a serious impact on natural resource base resulting into lower capacity to produce food. Improper land husbandry practices and inadequate nutrient replenishment has led to nutrient depletion in many developing countries calling for remedial measures to alleviate the situation (Lynam, 1993). In order to achieve this, Geng *et al.* (1990) recommends research priority strategies that minimise the use of non-renewable resources and increased use of those that provide a base, which is resource regenerative to maintain productivity of farm production systems.

The use of inorganic fertilizers for crop production in Tanzania has over the last ten years declined. This is mainly due to the removal of fertilizer subsidies by the government leading to drastic increases in their prices. Consequently, inorganic fertilizers are increasingly becoming unaffordable by most farmers (Ministry of Agriculture, 1996). According to Troeh and Thompson (1993), inorganic fertilizers are indirectly responsible for some of the environmental pollution problems. For example, Rodale (1987) pointed out that chemical fertilizers could have various negative effects on microorganisms in the soil. They kill the life in soils (bacteria, fungi and other micro-organisms) resulting in reduced soil ability to regenerate it's fertility year after year as is the case for the acid forming fertilizers. Bache and Heathcote (1969) reported rapid development of acidity on poorly buffered soils as a result of prolonged application of sulphate of ammonia fertilizer.

The use of organic materials could be an attractive alternative, and in some cases cost effective means, which could supply most of the essential nutrients, required for crop production. According to Uriyo *et al.* (1979) all organic materials that may be added to the soil to supplement its fertility for crop production are referred to as manures. The most commonly used manures include crop residues, green manures, miscellaneous weeds and excreta of farm animals (Kuhanda, 1997). Animal manures are any animal waste biomass, which can be used as a fertilizer (Reijntjes *et al.*, 1992). These can be incorporated into the soil by ploughing under to improve its fertility status. The following sections summarise the potential of animal manures as resources for improving soil fertility and land productivity.

2.2 The Role of Organic Materials in Crop Production

The use of organic materials for crop production has long been recognized as important to the soil building process. Prior to the introduction of inorganic fertilizers in early 1800s, animal manures, crop residues and other organic materials were the only source of additional nutrients into the soil for crop production (Wiggans and Williams, 1972). According to Parr *et al.* (1986) organic farming is a traditional practice in the tropics practised by most farmers before the introduction of inorganic fertilizers during the green revolution era. However, due to the constraints on the use of inorganic fertilizers as mentioned earlier, various researchers are now encouraging farmers to adopt other alternatives for soil fertilization. For example, Hill and Pierre (1982) advocate the use of ecological methods (minimum tillage, biological manipulation of soil, prevention of soil erosion by maintaining a crop cover and the addition of various types of organic materials and rock powders) for maintenance of soil fertility.

Several benefits accruing from the use of organic materials such as animal manures have been documented. These include provision of a wide range of essential nutrients for crop production such as nitrogen, phosphorus, potassium and various micronutrients in varying amounts. Kiely (1987) observed that about 90% of NPK and other nutrients ingested by animals pass through the faeces and urine. When these are collected and applied to farm lands they provide substantial amounts of nutrients to crops and their proper management and use can greatly reduce reliance on the use of inorganic fertilizers (Klausner and Bouldin, 1983b). The nutrients contained in these materials are slowly released hence there is a more pronounced residual effect in soil associated with their application.

Other outstanding attributes include long term improvement of soil physical characteristics such as soil structure, tilth, water holding capacity and soil permeability through enhancement of organic matter levels in the soil (Cassman and Rains, 1986). Hafez (1974) reported an increase in water holding capacity of soil, increased soil particle aggregation and reduced bulk density when various animal manures were applied.

Application of animal manures has also been reported to increase microbial population and activity (Vidyarthy and Misra, 1982).

2.3 Factors Affecting Quality of Animal Manures

Animal manures are highly variable materials as far as nutrient composition is concerned. The fertilizer value of animal manures depend on various factors such as type of the animal, age of the animal, quality of feeds given to the animal, storage conditions and manure application methods (Hinnish, 1971).

When animals are fed on high quality feeds such as mixtures of brans from cereals and oil cakes, manures produced are of better quality than when fed on forage alone. Young animals produce relatively high quality manures compared to mature animals and lactating ones. Proper storage of animal manures is important in conserving nutrients contained in them. For example, nitrogen losses by leaching and denitrification can be severe if the manures are stored in an open area and if are not applied at the right time (Sommerfeldt and Chang, 1985).

The average nutrient content of manures of most animal species range from 0.4% to 1.3% N; 0.2% to 0.8% P and 0.35% to 1.0% K (Kasembe *et al.*, 1983). Comparing different types of animal manures, Makawi (1982) observed that poultry manure contained higher levels of organic matter, total N, total P and decomposition in soil was very rapid compared to other manures evaluated. Castellanos and Pratt (1981) observed that composted chicken manure had much less total N than fresh chicken manure. The authors also observed that composting of animal manures reduced the nitrogen supplying power to almost 50% compared to fresh materials but it had the advantage of producing organic materials of much stable nitrogen and organic carbon contents. Klausner and Bouldin (1983a) noted that about 50% of N in fresh poultry manure is present as uric acid and it is ammonified rapidly by both aerobic and anaerobic microbes. With conventional storage methods and handling, about 50% of N excreted by laying hens is likely to be lost by ammonia volatilization before the manure is incorporated into the soil.

Based on the fact that organic manures vary greatly in their organic matter and nutrient contents, Makawi (1982) categorised animal manures with respect to their quality and fertilizing ability into three groups namely; high quality and quick nutrient availability manures such as poultry and horse manures; manures of moderate quality and nutrient availability, for example, sheep and cattle manures and manures of low quality and low nutrient availability as is the case of dried sludge. According to Semoka and Ndunguru (1983), the nutritive value of animal manures in Tanzania is relatively lower than that of most developed countries due to low animal nutrition and poor handling and storage methods.

Time and method of application of organic manures also influence fertilizer value of animal manures. It is suggested that the best time for application of animal manures is after land preparation (Donald and Beemer, 1981). Manures should be ploughed in the soil so as to allow the materials to rot before planting operation begins and also to avoid nutrient losses through processes such as ammonia volatilization and leaching.

2.4 Factors Affecting Decomposition of Organic Materials

Decomposition is a process basically mediated by microorganisms residing in the soil. Organic materials are broken down to simple substances that can be taken up by higher plants or by the microbes themselves (Swift *et al.*, 1979). The microbial actions lead to a reduction in size and change in chemical composition. The chemical composition is changed as a result of production of intermediates and the synthesis of decomposer tissues and humus in situ. During these processes, essential elements such as N, P and other nutrients are released and/or immobilized in ways/rates unique to each element (Alexander, 1977).

The rate at which nutrients are released from organic materials varies depending on the nature of the material and the nutrient in question. Klausner and Bouldin (1983a) estimated that under New York conditions the fraction of organic N in fresh dairy cattle that mineralizes during the first year is about 40% whereas about 12% mineralizes in the second year, 5% the third year, and about 2% during the fourth and the following years.

According to McCalla (1975) and Brady (1984) about 50% of N in most animal manures is available for plant uptake during the first year of application. However, poultry manure can release up to 90% of its N in the first year (Semoka and Ndunguru, 1983). Brady

(1984) observed that the first crop grown after manure application may recover in general about 20% of P and 50% of K. The rate of decomposition of organic materials such as animal manures depends on a number of factors which include:

2.4.1 Environmental factors

Soil properties govern to a large extent the rate at which decomposition takes place due to their influence on the dynamics of decomposer populations. Soil environmental factors include soil moisture, soil temperature, organic matter content, soil pH, oxygen supply, and inorganic nutrient supply (Alexander, 1991). These factors affect the decomposer organisms both quantitatively and qualitatively (Roper and Smith, 1991).

2.4.1.1 Soil pH

Under extreme acid or alkaline soil conditions, decomposition of organic materials slows down due to decreased microbial activity. Decomposition of organic material is optimum at the pH range of 6.5 to 7.5 where most nutrient elements such as N, P, K Ca and Mg are generally more available (Uriyo *et al.*, 1979). This range of pH favours the growth and activities of most soil micro-organisms responsible for the decomposition process.

2.4.1.2 Soil temperature and moisture

A combination of adequate moisture and temperature of the mesophyllic range (20 - 37°C) favours decomposition of organic materials. This range of temperature and adequate moisture content of the soil influence the growth and activities of most decomposing microbes. Above or below this temperature range decomposition process will slow down (Troeh and Thompson, 1993). According to Uriyo *et al.* (1979) most rapid decomposition takes place in a well aerated and moist soil. Under water logged conditions there is low concentration of oxygen. This promotes microbial processes such as denitrification, slowing down activities of most aerobic microorganisms, which contribute to the decomposition process.

2.4.2 Quality of Organic Material

The bulk of the organic residue and the chemical nature of the associated molecules determine the rate of decomposition. Dissimilation of added organic molecules is linked with the simultaneous synthesis of microbial tissues due to assimilation. Thus, the rate of decomposition is directly proportional to the supply and availability of nutrients such as nitrogen, phosphorus, sulphur, and other nutrient elements required by micro-organisms for their cell synthesis (Massawe, 1998). Proper nutrient balance is also important. The balance between carbon and nitrogen, for example, is one of the most important aspects of successful decomposition. Carbon is required as an energy source and as a building element in cell protoplasm.

Organic materials with high nitrogen content usually show high decomposition rates and nutrient release (Swift *et al.*, 1979). High carbon content reduces the decomposition rate of organic materials and enhances nutrient immobilization. Generally, a C/N ratio of less than 30:1 favours mineralization, while C/N ratios greater than 30 lead to immobilization.

Usually, Organic materials from plants have wide C/N ratio and hence slower decomposition rate compared with organic materials from animals which have relatively narrow C/N ratios. However, variations exist even within them, depending on the type of the crop or animal species. For example, legume plants have relatively high N content hence decompose faster than cereals which contain relatively low N. Percentage nitrogen is highest in young succulent plants than old mature plants thus, the former decompose faster than the latter (Troeh and Thompson, 1993).

2.5 Crop Responses to Animal Manures Application

A number of workers have demonstrated the potential for animal manures as a source of nutrients for crop production. Araujo *et al.* (1982) and Rweyemamu and Ndunguru (1984) observed that field bean grain yield and dry matter production were increased when cattle manure was applied. In an experiment done by Klausner and Bouldin (1983b), silage yields increased from 12.5 to 18.6 tons/ha due to application of 25 tons/ha of cattle manure. This yield increase was largely attributed to the extra N supplied from the organic N in the manure. Results by Augustburger (1982) indicated that fresh chicken manure produced highest yield in the first crop of potato but gave lowest in the second crop. It was concluded that this was due to fast release of N in poultry manure. In this study, mineral fertilizer, which was a mixture of urea and diammonium phosphate, produced inferior results compared to fresh poultry manure.

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 (Thomsen *et al.*, 1997). Liu *et al.* (1997) reported a significant increase in total dry matter yield and a general increase in plant tissue N and P concentrations in forage with increased rates of manure application from 560 to 2240 kg N/ha.

Plant growth is largely influenced by the supply of nutrients and water from the soil through roots. When such conditions are favourable and depending on the crop type, roots can extend to the subsoil extracting more nutrients and water. Relatively very few studies that relate plant root growth, yield and nutrient levels in the soil following application of manures have been reported. In one of such studies, Wright *et al.* (1985) observed that maximum root growth of barley crop occurred in soils, which received manures compared to other treatments. This was attributed to higher levels of organic matter and other soluble organic components of animal manures that have beneficial effects to plant growth in acid soils. In India, Matthew *et al.* (1996) observed that application of cattle manure alone, or in combination with inorganic fertilizers significantly increased N and P nutrients uptake in rice and resulted in higher dry matter production.

2.6 Use of Animal Manures in Tanzania

In Tanzania, substantial research has been carried out on the use of animal manures for crop production. Initial research efforts date back as early as 1928 (Martin 1928, Martin *et al.*, 1937; Scaife, 1968;1971). Generally, results from these studies indicate that in most cases application of animal manures increased yields of most field crops such as maize, sorghum, cotton and millet. A combination of animal manures with inorganic fertilizers resulted in highest yield responses compared to either of the sources applied alone.

Peat and Brown (1962), reported average cotton yields of about 550 kg/ha per year from application of animal manures. Scaife (1968) observed a significant increase in seed cotton yield from application of 7.5 tons per hectare of cattle manure at Ukiruguru - Mwanza. Scaife (1971) reported other positive crop responses to application of animal manures on groundnuts and Evans and Mitchell (1962) on pigeon pea in Bukoba region. In these studies, cattle manure increased yields of the crops and sustained the fertility of the soil. Application of animal manures and other organic materials such as compost and mulch have been known to sustain good yields of banana and coffee in Kilimanjaro region (Kasembe *et al.*, 1983). Using cattle and poultry manures, Massomo and Rweyemamu (1989) observed that both sources significantly increased common bean yield components such as number of branches/plant, pods/plant, dry matter yield/plant and seed yield per unit area. Poultry manure gave the highest values in all variables tested whereas cattle manure gave equivalent values to those, which resulted from application of sulphate ammonia. Semoka and Ndunguru (1983) observed that despite of the low nutrient contents of animal manures from open kraals, a similar trend in relation to their effects on crop yield were obtained suggesting long term beneficial effects of these sources on land productivity.

The role of animal manures in improving agricultural productivity in Tanzania has however remained far below it's potential since very little of the country's big reservoir is being used. This is mainly due to lack of awareness of the usefulness of animal manures as source of plant nutrients by most farmers in areas where extensive grazing system is being practised (Kasembe *et al.,* 1983). However, in areas where animals are zero grazed due to high population density and low livestock numbers, land application of animal manures is common (Kasembe *et al.,* 1983). Irrespective of this, manure management is still a major problem that imposes constraints to their efficient use for land fertilization in such areas.

Most of the reported research on animal manures has largely concentrated on field crop yield responses following their application. Effective and sustainable utilization of animal manures requires a quantification of the relationships between such responses and availability of nutrients in the soil. This is important in coming up with indications on manure recommendations.

2.7 Limitations of Animal Manures

Animal manures and other organic materials such as crop residues and compost used as fertilizers have a number of limitations. These limitations should be taken into considerations for efficient manure use. Most organic materials have low amounts of nutrients per unit weight. Large quantities of such materials must therefore be applied in order to meet nutritional requirements of crops. Also, due to their bulkiness they can not be easily transported far from the production areas otherwise the cost of handling and application may exceed their value. Another major limitation is that of nutrient imbalances which is oftenly encountered with the use of animal manures. Phosphorus is of particular interest due to relatively low content in most manures and slow rate of it's release from organic forms compared to other nutrients such as nitrogen (Kasembe *et al.*, 1983). Extensive use of animal manures for crop production is also hampered by their limited availability in some areas where livestock keeping is rare or completely not practised (Duncan, 1975).

Although animal manures are relatively free from pathogens as compared to other wastes such as night soils, a potential hazard does exist for pathogenic micro-organisms spreading to the environment (McCalla, 1975; Kasembe *et al.*, 1983). According to Van Ness (1975) pathogenic micro-organisms from livestock may enter the environment by way urine and faecal wastes from the animals. These may include bacterial pathogen *Bacillus anthracis* causing anthrax, Salmonella, Escherichia, Vibrio bacteria associated with tuberculosis infections and viral pathogens like foot and mouth causal agents. The use of animal manures is also associated with the risk of spreading weed seeds to new areas particularly if the manures are not well decomposed. Despite the above constraints animal manures could be valuable sources of plant nutrients if well managed.

CHAPTER THREE

3.0 MATERIALS AND METHODS

Pot and field experiments were conducted to evaluate the effectiveness of three animal manures on amaranthus (*Amaranthus cruentus* L.) yield, soil availability of N and P and root growth. The field experiment was conducted over a period of three crop cycles (between February and July, 1998) whereby manures were applied only in the initial crop cycle and no application was done in the subsequent crop cycles.

3.1 Description of the Experimental Site

The study was conducted at the Horticulture Unit, Sokoine University of Agriculture (SUA), Morogoro, Tanzania. This area is located at an altitude of 525 metres above sea level, at 6°5'S and 37°38'E. The area has a bimodal rainfall pattern, whereby short rains start between October/November and January followed by a dry spell in February. The long rains fall between March and May. The soil at the site was classified as Oxisol (Tropeptic Entrustox) by Kaaya (1989) using FAO-UNESCO (1974) classification system. The area was previously planted with banana. The crop was uprooted and the area was left to fallow for four years before this experiment was conducted.

Mean annual rainfall in the area is between 600 - 800 mm per year (Mkandawire, 1996). The 1997/98 cropping season received relatively higher amount of rains due to El -Nino rains. Some of the important meteorological data 1996/97 and 1997/98 seasons are shown in Tables 1 and 2.

Table 1. Meteorological data for January - June, 1996/97

Month	Temperature (^{o}C)		Average Rainfall (mm/Month)
	Max.	Min.	
January	34.0	19.5	105.0
February	31.0	21.6	151.5
March	31.0	21.8	127.9
April	28.4	20.5	208.5
May	28.0	19.9	132.0
June	27.3	16.5	2.0
Total	179.7	119.8	726.9
Mean	30.0	20.0	121.2

Source: Meteorological Station, Sokoine University of Agriculture, Morogoro, Tanzania.

Table 2. Meteorological data for January - June, 1997/98

Month	Mean Temperatures (°C)		Average Rainfall (mm/month)
	Max.	Min.	
January	31.7	21.3	226.9
February	32.6	22.8	233.1
March	32.5	23.7	114.8
April	30.1	21.9	215.8
May	29.8	18.8	44.7
June	28.8	17.2	31.0
Total	185.4	125.7	866.3
Mean	30.9	20.95	144.4

Source: Meteorological Station, Sokoine University of Agriculture, Morogoro, Tanzania.

3. 2 Soil Sampling and Characterization

Soil samples from 0 - 20 cm depth were collected for laboratory analysis and the pot experiment. The samples were randomly collected to cover and to represent the experimental area. The samples for the pot experiment were composited, air dried, ground and sieved to pass through an 8 mm sieve. A small subsample was composited, air dried, ground and sieved to pass through a 2 mm sieve for physical and chemical Characterization of the soil. Soil Characterization was carried out in the Department of Soil Science laboratory, SUA, Morogoro. The soil sample was analysed for soil texture, pH, organic carbon, total N, extractable P, exchangeable levels of Ca, Mg, Na and K, and cation exchange capacity. The samples were analysed in three replicates.

Soil texture was determined by the Bouyoucos hydrometer method (Juo, 1978). Soil pH was measured electrometrically in a 1:2.5 soil-water suspension (McLean, 1982). Organic carbon was determined by rapid dichromate oxidation method and percentage organic matter was estimated by multiplying the percentage organic carbon by the Van Bermnelen factor of 1.724 (Nelson and Sommers, 1982). Total nitrogen was determined by the Micro Kjeldahl method (Bremner and Malvaney, 1982) while extractable P was determined by Bray 1 Method (Bray and Kurtz, 1945). Exchangeable levels of Ca, Mg, K and Na, were determined by the atomic absorption spectrophotometer following the procedures outlined by Wilde *et al.* (1979). Cation exchange capacity was determined by the ammonium acetate saturation method (Thomas, 1982).

3.3 Animal Manures

The three types of animal manures namely; dairy cow, goat, and poultry manures used in this study were collected from SUA, Morogoro. Dairy cow manure was collected from Magadu dairy farm, SUA. It contained some amounts of straw from bedding materials and supplementary feeds mostly elephant grass and bana grass. Poultry manure was obtained from the layers project at SUA. Goat manure was obtained from Magadu goat project, SUA. The animals are kept in raised pens whereby the droppings are collected underneath. At the time of collection, the three animal manures had been separately stockpiled in an open area with no shelter. Dairy cow manure was sampled from a heap that was six months old, while goat and poultry manures were taken from three months old heaps.

The manures were separately covered with plastic sheets to prevent nutrient losses by rainfall before their application. Two small sub-samples from each manure type were taken for laboratory analyses in the Department of Soil Science, SUA in order to determine their nutrient composition. Before analysis, the manure samples were air dried and ground to pass through 2 mm sieve. The samples were then analysed for total N, total P and organic carbon following the procedures outlined in section 3.2.

3.4 POT EXPERIMENT

The pot experiment was conducted with the objective of evaluating the effects of the three animal manures on soil available levels of N and P, amaranthus shoot dry matter yield, root growth and tissue N and P.

The experiment was conducted between February and April, 1998, in a screen house at SUA, Morogoro. Four litres capacity plastic pots with drainage holes at the bottom were used. Each pot was filled with four kilograms of air dried sieved soil (8 mm sieve) from the field experimental site. The soil was thoroughly mixed with the animal manures according to the following treatments:

(1) Control (no manure applied);

(2) Dairy manure, rate 1;

(3) Dairy manure, rate 2;

(4) Dairy manure, rate 3;

(5) Goat manure, rate 1;

(6) Goat manure, rate 2;

(7) Goat manure, rate 3;

(8) Poultry manure, rate 1;

(9) Poultry manure, rate 2 and

(10) Poultry manure, rate 3.

The rates 1, 2 and 3 refer to manure application rates of 100, 150 and 170 kg N/ha, respectively. The rates used in this study were based on recommendations for inorganic N fertilizers for leafy vegetables.

The treatments were replicated three times in a split plot design, with rates of application as main plots and manure types as the subplots. Amaranthus seeds were then sown in the pots by broadcasting followed by slight stirring of the soil. Before sowing, the seeds were thoroughly mixed with sand at a 2:50 (seeds:sand) ratio giving application rate of 3 - 10 g/m^2. The pots were then watered using distilled water to approximately field capacity. Thinning was done to leave 10 plants per pot seven days after emergency. The pots were kept free from weeds throughout the experimental period. Watering was done as necessary.

Harvesting was done after four weeks of plant growth by cutting the plants 2 cm above the soil level. The plants were rinsed of any adhering particles using distilled water and were then oven dried at 65°C to constant weight for dry matter yield determination. The same samples were used for determinations of tissue N and P concentrations. The samples were ground and screened through a 1 mm sieve for tissue analysis. The samples were digested following the procedures described by Okalebo *et al.* (1993). After digestion, tissue N was determined by the Micro Kjeldahl method. Determination of P in the extract was by the Vanado-molybdate method (Jackson, 1958).

3.4.1 Soil analysis and root growth examination after harvest

After plant harvest, a small sub-sample of soil was collected for determination of soil available levels of nitrogen and phosphorus. In order to obtain the soil samples, the pots were watered to near field capacity and inverted on a wire mesh. A small portion of the soil was then sampled from each pot. Soil samples were air dried, ground and sieved through a 2 mm sieve. Available nitrogen was determined by the micro Kjeldahl method as outlined by Okalebo *et al.* (1993) while available P was determined by Bray 1 method (Bray and Kurtz, 1945).

Assessment of root growth was done for each treatment by measuring tap root length and determining root dry weights. Intact roots of five randomly selected plants from each pot were used. These were extracted from the soil boll by gently washing off the soil by running water from watering cans. The extracted roots were rinsed with distilled water and separately wrapped in moist absorbent paper. They were then placed in plastic bags and stored in a refrigerator in order to protect them from desiccation and shrinkage. Tap root length was directly measured using a ruler while root weights were taken after oven drying the roots at 65°C to constant weight.

3.5 FIELD EXPERIMENT

Field experiment was conducted to comparatively evaluate the effects of the three animal manures on amaranthus dry matter yields, tissue N and P concentrations and soil available levels of N and P.

The experiment was conducted over a period of three crop cycles each lasting for about one month.

3.5.1 Land preparation and experimental layout

Land preparation involved ploughing with a tractor followed by hand harrowing. The dimensions of the plots were 4.0 m x 1.5 m and the main plots were separated by a 1.5 m path while the subplots were separated by a 1.0 m path. The experimental layout and treatments were similar to those of the pot experiment. The manures were applied by broadcasting followed by incorporation into the soil using hand hoe before sowing.

3.5.2 Cultural practices

Amaranthus seeds were sown by broadcasting, a method commonly used by farmers. Before sowing, the seeds were mixed thoroughly with sand at the ratio of 2:50 giving a seeding rate of 3 - 10 g/m^2, or approximately 1.5 - 2.0 kg/ha as recommended by Tindall (1983). The experimental plots were kept free from weeds throughout the experimental duration. This was done by hand hoe weeding in the paths and hand picking in the plots.

Insect pests, particularly grasshoppers observed in the field were controlled by spraying Landecyhthrin (Karate), at an application rate of 1 cc/2 litres of water. Plots were irrigated manually using watering cans when necessary.

3.5.3 Data collection

3.5.3.1 Shoot dry matter yields

As was in the pot experiment, harvesting of the marketable part of amaranthus (leaves and stems) was done after four weeks of plant growth for each crop cycle. Harvesting was done on an area of 1.0 m x 1.0 m at the centre of each plot. Harvesting involved cutting the plants at 2 cm above the ground. The harvested plant samples from each treatment were separately oven dried at 65°C to constant weight and weighed using an electronic balance.

3.5.3.2 Tissue N and P concentrations

A sample of five plants per plot was taken during the third crop cycle. The samples were washed with distilled water, oven dried at 65°C and ground to pass through a 1 mm sieve. Determinations of tissue N and P concentrations followed the procedures outlined in section 3.4.

3.5.3.3 Soil available levels of N and P

Soil samples were taken after the first and third crop harvests. Treatment of the samples and determinations of available levels of N and P were done according to the procedures outlined in section 3.4.1.

3.5.4 Data analysis

The data collected from the pot and field experiments were subjected to statistical analysis using the MSTATC statistical programs. Standard ANOVA procedures for data analyses were used according to procedures outlined by Snedcor and Cochran (1993). Duncan`s New Multiple Range Test (DNMRT) was used to compare differences between treatment means. Linear correlations for various variables were carried out according to the procedures described by Steel and Torrie (1984).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Physical and Chemical Properties of the Experimental Soil

Some of the physical and chemical properties of the soil used in this study are summarized in Table 3. The texture of this soil was Sandy Clay Loam based on FAO (1977) classification system. This soil was an Oxisol (Tropeptic Entrustox) according to Kaaya (1989) who used FAO-UNESCO (1974) classification system.

The soil was slightly acidic, low in organic matter content, extractable P and total N. The soil was also low in exchangeable bases especially Ca and Mg (Table 3). According to Landon (1984) pH values of between 5.5 and 7.0 are considered medium, whereas organic matter content below 4% is considered low. Total N values of between 0.1% to 0.2% are classified as low whereas C.E.C for top soils in the range of 15 to 25 me/100 g of soil is classified as medium. The soil available P content of less than 15 μg P/g of soil is considered low (Singh *et al.*, 1977).

The low contents of organic matter and total N could be attributed to the high rates of continuous mineralization and little addition of the same in this soil. This is common in soils under tropical conditions (Uehara and Gillman, 1981). The low available P observed in this soil could be due to high P fixation tendency of Oxisols (Troeh and Thompson, 1993). The C.E.C of this soil is low according to Landon (1984).

Table 3. Some physico-chemical properties of soil used in this study

Parameter	Value
Sand (%)	47
Silt (%)	22
Clay (%)	31
Textural Class	Sand Clay Loam (FAO, 1977)
Total N (%)	0.154
Exchangeable bases (me/100g soil)	
K+	1.68
Na+	0.54
Ca++	2.66
Mg++	1.99
C.E.C (me/100g soil)	6.97
Extractable P (μg/g)	6.52
pH (in water 1:2.5)	5.7
Organic carbon (%)	0.79

4.2 Chemical Properties of Animal Manures Used in the Study

Some chemical properties of the animal manures used in this study are shown in Table 4. The animal manures differed with respect to the variables examined. Total N and total P contents of the three animal manures followed the trend, poultry manure > goat manure > dairy cow manure. Organic carbon was highest in dairy cow manure followed by goat and poultry manures, which had similar values. The observed differences among the three animal manures can be attributed to among other things, differences in animal species.

Mathers *et al.*(1972) observed that in about 23 samples of various animal manures analysed, the total N ranged from 1.16% to 1.96% and averaged at 1.34%. The highest value of total N was observed in poultry manure. The three manures used in this study can be rated as being of medium quality according to Mathers *et al.* (1972).

Table 4. Some characteristics of the animal manures used in the study

Parameter	Animal manure type		
	Dairy cow manure	Goat manure	Poultry manure
Organic carbon (%)	20.94	14.99	14.97
Total N (%)	1.4	1.6	1.8
Total P (%)	0.1	0.2	0.5
C:N ratio	14:1	9:1	8:1
C:P ratio	176:1	72:1	28:1

4.3 POT EXPERIMENT

4.3.1 Effect of animal manures on soil available N and P

Soil available levels of N and P after harvesting are presented in Figures 1 and 2. There was significant ($P < 0.01$) manure type X application rate interaction, suggesting variation in the effectiveness of the amendments at different rates of application. Soil available N and P significantly ($P < 0.05$) increased with increasing rate of manure application for each manure type. The highest rate of application (170 kg N/ha) resulted in highest effect on soil available levels of N and P for all manure types.

Results of the analysis of variance indicated that the three manure types differed significantly ($P < 0.01$) in terms of soil available levels of N at 150 and 170 kg N/ha and P at all of the three manure application rates. The trend was; poultry manure > goat manure > dairy cow manure. The general trend observed for soil N and P available levels following application of the three manures was expected given their initial differences in total N, total P and organic carbon (Table 4). Poultry manure had highest values of total N and total P and narrowest C/N and C/P ratios compared to goat and dairy cow manures (Table 4). Klausner and Bouldin (1973) 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 first few days after application in the soil.

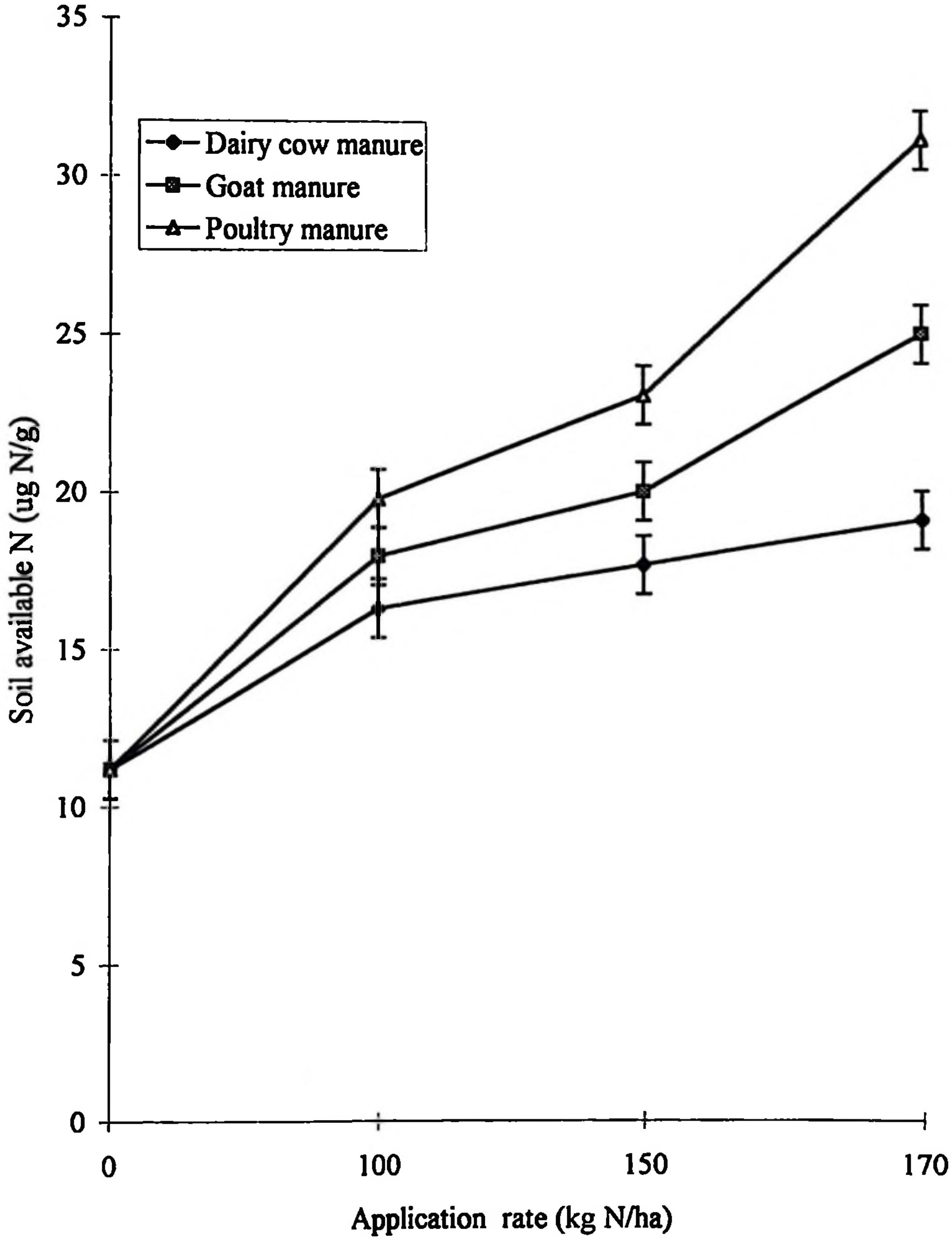

Figure 1. Effect of the animal manures on soil available N

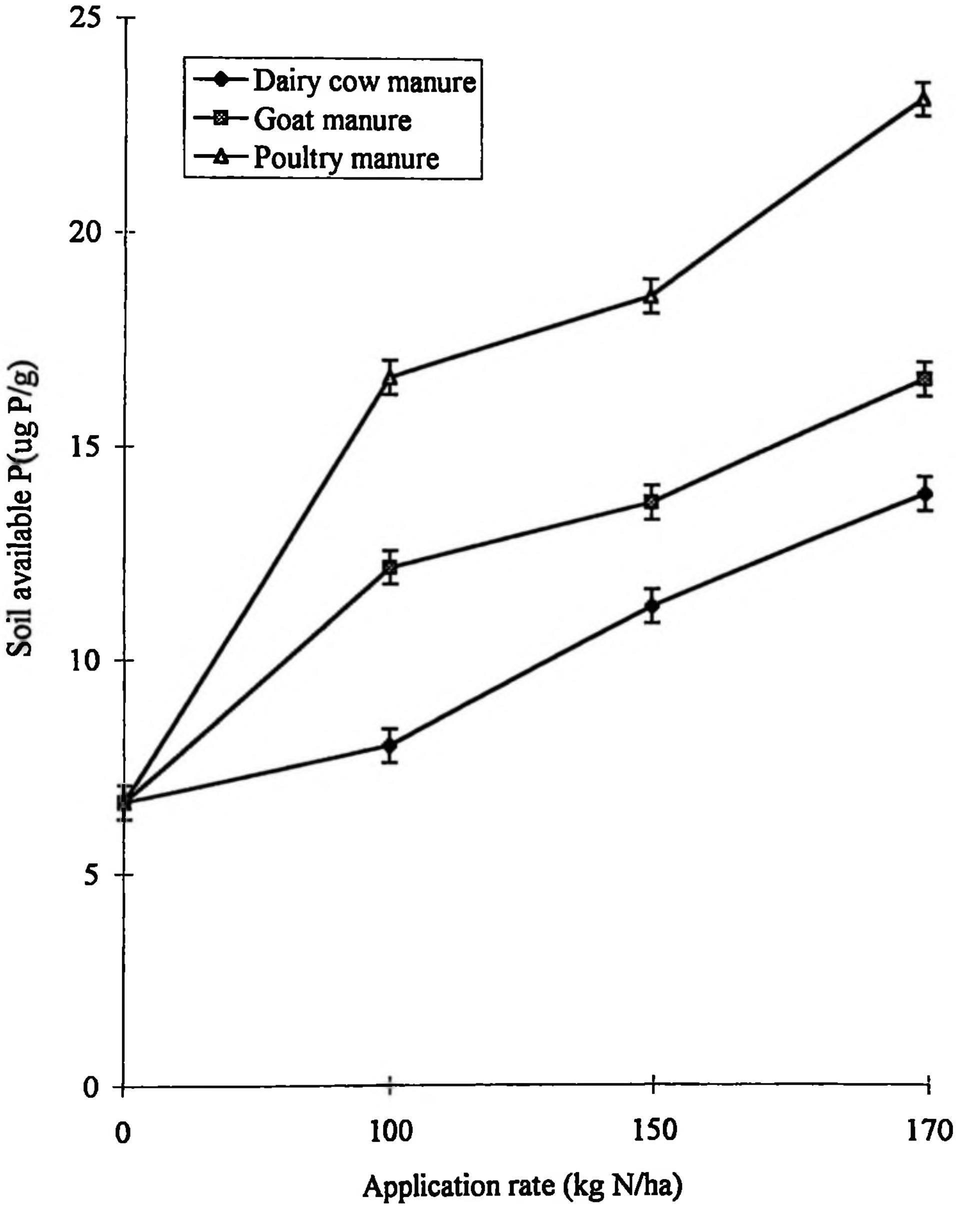

Figure 2. Effect of the animal manures on soil available P

The increase in soil available levels of N and P with application rates of the animal manures could be attributed to increased microbial activities following increased concentration of nutrients for the decomposing micro-organisms. Consequently, this could have resulted in increased decomposition of the organic forms of N and P, hence increased of levels soil available N and P. Similar results were reported by Bomke and Lavkulich (1975) and Schlegel (1992). The researchers observed that poultry manure had highest effect on soil available levels of N and P compared to other animal manures evaluated (cattle and sheep manures) and that these levels increased with manure application rates. Soil P increased from an initial level of 13 ppm Bray-1 P to 67 ppm after three annual applications of the manures at the rate of 7.2 ton/acre.

4.3.2 Effect of the animal manures on amaranthus root growth

Results of taproot length and root dry weight are summarized in Figure 3 and Table 5, respectively. Taproot length and root dry weight were significantly influenced by the application of the three animal manure types. There was a significant manure type and rate of application interaction ($P < 0.05$) suggesting that the two root parameters were differentially affected by the application of the manures at different application rates (Appendix 1). Irrespective of the manure type, tap root length and root dry weight increased with increasing manure application rate.

The effect of the three manure types on the two variables differed significantly except for the lowest rate of application (100 kg N/ha), where there was no significant difference between the three manures. The trend of the effects of the manure types on these two variables was; poultry manure > goat manure > dairy cow manure.

The above responses are consistent with the results of available levels of N and P (Figures 1 and 2) which indicate that poultry manure resulted in highest levels of available N and P compared to goat and dairy cow manures. This suggests that the observed responses in root growth were largely influenced by the increased levels of N and P following applications of the animal manures. Similar results were reported by Wright *et al.* (1985), who observed that maximum root growth and rooting depth of barley crop were in soils that received animal manures compared to where manures were not applied. They attributed this to increased level of organic matter and plant nutrients especially N and P.

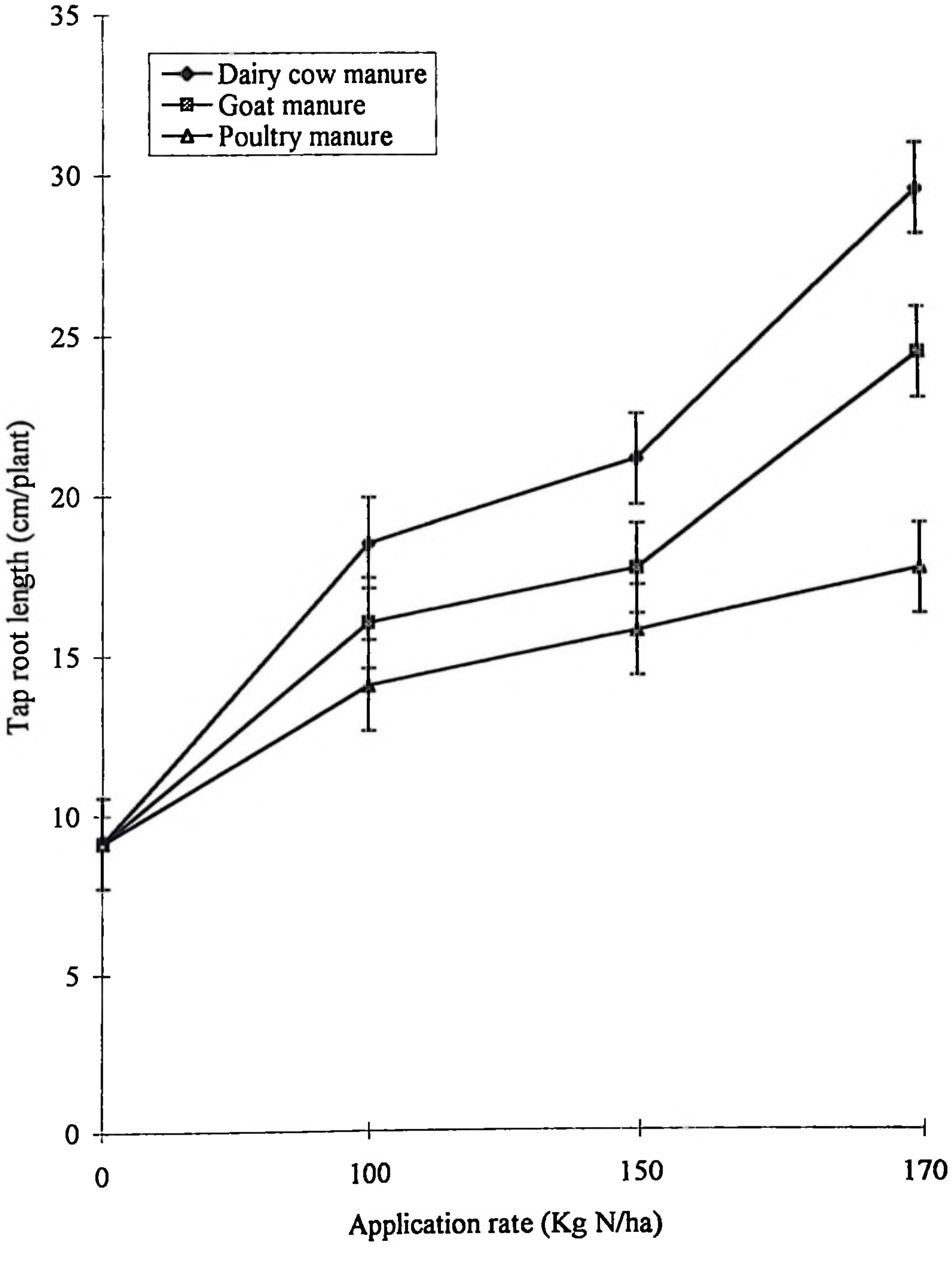

Figure 3. Effect of the animal manures on amaranthus tap root length

Table 5. Effect of the animal manures on amaranthus root dry weight

Rate (kg N /ha)	Manure type	Root weight (mg/pot)
Control		50.7g
100	Poultry	103.0bc
	Goat	84.7de
	Dairy cow	67.3efg
150	Poultry	123.0b
	Goat	95.0cd
	Dairy cow	73.0ef
170	Poultry	157.0a
	Goat	117.7b
	Dairy cow	93.7cd
CV (%)		12.79

Means followed by the same letter(s) within the columns do not differ significantly at $P < 0.05$ according to DNMRT.

4.3.3 Effect of the animal manures on tissue N and P concentrations

Results of tissue N and P concentrations are shown in Table 6. The ANOVA results for tissue N and P concentrations indicated a significant manure type X application rate interaction ($P < 0.01$), suggesting different effects of the manures at different rates of application (Appendix 1). Applications of the three manures significantly ($P < 0.05$) increased tissue concentrations of N and P and the effect increased with increasing rate of manure application.

Comparison of means of different treatments indicated that there was significant difference among the manure types. Poultry manure resulted in highest concentrations of tissue N and P followed by goat and dairy cow manure (Table 6). Explanation of the above observations can largely be based on the nutrient composition of the three manures (Table 4) and consequently, their effect on the soil available levels of N and P (Figures 1 and 2) which indicate that generally, application of poultry manure resulted in highest levels of soil available N and P compared to goat and dairy cow manures. It is therefore logical to assume that the highest values of tissue concentrations of N and P observed where poultry manure was applied is a reflection of increased uptake of N and P relative to the other two animal manures.

Table 6. Effect of the animal manures on amaranthus tissue N and P

Rate (kg N/ha)	Manure type	Tissue concentrations	
		N	P
		-------(%)--------	
Control		2.21f	0.20f
100	Poultry	3.10d	0.52bc
	Goat	2.72e	0.42cde
	Dairy cow	2.72e	0.30de
150	Poultry	3.93b	0.56b
	Goat	3.33cd	0.46cd
	Dairy cow	3.00de	0.39e
170	Poultry	4.45a	0.70a
	Goat	3.50c	0.50b
	Dairy cow	3.50c	0.45cde
CV (%)		5.75	6.16

Means followed by the same letter(s) within the columns do not differ significantly at $P < 0.05$ according to DNMRT.

Established tissue concentration critical ranges for some related vegetable crops (such as spinach, lettuce and cabbage) are 3.7% to 5.55% N and 0.3% to 0.7% P (Marschiner, 1995). Based on the above critical ranges, applications of the three manures increased tissue N and P from deficient levels to adequate ranges particularly at 170 kg N/ha rate of application. These results are somewhat in agreement with those of Larney and Janzen (1996) who observed significant effect on tissue N and P concentrations which increased with increasing rate of applications of poultry and pig manures. They attributed this to enhanced levels of soil available N and P.

4.3.4 Effect of the animal manures on amaranthus shoot dry matter yield

Shoot dry matter yield results are summarized in Figure 4. Yields were significantly ($P < 0.05$) increased by the applications of the three animal manures and increased with increasing application rate. Comparison of the different manures indicated that poultry manure resulted in significantly higher yields relative to goat and dairy cow manures. The trend was poultry manure > goat manure > dairy cow manure.

These results are consistent with those of soil available N and P (Figures 1 and 2) and those of tissue N and P (Table 6) which indicate similar trends, suggesting that the observed responses were largely due to differences in N and P uptake by amaranthus which resulted from differences in soil available N and P. Application of poultry manure resulted in significantly higher levels of soil available N and P and tissue concentrations of N and P compared to the other two manures.

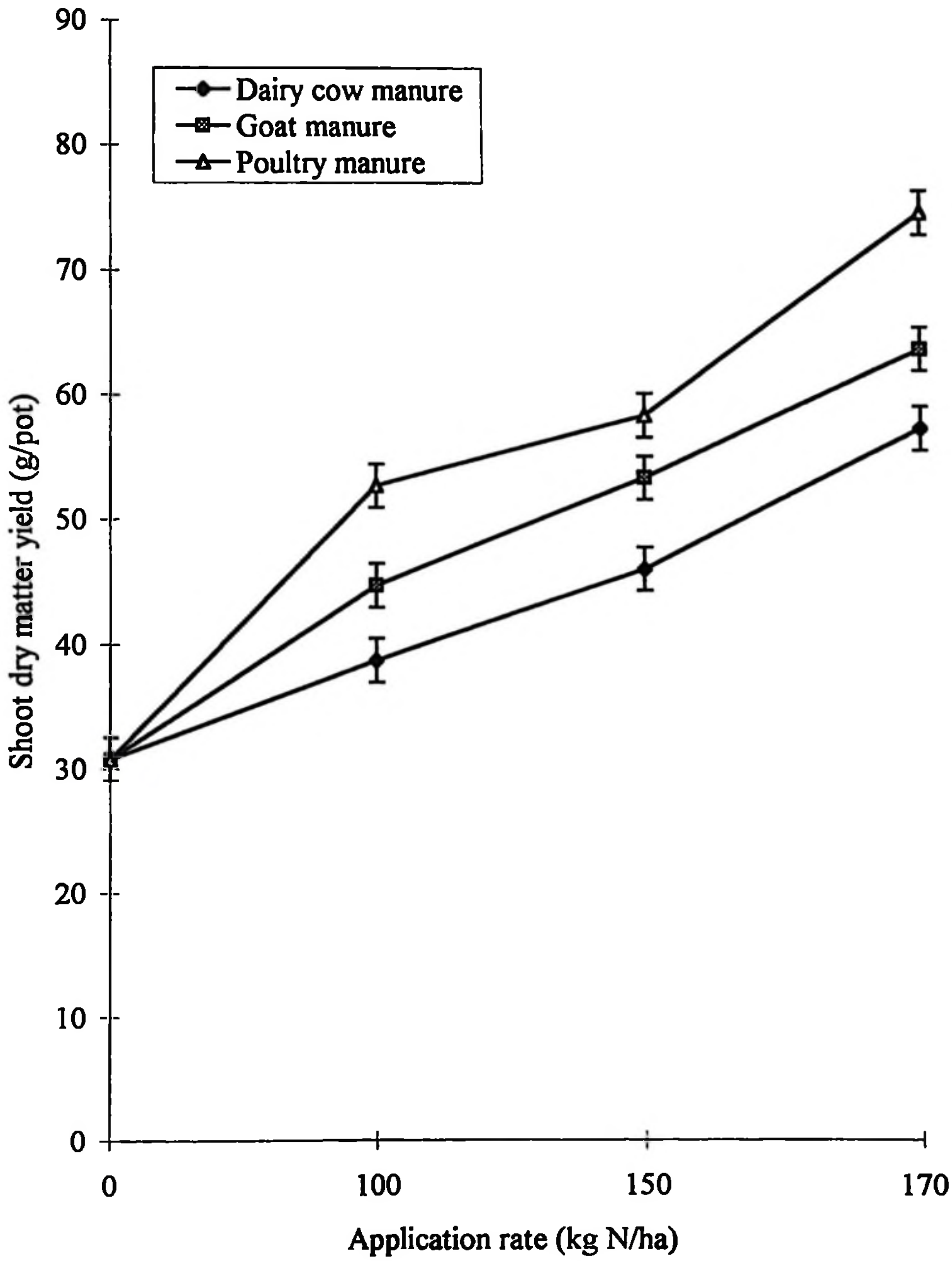

Figure 4. Effect of the animal manures on amaranthus shoot dry matter yield

The above explanation is also supported by the correlation coefficients (Table 7) which indicate that shoot dry matter yield was highly and positively correlated to soil available levels of N ($r = 0.90$) and P ($r = 0.93$), and tissue concentrations of N ($r = 0.93$) and P ($r = 0.93$). Shoot dry matter yield was also positively correlated with tap root length ($r = 0.88$) and root weight ($r = 0.86$). This suggests that the observed shoot dry matter yield was highly related to the availability and uptake of N and P.

These results are in agreement with those reported by Massomo and Rweyemamu (1989) who observed significant effects on yield of common beans following application of poultry manure. They concluded that the observed effects were indication that animal manures corrected both diagnosed and undiagnosed macro and micro nutrient deficiencies in the soil. Also, Larney and Janzen (1996) reported that when different manures were applied in an eroded soil, yields of wheat obtained from animal manure treatments were comparable to yields obtained from normal soils indicating significant soil improvement following manure application. They further reported that the increase in yield was mainly due to the increase in N and P available levels following application of manures in the 0-15 cm soil depth. The highest yielding treatments were those with poultry manures.

Table 7. Correlation between shoot dry matter yield and soil available N and P, tissue N and P content, taproot length and root dry weight

Shoot dry matter yield:	Soil available Levels		Tissue concentration		Tap root length	Root dry weight
	N	P	N	P		
Correlation	0.90	0.93	0.93	0.93	0.89	0.86
Student's T value	11.77	14.93	14.33	14.46	11.36	9.96
Probability	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**

** = Highly significant at $P < 0.01$.

4.4 FIELD EXPERIMENT

The experiment was conducted to evaluate under field conditions the effects of the different animal manures and rates of application on the variables evaluated under the pot experiment except for root growth. This experiment was conducted over three crop cycles within the same growing season. The animal manures were applied only once during the first crop cycle. Each crop cycle lasted for approximately one month. The experiment was conducted over three crop cycles in order to get indication on mineralization trends of the manures.

4.4.1 Effect of the animal manures on soil available levels of N and P

Results of soil available levels of N and P after harvesting (first and third crop cycles) are summarized in Figures 5 and 6 and Table 8. There was a significant ($P < 0.01$) manure type X application rate interaction during the first and third crop cycles suggesting variation in effectiveness of the three manures at different rates of application (Appendix 2).

Irrespective of the type of animal manure, soil available levels of N and P significantly ($P < 0.01$) increased with rates of application during both first and third crop cycles. As it was in the pot experiment, the highest rate of application (170 kg N/ha) resulted in highest effect for all manure types and crop cycles. The trend was; poultry manure > goat manure > dairy cow manure.

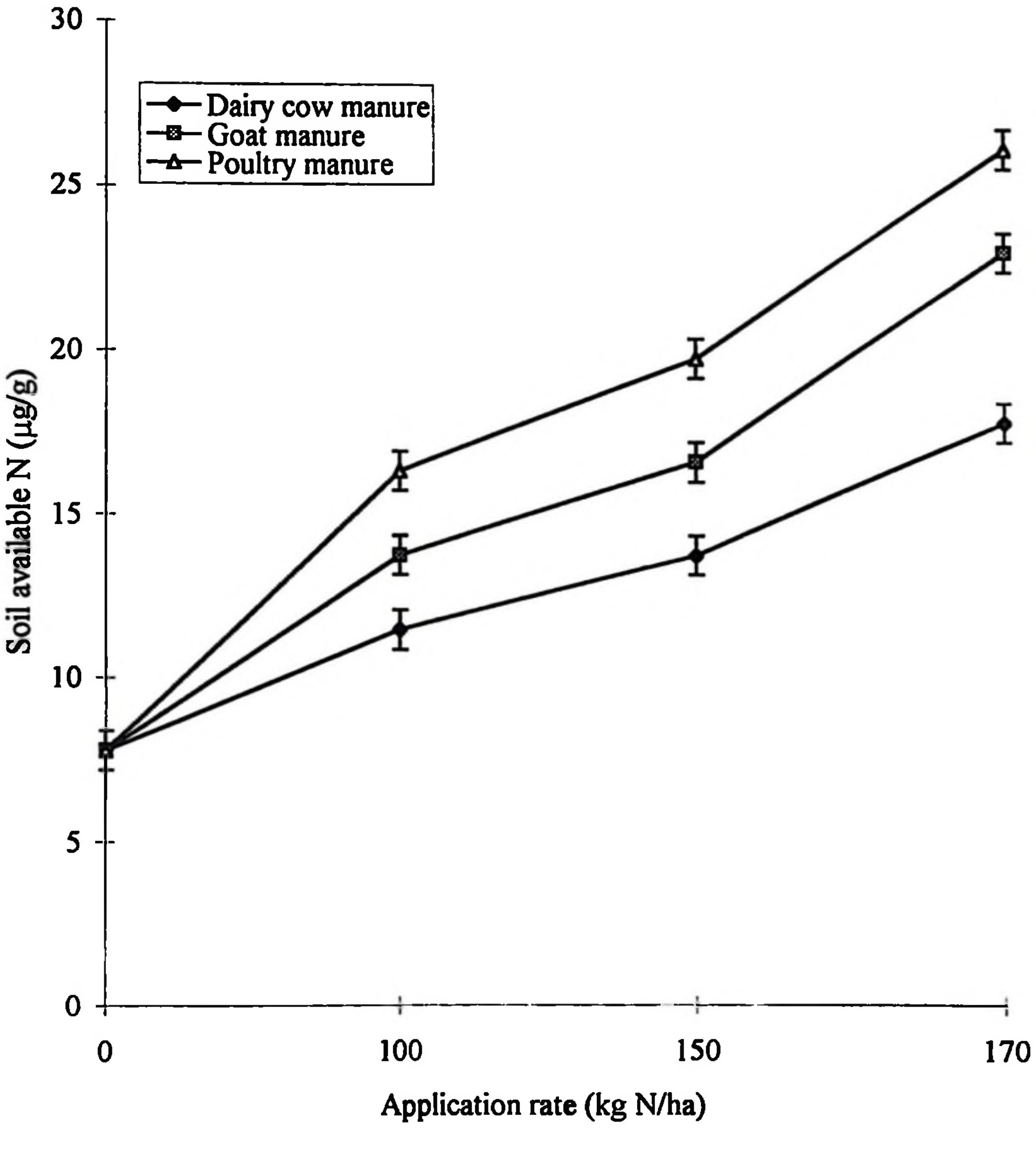

Figure 5. Effect of the animal manures on soil available N during first crop harvest

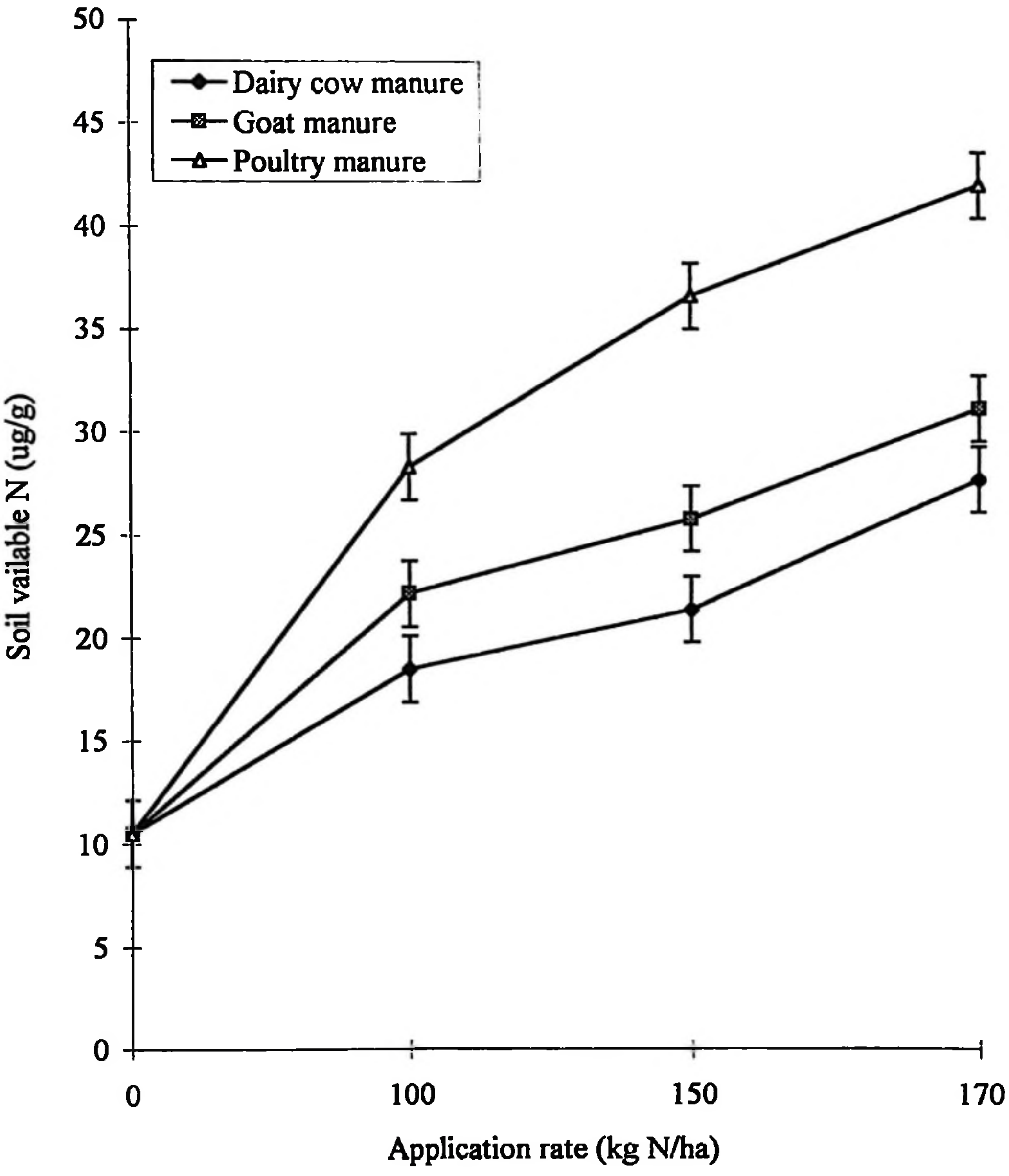

Figure 6. Effect of the animal manures on soil available N during the third crop harvest

Table 8. Effect of the animal manures on the soil available P

Rate (kg N/ha)	Manure type	Soil available P (μg/g soil)	
		1*	3**
Control		7.04g	7.32g
100	Poultry	16.56c	22.98bc
	Goat	13.90e	18.56c
	Dairy cow	11.31f	12.30e
150	Poultry	20.25b	26.18b
	Goat	16.16c	21.39bc
	Dairy cow	14.15de	15.53d
170	Poultry	25.12a	31.42a
	Goat	19.23b	23.99bc
	Dairy cow	14.83d	18.75c
CV (%)	--	6.50	9.44

1* = First crop cycle.

3** = Third crop cycle.

Means followed by the same letter(s) within the columns do not differ significantly at $P < 0.05$ according to DNMRT.

The observed trend was consistent with the differences in the three manures with respect to total N, total P and organic carbon. As pointed out earlier, poultry manure had the highest values of total N and P and narrowest C/N and C/P ratios compared to the other manures (Table 4).

The rate at which organic N and P mineralizes is to a large extent influenced by total N, total P and the balance between C, N and P in organic materials. Janson and Person (1982) suggested that the optimal C/N ratio is from 25:1 to 30:1 whereas Tisdale (1985) observed that for mineralization to take place organic materials must contain at least 0.2% of total P. Generally, the C/P ratio < 100:1 leads to mineralization whereas C/P > 100:1 leads to immobilization (Janson and Person, 1982).

The levels of available N and P after the third crop cycle were significantly higher (P < 0.01) for all manure types compared to those of the first crop cycle. Irrespective of the shorter experimental duration (three months) this trend was expected since the decomposing micro flora require substantial time to act on organic materials. Klausner and Bouldin (1973) observed that organic N and P mineralizes over a period of time which eventually decreases with increasing time after the initial application. Working with various animal manures Turner and Thompson (1983) observed that silage corn dry matter yields increased significantly in the first and second year of application indicating substantial mineralization of organically bound nutrients even after the second year of application.

4.4.2 Effect of the animal manures on tissue N and P concentrations

Results for tissue N and P concentrations in amaranthus plants after the third crop harvest are presented in Figures 7 and 8, respectively. There was a significant ($P < 0.05$) manure type X application rate interaction suggesting variation at different rates of application. Application of the three animal manures significantly ($P < 0.01$) increased tissue concentrations of N and P with increasing rates of application.

Comparisons of the three manures revealed that application of poultry manure resulted in highest values of tissue N and P at all application rates. The trend was; poultry manure > goat manures > dairy cow manures. These results are consistent with those of soil available levels of N and P (Table 8 and Figures 5 and 6) which show that application of poultry manure resulted in highest levels of soil available N and P compared to the other two manures. This suggests that the observed responses in tissue N and P were a result of increased uptake of N and P following mineralization of organically bound forms of N and P.

As pointed out earlier, the established critical ranges for tissue N and P for leafy vegetable crops are from 3.7% to 5.55% N and from 0.3% to 0.7% P (Marschiner, 1995). Based on these values, tissue N and P were increased from deficient to adequate ranges following application of the three animal manures. The results observed in this study are in agreement with those reported by Liu *et al.* (1997) and Schlegel (1992) who observed significant increase in tissue N and P following application of animal manures.

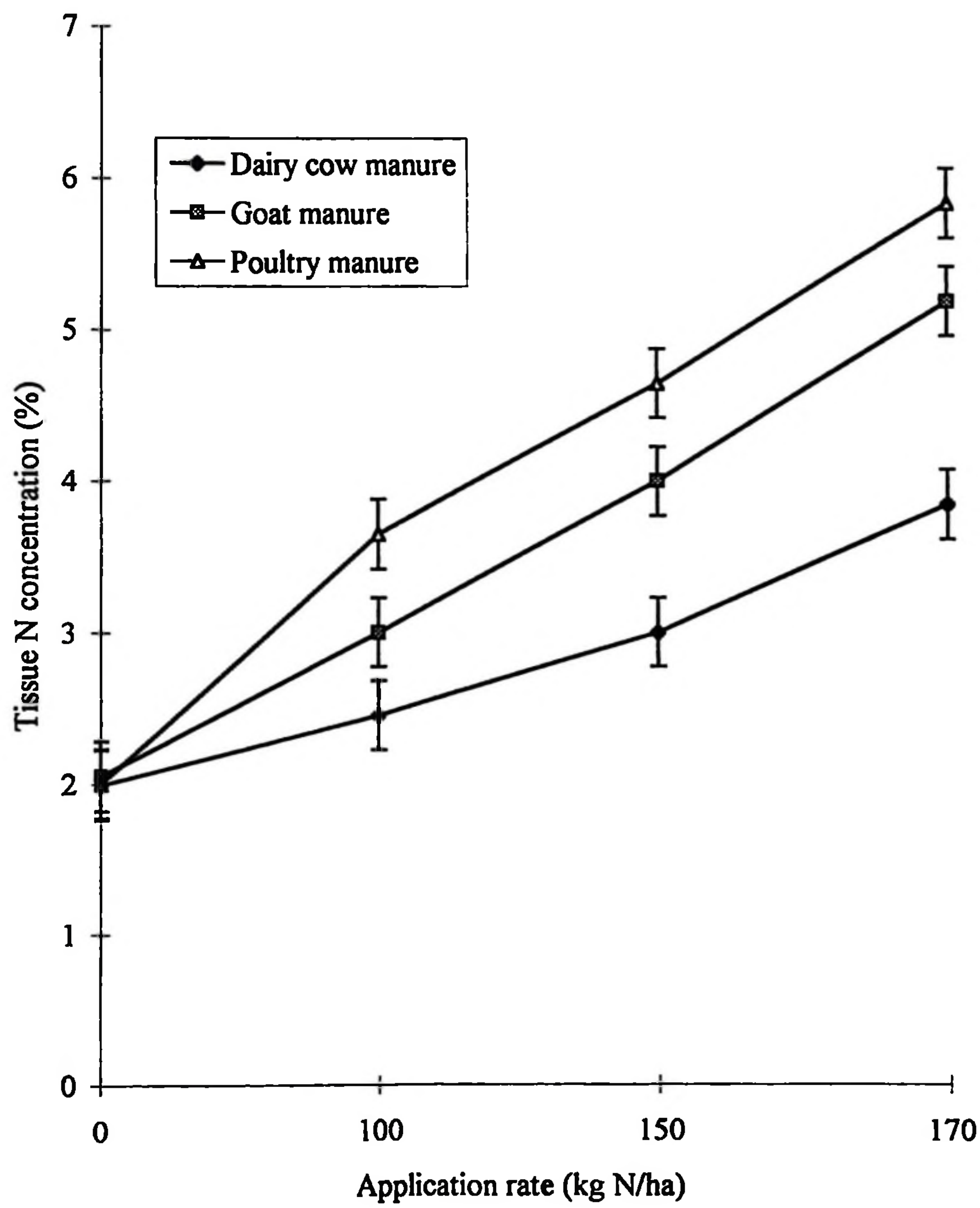

Figure 7. Effect of the animal manures on tissue N during the third crop harvest

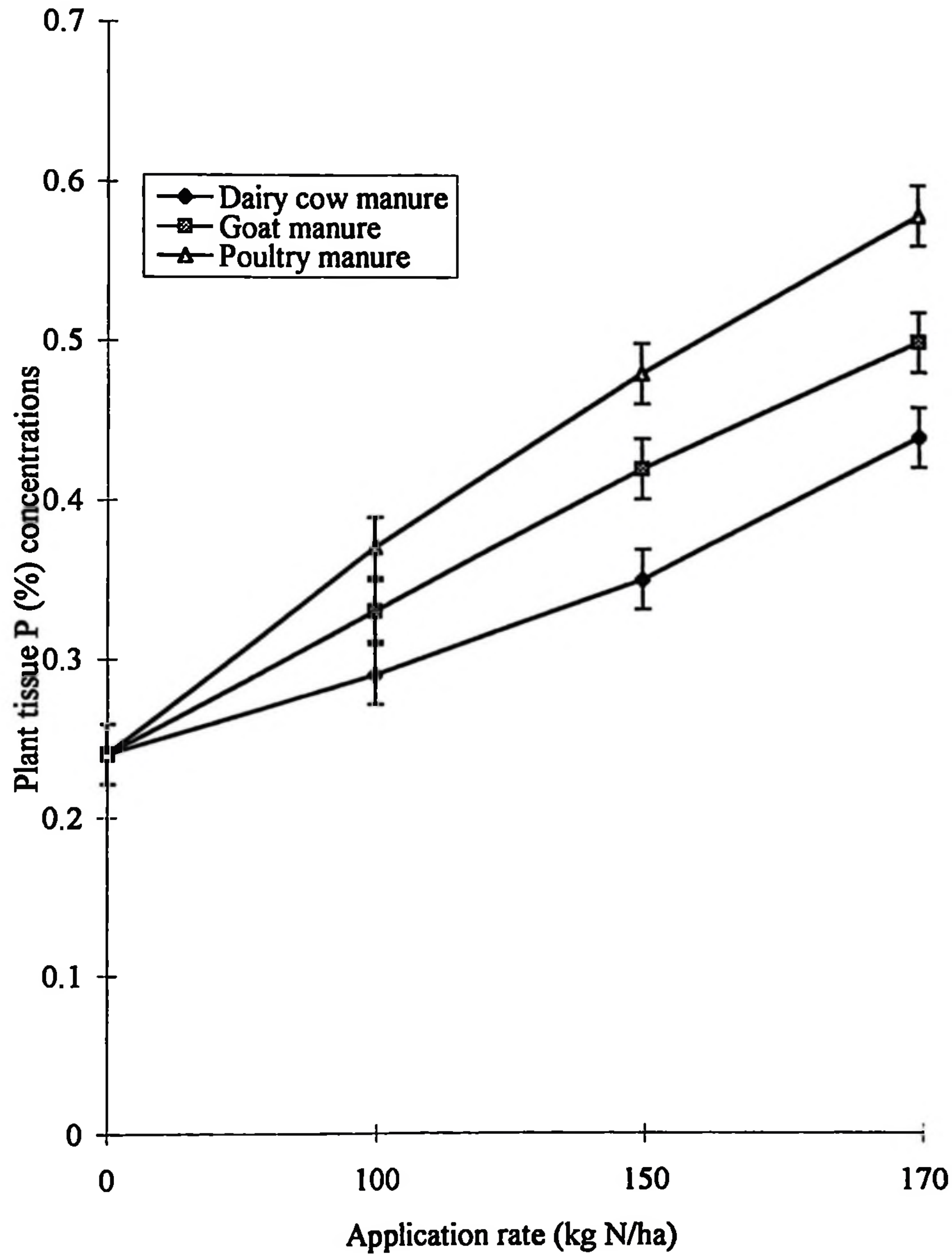

Figure 8. Effect of the animal manures on plant tissue P during the third crop harvest

4.4.3 Effect of animal manures on amaranthus shoot dry matter yield

Shoot dry matter yields of amaranthus for the first, second and third harvests are presented in Figures 9, 10 and 11, respectively. Amaranthus yields increased over successive harvests during the three months of the experimental work. Highest yields were obtained during the third harvest and lowest yields during the first harvest. This was consistent with the results of the soil available N and P (Figures 5 and 6 and Table 8) which indicate that the highest levels of available N and P were obtained after the third crop harvest. This suggests that the observed responses were largely due to increased levels of N and P following increased mineralization of organic forms of N and P with time.

There was a significant ($P < 0.01$) manure type X application rate interaction for all harvests indicating differential effects of the three manures at different rates of application. All the animal manures significantly ($P < 0.01$) increased amaranthus yields and the responses increased with increasing rate of application in all three crop harvests. Comparison of the three types of manures indicates that for all three crop harvests poultry manure gave the highest response followed by goat and dairy cow manures.

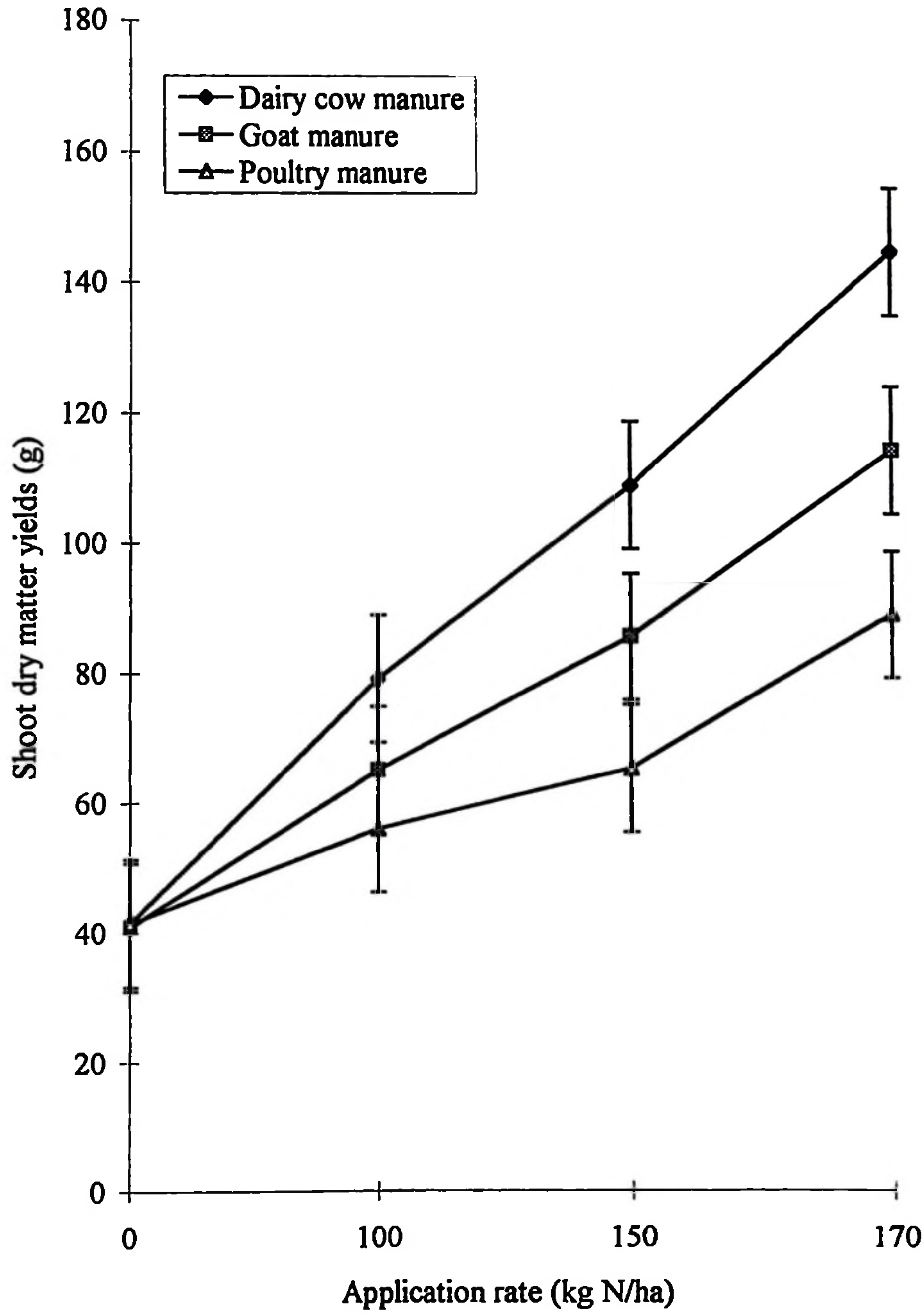

Figure 9. Effect of the animal manures on amaranthus shoot dry matter yield at the first crop harvest.

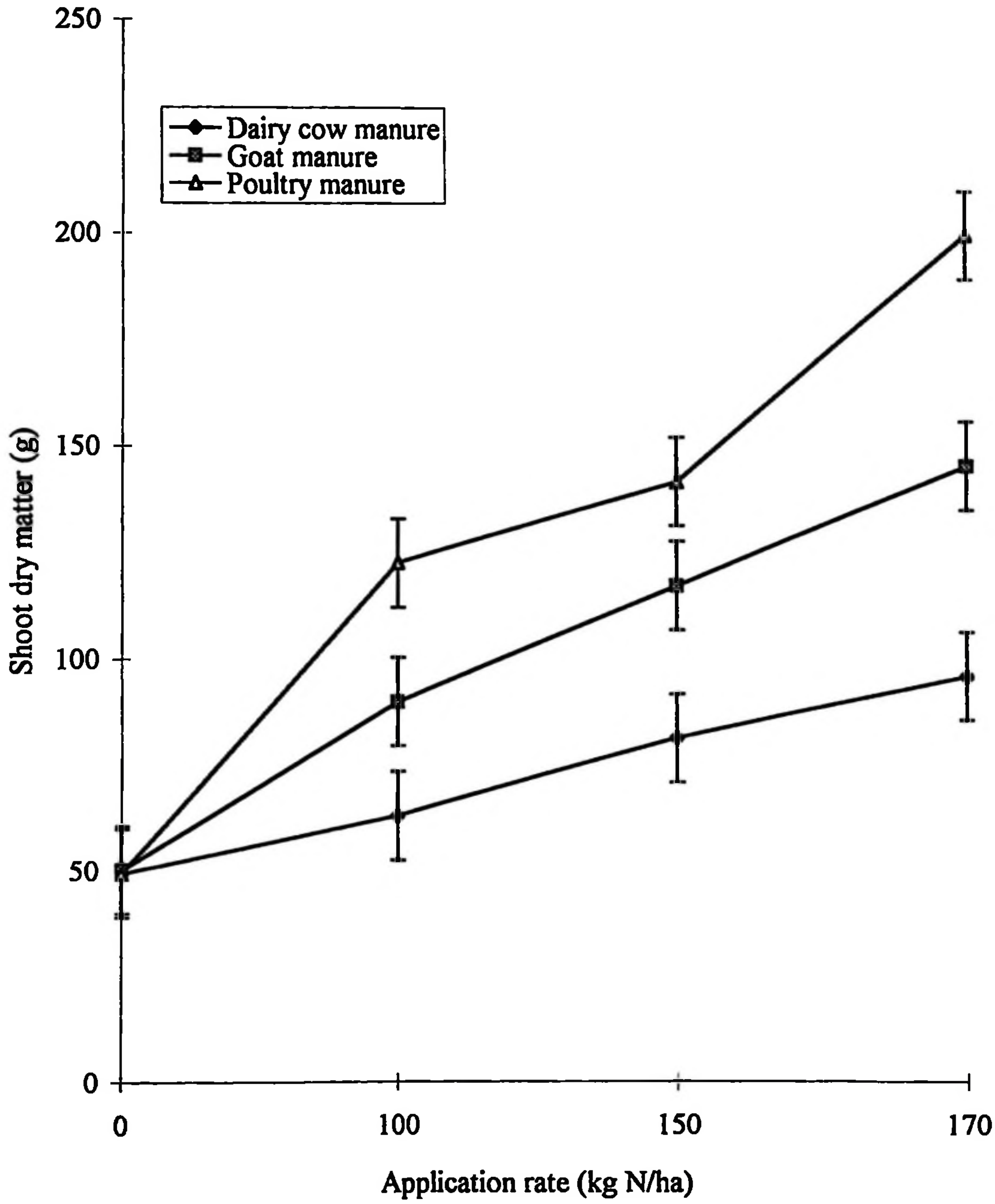

Figure 10. Effect of the animal manures on amaranthus shoot dry matter yield at the second crop harvest

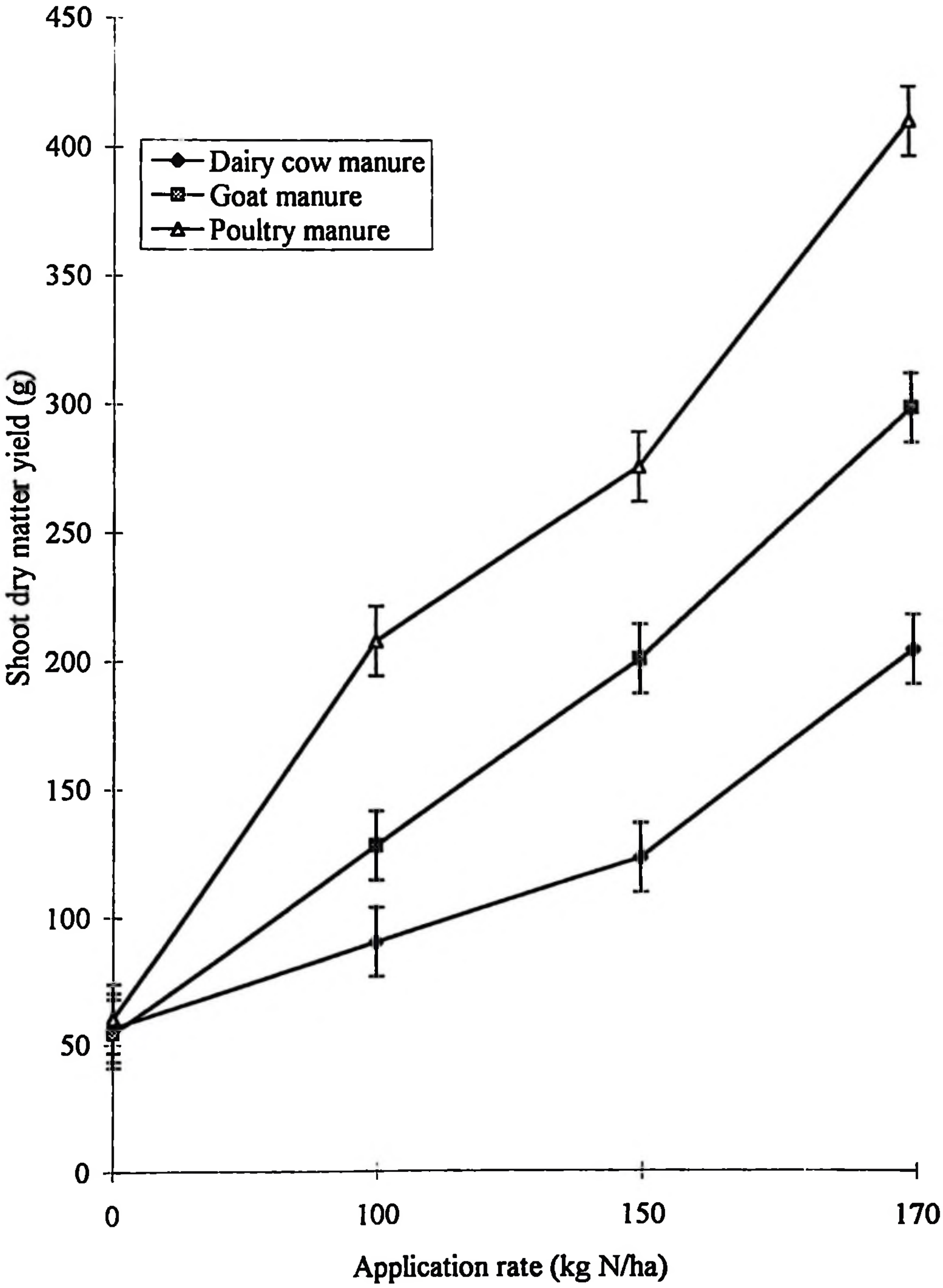

Figure 11. Effect of the animal manures on amaranthus shoot dry matter yield at the third crop harvest

The above responses are consistent with the results of the soil available N and P (Table 8 and Figures 5 and 6) and those of tissue concentrations of N and P (Figures 7 and 8) which indicate that poultry manure gave the highest response followed by goat and dairy cow manures. As discussed earlier, this could be due to differences in nutrient composition of the three manures as reflected by total N, total P and organic carbon values (Table 4). In this case, poultry manure was expected to give highest response compared to the other two manures since it contains easily decomposable materials, most of which are in the form of urea and uric acid.

The above observations are supported by the correlation coefficients [(Table 9(a) and 9(b)]. The results indicate that shoot dry matter yield was highly and positively correlated to soil available levels of N [($r = 0.88$ (1), $r = 0.94$ (3)] and P [($r = 0.87$ (1), $r = 0.94$ (3)] in the first (1) and third (3) crop cycles, respectively. Shoot dry matter yield was also positively correlated to tissue concentrations of N ($r = 0.92$) and P ($r = 0.89$) during the third crop cycle. This shows that the observed responses in shoot dry matter yield were highly related to the availability and uptake of N and P.

Results of the field experiment therefore, confirm those of the pot experiment where highest responses were obtained from poultry manure treatments and amaranthus dry matter yield was highly related to soil availability of N and P. These results are in agreement with those reported by Obiero (1996) who observed that, when various animal manures were applied at the rates of 10 and 20 tons/ha amaranthus plant growth was increased particularly when the manures were amended prior to sowing. Working with six types of animal manures, Larney and Janzen (1996) observed significant dry matter yield increase of wheat. They observed that the best overall effect was from poultry manure treatments. Also, Randall *et al.* (1975) observed that maize yields were significantly increased in subsequent years after application of dairy cow manure. They concluded that the effect was largely due to adequate time of mineralization of the applied manures.

Table 9(a). Correlation between shoot dry matter yield and soil available N and P at harvesting in the field experiment

Shoot dry matter yield:	Soil available N and P			
	N		P	
	1	3	1	3
Correlation	0.88	0.94	0.87	0.94
Student's T value	8.41	16.47	10.40	16.18
Probability	0.00**	0.00**	0.00**	0.00**

1 = First crop cycle

3 = Third crop cycle

** = Highly significant at P < 0.01

Table 9(b). Correlation between shoot dry matter yield and tissue N and P at harvesting in the field experiment

Dry matter yield:	Tissue concentrations	
	N	P
Correlation	0.92	0.89
Student's T value	14.02	11.43
Probability	0.00**	0.00**

** = Highly significant at P < 0.01

4.4.4 Net available N and P and implications on manure recommendations

Tables 10 and 11 show net available values of N and P after the third crop cycle. The net available N from poultry manure at the rate of 170 kg N/ha after the third harvest was 31.80 μg N/g (Table 10). This implies that 63.6 kg of N/ha were in the available form after the third crop cycle. Recommended rates of N and P for Southern Highlands of Tanzania for most field crops is 40 - 50 kg N/ha and 20 kg P/ha (Ministry of Agriculture and Cooperatives, 1996). Based on this, applications of poultry, goat and dairy cow manures at the rates of 5.8 tons/ha, 9.8 tons/ha and 13.4 tons/ha respectively, will meet the recommendation of 40 kg N/ha.

Considering data for P, application of poultry manure resulted in net available P of 24.1 μg P/g at the application rate of 170 kg N/ha (Table 11). Thus, 48.2 kg P/ha was in the available form after the third crop harvest following initial application of poultry manure. The above application rates of poultry, goat and dairy cow manures which are based on N requirements will provide 30.5 kg P/ha, 31.6 kg P/ha and 26.8 kg P/ha, respectively. These will suffice the P recommendation (20 kg P/ha) for the region.

Table 10. Effect of animal manures on net soil available N

Rate (kg N/ha)	Manure type	Soil available N (µg/g soil)	
		1*	3**
100	Poultry	6.24	18.10
	Goat	4.95	11.94
	Dairy cow	2.67	8.27
150	Poultry	9.90	26.43
	Goat	6.79	15.59
	Dairy cow	3.95	11.17
170	Poultry	16.39	31.80
	Goat	13.22	20.96
	Dairy cow	8.01	17.50

1* = First crop cycle

3** = Third crop cycle

Table 11. Effect of the animal manures on net soil available P

Rate (kg N/ha)	Manure type	Net available P (μg/g soil)	
		1*	3**
100	Poultry	9.52	15.66
	Goat	6.86	11.24
	Dairy cow	4.27	4.98
150	Poultry	13.21	18.86
	Goat	9.12	14.07
	Dairy cow	7.11	8.21
170	Poultry	18.08	24.10
	Goat	12.19	16.67
	Dairy cow	7.79	11.43

1* = First crop cycle

3** = Third crop cycle

It is important to note that similar calculations can be carried out at 100 kg N/ha and 150 kg N/ha rates of manure application. The decision on the application rate to operate at will depend on among other things, availability of the animal manures and crop requirements. It is also worthy to note that despite the fact that net available levels of N and P were relatively low in this study, frequent application of such manures could immensely enhance fertility of this soil and others with similar properties.

According to the research findings by Kimbi *et al.* (1999) manure output that is available in the country for agricultural use is estimated to about 13.5 million tons per year. This is equivalent to 94,500 tons of total N, if the average N content of the manure is assumed to be 0.7% (Kyomo and Chagula, 1983). Large quantities are obtained from cattle manure followed by goat and poultry manures. This suggests that animal manure output in most parts of the country is enormous. Thus, if effectively used the problem of declining soil fertility and land productivity could be substantially reduced.

Main documented limiting factors for use of animal manures for crop production in Tanzania have been established to be lack of technical know how, long distances from the source to the fields, inferior transport facilities, insufficient amounts of manure and cultural values (Kimbi *et al.*, 1999). These factors should be addressed in promoting animal manure utilization through initiatives such as educational programs.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to comparatively evaluate the effects of poultry, goat and dairy cow manures on selected soil chemical properties, shoot dry matter yield, root growth and tissue concentrations of N and P.

Results of the pot experiment indicated that applications of the three animal manures significantly influenced the soil chemical properties evaluated. Irrespective of the manure type, soil available levels of N and P increased with increasing rates of application. The results also revealed significant variations among the three manures and the trend was; poultry manure > goat manure > dairy cow manure. Similar trends were also observed for other attributes evaluated namely; amaranthus shoot dry matter yield, tap root length, root dry weight and tissue concentrations of N and P. These responses could largely be due to differences in total N, total P, C/N and C/P ratios of the three 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 goat and dairy cow manures. Amaranthus shoot dry matter yield was highly and positively correlated to soil available levels of N and P, tap root length and weight and tissue concentrations of N and P indicating that the responses were largely due to availability and uptake of N and P.

Generally, results of the field experiment confirmed those of the pot experiment. Soil available levels of N and P after the third crop harvest were higher compared to those obtained during the first crop cycle indicating that mineralization of N and P increased with time after the initial application. As was in the pot experiment, highest responses of the evaluated parameters were obtained from poultry manure followed by goat and dairy cow manures. Amaranthus shoot dry matter yield was positively and highly correlated to available levels of N and P and tissue concentrations of N and P.

Based on the fertilizer recommendations of N and P for Southern Highlands of Tanzania (N = 40 - 50 kg N/ha and 20 kg P/ha) and the application rate of 170 kg N/ha used in this study, applications of 5.8 tons/ha of poultry manure, 9.8 tons/ha of goat manure and 13.4 tons/ha of dairy cow manure will meet the recommendation of 40 kg N/ha. The above applications rates will also provide 30.5 kg P/ha, 31.6 kg P/ha and 26. 8 kg P/ha for the respective manures, which would suffice P recommendation. Applications of the evaluated animal manures could therefore immensely improve fertility of this soil and others with similar properties. Given it's superior responses, poultry manure could be a very attractive fertilizer alternative particularly for annual crops with short growth cycles such as amaranthus. Results of this study should however, be confirmed under different field conditions and for longer experimental duration. Other areas for further study could be the effect of N and P concentrations on the taste and storability of amaranthus leaves after manure application.

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Appendix 1. Summary of Analyses of Variance for all variables tested in pot experiment showing F test values

Variables tested	Rates (A)	Manure type (B)	Interactions (A x B)
Shoot DM yield	22.71**	171.58**	3.87**
Root length	5.02*	479.16***	2.69*
Root dry weights	23.86**	76.36**	3.65*
Soil available N	10.46*	115.05***	7.94***
Soil available P	65.72***	594.85***	9.92***
Tissue N (%)	38.13**	127.15***	7.4***
Tissue P (%)	28.70**	38.07**	4.83**

* = Significant at P = 0.05

** = Significant at P = 0.01

*** = Significant at P = 0.001

Appendix 2. Summary of the Analyses of Variance for all variables tested in field experiment showing F test values

Variables tested	Rates (A)	Manure types(B)	Interaction (A x B)
DM (1)	2.541*	62.327***	3.506**
DM (2)	1.996*	67.056***	1.662**
DM (3)	40.038**	212.803***	9.614***
Available N (1)	230.20***	183.50***	11.234***
Available N (3)	24.683***	134.065***	3.236*
Available P (1)	90.318***	337.154***	11.086***
Available P (3)	23.948**	223.584***	3.683*
Tissue %N (3)	8.003*	48.433***	1.345**
Tissue %P (3)	20.297**	123.034***	2.068**

* = Significant at = 0.05

** = Significant at = 0.01

*** = Significant at = 0.001

DM = Shoot dry matter yield

(1) = First crop harvest

(2) = Second crop harvest

(3) = Third crop harvest