THE RESPONSE OF CHINESE CABBAGE *(Brassica campestris* L.) TO FARMYARD MANURE SLURRY APPLIED TO AN ACID SOIL

By

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ABSTRACT

A glasshouse pot experiment was conducted at the Sokoine University of Agriculture (SUA), Morogoro, Tanzania, to evaluate the response of chinese cabbage (*Brassica campestris* L) to farmyard manure slurry (FYM-slurry) applied to an acid soil as an alternative source of plant nutrients. The soil used in this study was collected from the central part of SUA farm and the FYM-slurry from the storage lagoon at Magadu Dairy Unity, SUA. Based on laboratory analytical data of the soil and FYM-slurry, the soil was categorised as of low fertility status and the nutrient contents in the FYM-slurry (solid and liquid portions) categorised as medium. Eighteen, 12kg, 8mm sieved soil samples portions were weighed into 18, 15 litre capacity plastic buckets and moistened to field capacity. Six, twenty one days' old chinese cabbage seedlings raised in a nursery were planted in each bucket and the moisture content in the buckets maintained at about field capacity. Just before applying the FYM-slurry, the plants were thinned to 3 plants per bucket. FYM-slurry at equivalent rates of 0, 166.6, 208.33, 250, 291.67, 333.33, 375, 416.67 and 500m^3ha^{-1} were applied to the buckets 7 days from the transplanting date in six equal splits at intervals of ten days and each treatment was replicated twice. The FYM-slurry was incorporated into the topsoil in the buckets followed with addition of water so as to maintain the soils in the buckets at field capacity, throughout the growing period. At 66 days from the date of transplanting, the whole chinese cabbage plants above the soil in the buckets were harvested and fresh weights according to treatments recorded. The fresh plant materials were then dried to constant weight at 70°C, ground into fine powder and nutrient contents determined. It was observed that application of FYM-slurry significantly increased the fresh and dry matter yields and the macronutrient contents of the chinese cabbage plants. The increases were attributed to increase in the fertility status of the soil consequent to the release of the plant nutrients contained in the FYM-slurry through chemical and biological transformations of the FYM-slurry. The micronutrient contents of the chinese cabbage decreased with increasing levels of FYM-slurry and this was probably due to the increase in soil pH. It was concluded that FYM-slurry could substitute inorganic fertilisers and other organic soil amendments as a source of plant nutrients for chinese cabbage and other short-term vegetable crops. The FYM-slurry improved physical, chemical and biological attributes of soil fertility and productivity hence the positive response by the chinese cabbage plants to the FYM-slurry. FYM-slurry application rates at 250-300m^3ha^{-1} were suggested as optimal levels for chinese cabbage, subject to verification under field conditions.

DECLARATION

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

Signature:.........................

Date:....30·5·2003.....

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GLOSSARY OF ABBREVIATIONS AND SYMBOLS

Al	Aluminium
BS	Base saturation
C	Carbon
Ca	Calcium
$CaCO_3$	calcium carbonate
CAFOs	Confined animals feeding operation
Cd	Cadmium
CEC	cation exchange capacity
cm	centimetre
CO_2	Carbon dioxide
Cu	Copper
DTPA	Diethylene triamine pentaacetic acid
FAO	Food and Agriculture Organisation of the United Nations
Fe	Iron
FYM	Farmyard manure
g	gram
H	Hydrogen
H_2SO_4	Sulphuric acid
ha	hectare
HCl	Hydrochloric acid
HNO_3	Nitric acid
K	Potassium
kg	kilogram
l	litre

m^3	cubic metre
m	metre
Mg	Magnesium
mg	milligram
mm	millimetre
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
Na	Sodium
NaOH	Sodium hydroxide
Ni	Nickel
OC	Organic carbon
OM	Organic matter
P	Phosphorus
UK	United Kingdom
USDA	United States Department of Agriculture
Zn	Zinc

CHAPTER ONE

INTRODUCTION

The crop producing capacity of a soil is influenced by its physical, chemical and biological properties such as pH, mineralogy, moisture content, aeration, organic matter content and presence and availability of the essential nutrients required for plant growth. Most of the soils especially those in the tropics and sub-tropics lack some of these properties, thus for optimum crop production some modifications to the soils must be undertaken. Addition of farmyard manure (FYM) to soils has some positive effects in modifying the soil properties. Farmyard manure influences the growth and activities of the soil microorganisms, increase the moisture retention capacity of the soil and supply plant nutrients upon decomposition and mineralisation hence modify the availability of the plant nutrients. Generally the faeces of livestock consists chiefly of undigested food, which has escaped bacterial and digestive enzyme action in the alimentary canal, digestive fluids, waste mineral matter, worn out cells from the intestinal linings, mucus and foreign matter such as dirt consumed along with food (Jain and Kumar, 1995). Further livestock faeces contain some ruminal and intestinal microorganisms, which are likely to extend organic matter decomposition in the soil. Farmyard manure is, therefore, a semi-solid (faeces) and liquid (urine) excreta of livestock generally mixed with litter used for bedding and some feed wastage. The composition and quantity of FYM vary widely according to the kind of animal, the feed given to the animal and the type of litter used as bedding materials (Müller-Sämann and Kotschi, 1994). The amount of fresh matter produced by well-fed adult dairy cow is about 10 tons (30% dry matter) per annum. For local cattle kept for social purposes or as draught animals, this quantity is in the order of 2-3 tons, usually with a somewhat higher dry matter content

(Euroconsult, 1989), due to the amounts of feeds consumed. Dairy animals are of large sizes hence do consume more food than those kept for social or draught purposes.

Farmyard manure has been in use from time immemorial by farmers and is still in use, particularly in developing countries by peasant farmers (Uriyo *et al.*, 1979). Jain and Kumar (1995) pointed out that animal excreta are available at backyard premises of rural houses and in the dairy sheds and at times may become a health hazard. In the tropics and subtropics, the use of FYM is common, although usually only small quantities are available and most of which is reserved for fruits and vegetables and backyard gardens (Euroconsult, 1989). Jain and Kumar (1995) showed that FYM is one of the major under-utilised resources in agricultural production in many countries. For example many farmers regard FYM slurry as a valueless by-product that causes problems, while in fact FYM-slurry is rich in plant nutrients and is therefore a useful soil amendment. Frost and Stevens (2000) reported that dairy manure slurry contains about 0.3-1.5kg N m^{-3}, 0.6kg(P_2O_5) m^{-3} as available P and 3.2kg(K_2O) m^{-3} as available K. Animal manure could, therefore, be an important source of plant nutrients, especially nitrogen (N), which is the most limiting plant nutrient in most cultivated soils, in the tropics.

Due to land use pressure, intensive raring of animals has increased significantly resulting into high production of FYM-slurry at the backyards. The use of FYM-slurry has many benefits, which include the provision of a wide range of essential nutrients for crop production such as N, P, K and various micronutrients in varying amounts. The FYM-slurry is rich in N, which can be used to sustain and increase crop production especially in the production of vegetables. Currently, organic farming is being emphasised so as to reduce the effect of inorganic fertilises in crop production particularly vegetables. Therefore, apart from reducing the costs of buying inorganic fertilisers, the use of FYM slurries will help in fetching good markets for the produce. which significantly may increase the farmer's income and reduce health hazards on the side of consumers. The use of FYM-slurry will also reduce pollution caused by mismanagement of manure slurries.

Farmyard manure slurries have been used commercially for decades for vegetable production in the world. Today, society demands for efficient use of manurial materials because recycling of organic wastes in agriculture is viewed as an important aspect with respect to reducing environmental pollution.

Although it has been shown that proper manure management can be profitable through reduced fertiliser costs, many farmers do not credit the nutrients contained in FYM. This could be attributed to the fact that most of the nutrients contained in FYM are not immediately available for absorption by plants. Decomposition of FYM produces a variety of gases, including CO_2, NH_3 and H_2S which are lost through volatilisation. Also during the decomposition process soluble mineral compounds are released that may be lost by leaching. Further, during storage unaerated FYM-slurry produces bad smell which cause air pollution (Simpson, 1986) hence limits its use as soil amendment in crop production. Special care and equipment are also required during preparation, storage and application of FYM-slurry. Storage of FYM-slurry require waterproof tanks (Simpson, 1986) due to its bulkiness hence it is expensive to have adequate storage thus farmers are obliged to spread FYM-slurry at inconvenient periods and leave it on the soil surface with consequent N losses. For effective use of FYM-slurry, it should be incorporated into the soil immediately after application to reduce N losses and environmental pollution.

Importance of vegetables as food and supplier of vitamins, proteins, carbohydrates and minerals is well known. Most vegetables being short duration crops, fit very well in intensive cropping systems and are capable of giving very high yields and high economic returns to the farmers beside improvement of the health standards of the farmers. Vegetable crops make a heavy demand for nutrients from the soil, which is met jointly by the nutrient reserves in the soils and applications of manures and fertilisers. Intensive vegetable production depends on industrial fertilisers, which are unaffordable to the rural people, due to their low income base. Farmyard manure contains all the essential nutrient elements required for plant growth. Use of farmyard manure in vegetable production could supply significant amounts of the nutrients for plant growth thus greatly reducing the reliance on the use of inorganic fertilisers (Klausner and Bouldin, 1983). The nutrients contained in the FYM and FYM-slurry are slowly released hence there is a more pronounced residual effect in the soil associated with its application. Therefore, use of FYM could help peasants in the rural areas to undertake crop production activities at reduced costs.

The aim of this study was, therefore, to asses the usefulness of FYM-slurry as a soil amendment and the response of chinese cabbage to FYM-slurry applied to an acid soil with the following objectives: (i) To determine the contents of the essential plant nutrients in the solid and liquid portion of FYM-slurry of dairy animals at Magadu Dairy Unit SUA.

(ii) To determine the uptake of the essential nutrient elements by chinese cabbage plants from an acid soil to which different rates of FYM-slurry have been applied.

(iii) To determine the magnitude of response by chinese cabbage to FYM-slurry applied to an acid soil in terms of fresh and dry matter yields.

(iv) Based on objectives (i) to (iii) suggest the optimum rate of FYM-slurry for optimal chinese cabbage production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Composition of farmyard manure and farmyard manure slurry

Farmyard manure is a combination of faeces, urine, bedding materials and feed wastage. The chemical composition of FYM vary from place to place depending upon such factors as species, age and the condition of the animals, nature and amounts of feed given to the animals and handling and storage of the manure (Euroconsult, 1989).

Generally nutrient contents in manures collected from animals kept intensively are higher than those kept extensively due to the fact that, the intensively kept animals are supplemented with feeds of higher nutrient contents such as N and it is possible to collect all the excreta (dung and urine), throughout the day. Extensively reared animals normally graze on field forage, which contains low quantities of nutrients, hence, low nutrient contents in their excreta. In addition most of their excreta are lost in the field during grazing.

FYM-slurry is a waste product of livestock, which is a mixture of faeces and urine and may contain spilled feeds and wastewater (Koriath, 1977). Farmyard manure slurries are excreta, which have been deposited on solid or slated floors and feed wastage with no bedding materials and then washed into lagoons or storage tanks. The degree of dilution is very important in estimating the fertiliser equivalent of the slurry. The amounts of undiluted slurries produced by cattle per day are roughly proportional to their body weights provided that the animals are well fed. This is because animals do consume feed (dry matter and water) proportional to their body weights hence the amounts of excreta follow suit.

Within the same animal species, the composition of dung and urine varies according to fodder which also depend on site or source of the forage and season and water given to the animal as well as to the age of the animal and how it is used (Müller-Sämann and Kotschi, 1994). For example young animals and good milk-producing cows excrete less nitrogen than working or old animals because they are more efficient users of protein. Except in the case of poultry, the proportion of soluble nitrogen in fresh dung is relatively low. Fresh cattle, horse or sheep dung contains 0.5-0.6% N, and of this only 10% is soluble N (Müller-Sämann and Kotschi, 1994). Storing and rotting the dung increases the content of available N through mineralisation of organic materials/compounds in the dung. 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). The above rates are extremely low, when compared to the contents of the same for inorganic fertilisers.

The composition of urine varies even more widely than that of dung (Müller-Sämann and Kotschi, 1994). It has been shown that urine is particularly rich in potassium and nitrogen, whereas dung contains mainly calcium, nitrogen, phosphate and magnesium. The nitrogen in urine is present in soluble form and is readily available to plants. The ($N:P_2O_5:K_2O$) ratio of cattle manure is approximately 10:5:13. This implies that P content in the cattle manure is low compared to N and K. For the nitrogen in urine, 30% to 60% of the total nitrogen can be regarded as available, depending on soil and climatic conditions.

2.2 Effects of handling and storage on the nutrient contents of farmyard manure and FYM-slurry

Several factors may affect the composition and quality of farmyard manure and farmyard manure slurry as far as crop production is concerned. Methods of handling and storing manure affect its nutrient content. Under solid systems of handling manure such as daily scrap and haul, manure pack, open lot and deep pit, N losses are 15-35%, 20-40%, 40-60% and 15-35%, respectively. With liquid systems, N losses are 15-30%, 15-40% and 70-80% under anaerobic pit, oxidation ditch and lagoon, respectively. P and K losses are only 5 to 15% under all systems except in the open and lagoon systems where 50% of these nutrients are lost (Tisdale *et al.*, 1993). In open-lot storage, significant amounts of N are volatilised as NH_3 gas and considerable quantities of nutrients may be washed away when it rains. When manures are stored anaerobically, as in a large densely packed pile and aerated lagoon, high N loss occurs through nitrification. Myres *et al.* (1994) reported losses of more than 20% of N when FYM was stored for 3-6 months in cool conditions, probably due to volatilization and leaching processes.

There are invariable losses of nutrients either by leaching or volatilization when manures remain exposed to the sun and rain during the decomposition process especially nitrogen (Eghball and Power, 1999). During the rainy season, nutrient losses from composting manure heaps are extensive due to the removal of the water soluble constituents from the composting manure heaps (Müller-Sāmann and Kotschi, 1994; Jain and Kumar, 1995). When manures are stored under the sun, considerable amounts of ammonia combine with carbonic acids to form carbonates and bicarbonates. The ammonium carbonates and bicarbonates being unstable, liberates gaseous ammonia

(NH_3) into the atmosphere (Jain and Kumar, 1995) according to the following chemical reaction;

$$NH_4HCO_3 \rightarrow NH_3\uparrow + H_2O + CO_2\uparrow$$

The decomposition of FYM produces many gases, including CO_2, NH_3, and H_2S. It also releases soluble mineral compounds that may be lost by leaching. The microbial decomposition of FYM starts as an aerobic process in the loose litter with the generation of heat. Much C is lost as CO_2, the urine N converted to NH_3, which may either be lost through volatilization, adsorbed by the decomposing mass or converted to nitrate (Swift *et al.*, 1979). With compaction, anaerobic decomposition sets in reducing the rate of decomposition and fall in temperature of the decomposing mass with the consequent formation of complex nitrogen compounds (Swift *et al.*, 1979). FYM left in the open may lose most of its potassium, some of its phosphorus much of its nitrogen and varying amounts of other nutrients (Troeh and Thompson, 1993) through various chemical and biological processes.

Matsumoto *et al.* (1997) observed that the mean N content of FYM samples stored for 0 to 6 months was 22 mg N kg^{-1} and 16 K kg^{-1} dry weights, When stored for over 24 months the contents decreased to 15 mg N kg^{-1} and 5 mg K kg^{-1} dry weight. It has been reported that the fertilising effect of FYM decreases during the storage period since inorganic N, the easily decomposable N and other nutrients in the FYM decrease during storage (Matsumoto *et al.*, 1997) due to volatilization and/or leaching of these nutrients during storage. It has also been reported that the mean moisture content of FYM can be 80% for sample piled for 0 to 6 months and this moisture content decreases as the storage period is prolonged hence reduce the volume and weight of the decomposed manure (Matsumoto *et al.*, 1997). This is due to its exposure to the sun, which cause water loss through evaporation. N in chicken manure is easily lost through volatilization and leaching (to the surface and ground water) in the field as well as during composting and storage. Suwardi and Goto (1997) observed that higher N content was obtained after short-term composting (less than 1 month) while low N was obtained by long-term composting (more than 2 months). This was due to the losses of N as NH_3 through volatilization and NO_3 through leaching as piled manures are not protected.

When FYM is broadcasted without incorporation into the soil as solid or slurry, N losses are 15-30% and 10-25%, respectively while broadcasting with incorporation into the soil, losses are 1-5%. In knifing and irrigation applications of liquid FYM, the N losses are 0-2% and 30%, respectively. Immediate incorporation of FYM slurry will minimise N volatilization (Tisdale *et al.*, 1993).

The proportion of soluble N can be substantially improved through proper storage. For example the animal dung stored in deep pits contained six times as much N as the N contained in the dung stored above ground after 4 months (Müller-Sämann and Kotschi, 1994). The reason for the high N content for deep pit stored dung is due to its protection from losses of N through volatilization or leaching. Further, FYM contains hormones, vitamins and antibiotics and growth-regulating substances such as biotin, which stimulate the effect of root growth and the growth of microorganisms (Brady, 1990; Müller-Sämann and Kotschi, 1994).

2.3 Factors affecting the extent of use of farmyard manure and farmyard manure slurries in crop production

The problems that arise in connection with the handling and use of FYM are complex and these are associated with inappropriate preparation and processing. The management and handling of FYM requires time, money, equipment and labour (Eghball and Power, 1999) which are not affordable by many small scale farmers due to their low incomes. Due to the bulkiness of FYM, and FYM-slurry the FYM can not easily be transported far from the production sites thus the costs of handling and application may exceed their values (Chang *et al.*, 1998). The use of FYM is, therefore, often confined to the home gardens or close to the production sites.

Lack of information and training of farmers on efficient methods of conserving and storing FYM is another problem. When the manure is brought to the field and left for long periods unprotected from the sun and rain, it tends to lose some of its nutrients through volatilization and leaching. As a result farmers may fail to recognise the potential of using FYM in crop production. 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). Apart from the afore mentioned problems, other social and cultural conditions may present obstacles to the use of FYM. For example, the raising of livestock on communal rangeland practised in many parts of Africa makes it more difficult to utilise FYM (dung) (Müller-Sämann and Kotschi, 1994) because during grazing the dung and urine, are scattered all over the grazing area, making it impossible to gather or collect the manure.

The concentration of nutrients in FYM is very low compared to that in inorganic fertilisers due to several probable reasons, such as low nutrient content in the feeds, high digestibility of the feeds and handling and storage procedures of the manure. Due to the low amounts of nutrients per unit weight of FYM, large quantities must be applied in order to meet nutritional requirements of crops (Duncan, 1975). For example one tonne of traditional FYM made with straw supplies N, P and K in the same amounts as 50-100kg of modern concentrated NPK compound fertiliser. However, FYM also supply substantial amounts of calcium, magnesium, sulphur and the trace elements, all largely neglected in modern fertilisers (Simpson, 1986). If FYM is well conserved and incorporated into the soil, it can give considerable savings in the amounts of fertiliser required because losses of some nutrients will be reduced. Also appreciable proportions of the total nutrient contents of manures occur in complex organic forms, which have to be mineralised before they release the nutrients, thus, not all the nutrients will be available for the first crop after application (Simpson, 1986). It has been noted that, large proportion of the nutrients remains in the soil, resulting in residual effects for successive crop (Uriyo *et al.*, 1979).

Nutrient release from manure is also highly variable depending on the species of animal in question, methods of handling and storage and soil conditions. For example manure applied to moist soil will decompose faster than that applied to dry soil (Müller-Sämann and Kotschi, 1994) hence nutrient release will be faster in moist soil than in dry soil.

Farmyard slurries, if not aerated during storage produces or are transformed to evil-smelling products of anaerobic decomposition and causes air pollution. The bad smell is not prominent in cattle slurries as compared with the stench of unaerated pig slurry.

perhaps due to low dietary nutrient utilisation (digestion and absorption) in pigs compared to cattle. Animal grazing herbage treated with cattle slurries may have a risk of hypomagnesaemia, due to the antagonistic relationship between K and Mg uptake by plants hence the grass takes up luxurious amounts of potassium, which inhibit Mg uptake (Simpson, 1986). Animal manure is also associated with risk of spreading weed seeds to new areas.

2.4 Methods of application of farmyard manure and farmyard manure slurries

Application of FYM to soils can be done by spreading with or without incorporating into the soils for both solid and liquid FYM and knifing and irrigation for slurries (Tisdale *et al.*, 1993). Also application of slurry can be done by splash-plate, surface spreading, shallow injection, deep injection, band spreading and trailing shoe (Frost and Stevens, 2000). With splash plate, losses of ammonia and odour are less than 1% of the total losses in the subsequent 3 days, because there is a minimum exposure of the FYM hence low losses. In surface spread method, 30% of total ammonia loss takes place in the first hour and 85% within the first 12 hours. Shallow injection of slurry into shallow channels is more suitable than deep injection and has potential to improve efficiency of nitrogen use from slurry. Band-spreading increase slurry-soil contact compared to surface spreading. Application of slurry by trailing shoe has resulted in low ammonia losses, better nitrogen use efficiency and higher yields than either splash plate or band spreading (Frost and Stevens, 2000). The study conducted by Bittman *et al.* (1999) showed that manure applied with the drag-shoe applicator produced consistent crop response similar to N fertiliser at equivalent rates of mineral N. Slurry applied with the conventional splash plate applicator may lose up to 80% of its NH_4-N. Injecting manure beneath the soil surface has shown to reduce NH_4-N loss compared with surface application (Bittman *et al.*, 1999), possibly because for the injection method there is a minimum exposure of the slurry to the atmosphere hence low NH_4-N loss through volatilization.

Research conducted in confined animals feeding operations (CAFOS) indicated that, employing anaerobic lagoon storage and spray irrigation, an estimated value of 88% of manure N is lost into the atmosphere, as compared to 34% by CAFOS using earthen basins and soil injection of liquid manure (Jackson *et al.*, 2000). Lower application rates of N are required when manure is banded rather than when broadcasted (Bittman *et al.*, 1999).

Slurry can best be utilised as a source of plant nutrients through land spreading (Frost and Stevens, 2000). For effective use, slurries should be incorporated into the surface soil immediately after application to reduce N losses. The rate of application of slurry should be varied according to the estimated fertiliser N equivalent available for the first crop (Frost and Stevens, 2000).

2.5 Effect of farmyard manure and farmyard manure slurry on the biological, physical and chemical properties of soils

Mineralisation of decomposing manures such as FYM is a major source of plant nutrients (Woomer *et al.*, 1994). The activities of microorganisms and soil fauna serve to promote soil aggregation, leading to reduced erosion and greater water infiltration (Woomer *et al.*, 1994). FYM influence the growth and activities of microorganisms in the soil by creating favourable physical and chemical environmental conditions for growth and multiplication and by offering a source of energy and other nutrients (Powell and Wu, 1999). Continued application of organic manure (FYM) increases organic carbon, nitrogen contents and cation exchange capacity of soils, as well as the population of bacteria, fungi and actinomycetes in the soil (Lee and Wani, 1988). Studies have shown that liquid hog manure application may enhance enzyme activities. microbial biomas and the N mineralizer population in the plow layer of a soil in a corn silage monoculture (Lalande *et al.*, 2000) hence increasing the rate of decomposition which increases the availability of the plant nutrients.

Anaerobic digestion of animal slurries involves bacteriological breakdown of organic matter to produce biogas (approximately 70% methane) and digested effluent according to the following equation:

$$\text{Slurry-}C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4 + \text{digested effluent.}$$

The methane produced can be utilised as a source of energy (bio-gas) or lost through volatilization. The pollution potential and odour of the digested effluent are lower than in the original slurry. Anaerobic digestion also improves the availability of N content from slurry (Frost and Stevens, 2000).

The humus formed from the resynthesis of the products of organic matter decomposition plays a significant role in the formation of soil aggregates, in the control of soil acidity (buffering effect), in the cycling of nutrient elements and in the detoxification of the harzadous compounds (Sposito, 1989). Humus enhances mineral break down and in turn, nutrient availability in two ways. First humic acids react with soil minerals thus initiating and enhancing their decomposition, thereby releasing essential base-forming cations as follows:

$$KalSi_3O_8 + \text{H-micelle} \rightarrow HAlSi_3O_8 + \text{K-micelle}$$

The potassium is changed from a structural component to an adsorbed ion, which is more readily available to plants. Second, humus form stable organomineral complexes with certain nutrient ions. For example, non-humic organic acids, polysaccharides and fluvic acid can form complexes with metallic ions such as Fe^{3+}, Cu^{2+}, Zn^{2+} and Mn^{2+}. The cations are released from the minerals in which they are found and held in complex forms by the organic molecules which may later be taken up by plants or may take part in the synthesis of clay and other inorganic constituents (Brady, 1990).

Humus improves soil water retention by increasing both infiltration rate and water-holding capacity (Brady, 1990). It also increases granulation and aggregate stability, reduce plasticity, cohesion and stickiness of clay soils thus improving its workability (Brady, 1990). Soil humus chelate with metal ions to form complex compounds of which some of these are micronutrients (for example Zn) and are made more available to plants because they are kept in soluble form. In case of Al^{3+}, which are toxic to plants in very acid soils, organic matter alleviates the toxicity by binding the aluminium ions in non-exchangeable form (Brady, 1990).

Nutrient recycling is becoming an increasingly important element of environmentally sound sustainable agriculture. Benefits from manure, in addition to macronutrients and micronutrients may be related to the organic components that improve soil moisture relations and reduces downward movement of N, K and micronutrients (Tisdale *et al.*, 1993). While the nutrient input improves soil fertility, the organic input has a profound and vital role to play on important soil physical properties such as its tilth, water-holding capacity and provide more favourable environment for root growth. Thus FYM additions to soils leads to an improvement in overall soil productivity, of which soil fertility is a key component (Jain and Kumar, 1995). FYM improves soil physical properties, better root growth and it can improve the availability of soil nutrients and microbial activity as well as it adds humus to the soil (Tandon, 1993).

The organic portion of FYM maintains or improves the physical fertility of the soil like workability, drainage and water holding capacity (Euroconsult, 1989). Studies conducted by Sommerfeldt and Chang (1985) in Southern Alberta found that application of even relatively low rates of manure maintained or increased the organic-matter content and improved the physical conditions of the soil. It was also pointed out that plant available water-holding capacity of a soil might be increased when manure was applied to the soil (Sommerfeldt and Chang, 1985).

Hafez (1974) showed that manure from various domestic animals could increase the aggregation of soil particles and reduce the soil's bulk density. Working with Dinuba fine sandy loam, Hafez (1974) observed that application of manure reduced the bulk density progressively from 1.43 to 1.10 g cm^{-3} when 2.5 to 10.0 tons ha^{-1} of FYM were added to the soil.

Application of sewage effluent was found to increase soil pH, total Fe and caused very large increases in total C and P, fluoride-extractable P and KCl-extractable P (Holford *et al.*, 1997) indicating that sewage effluent can be utilised as a source of plant nutrients. Ye and Yang (1997) observed that organic manure increased soil DTPA-extractable Fe and Zn, by 14 and 4mg kg^{-1} soil, respectively. DPTA-extractable Cd and Ni were found to decrease with the addition of FYM (pig and cow manure) whereas these manures resulted in increased DPTA-extractable Zn (Arnesen and Singh, 1998). Probably Cd and Ni form insoluble complexes with organic matter in the manure while manure increase mineralisation of Zn.

Wong *et al.* (1995) showed that application of FYM and *Calliandra* (*Calliandra calothyrsus meissner*) prunings significantly lowered Al saturation from 80% to 68% of an acid oxisol in Burundi. The reduction in exchangeable Al, which was attributed mainly to the applied organic materials (FYM and *Calliandra* prunings), increased maize grain yield. Under very acid soil conditions (pH<5.0), much Al become soluble. The FYM binds the Al in an unaexchangeable form through the formation of complex compounds. This organic matter-aluminium interaction help to account for better plant growth at low soil pH (Brady, 1990).

Joam *et al.* (2000) found that crop production on acid soils could be improved greatly by adjusting the pH to near neutrality. While soil acidity is commonly corrected by liming, there is evidence that manures as a soil amendment can raise the pH of acid soils. It has been reported that the application of manure to acidic soils increased the pH of two soils with pH values4.8 and 5.5 to pH 6.0 and 6.3, respectively (Joam *et al.*, 2000). The increases in pH of the soils were due to the alkaline reaction of the manure and the buffering effects of bicarbonates and organic acids in the cattle manure.

Barkle *et al.* (2000) observed changes in organic carbon and total nitrogen over four years in a soil receiving a high application of dairy farm effluent. Regular irrigation with very dilute mixture of water; urine and faeces (dairy farm effluent) at high rates increased the soil microbial biomas, pH, organic carbon and total nitrogen (Barkle *et al.*, 2000). This shows that, it is profitable for the farmer to use FYM slurry, because this is largely a N-K fertiliser equivalent and the best returns were obtained by using it on non-legumes (Tisdale *et al.,* 1993). Lund and Doss (1980) reported that application of high rates of manure increased soil pH, exchangeable potassium, extractable manganese and phosphorus and cation exchange capacities of soils.

Klausner *et al.* (1994) concluded that, efficient use of manure increase N-recycling, eliminates excessive purchase of fertiliser-N and other inorganic fertilizers' and reduces N loss to the environment. This recycling will not only reduce the need for additional inorganic fertiliser elements, but also simultaneously provides organic matter and soil cover that are essential for sustainable agriculture (Tisdale *et al.,* 1993). Addition of 35t FYM per ha was reported to have increased the soil's organic carbon by 0.2% under a three years ley (Wilson and Brigstocke, 1981). Regular application of FYM of 10 to20 t ha^{-1} over 27 years improved the CEC from15 Cmol(+) kg^{-1} soil to 19 and 21 Cmol(+) kg^{-1}, respectively (Müller-Sämann and Kotschi, 1994). Regular applications of FYM greatly reduced soil acidity and contents of free Al and Mn, increased contents of exchangeable Ca and Mg and promotes root growth and the uptake of P (Müller-Sämann and Kotschi, 1994).

Manure is also an important source of humus and has a beneficial long-term effect on the structure and carbon-economy of the soil. During decomposition the FYM and FYM-slurry components or constituents are broken down to simpler substances that can be taken up by higher plants or by the microbes themselves (Swift *et al.*, 1979). The microbial transformations lead to the reduction in size and changes in chemical composition of the FYM and FYM-slurry. The chemical composition of humus is changed as a result of production of intermediates and the synthesis of microbial tissue and humus in situ. During these processes, essential elements such as N, P and other nutrients are released and/or immobilised in ways and rates unique to each element (Alexander, 1977).

2.6 Crop response to farmyard manure and farmyard manure slurries

The extent of crop response to farmyard manure varies with the composition of the farmyard manure, method of application, location and soil environmental conditions. Farmyard manure influences soil productivity through its effect on physical, chemical and biological soil properties (Lee and Wani, 1988). FYM is an effective source of nutrients for most crops especially those with relatively high N requirements such as corn, sorghum, small grains and grasses, vegetables and ornamentals (Brady, 1990). A number of workers have demonstrated the potential of animal manures (FYM) as a source of nutrients for crop production. Araujo *et al.* (1982) and Rweyemamu and Ndunguru (1984) observed that field bean grain yields and dry matter production were increased when cattle manure was applied to the soil. In an experiment done by Klausner and Bouldin (1983) silage yield increased from 12.5 to 18.6 tons ha^{-1} due to application of FYM (cattle manure). This yield increase was largely attributed to the extra N supplied from the organic N in the manure. Schlegel (1992) observed significant sorghum grain yield increase when cattle manure was used. Application of sheep manure to a sandy loam soil gave significantly higher yields of barley compared to where manure was not applied (Schlegel, 1992; Thomson *et al.*, 1997). Yields were higher in the second year than during the year of application and this was attributed to the gradual increase in levels of nutrients in the soil from mineralised organic components of the manure applied (Thomson *et al.*, 1997). Liu *et al.* (1997) reported a significant increase in total dry matter yield and a general increase in plant tissue N. P contents in forage with increased rates of manure application from 560 to 2240kgN ha^{-1}. Using cattle and poultry manures, Massomo and Rweyemamu (1989) observed that, both manures significantly increased common bean yield components such as the number of branched plants, pods per plant, dry matter yield and seed yield per unit area. Results from the glasshouse experiment conducted by Nonga (1999) at SUA indicated that, applications of FYM increased soil available levels of N and P, amaranthus shoot dry matter yield, taproot length, root weight and tissue contents of N and P, indicating that FYM can be used to improve the production of crops.

Simpson (1986) reported that the most profitable yield increases form FYM application are usually obtained in potatoes, sugar beet, mangold, turnips and vegetables. Many series of field experiments done on yield response to FYM applied at rates of 25-30t ha^{-1} have shown increases in sugar beet yields that varied from 0.8-4 tonnes of fresh beet ha^{-1}. Potatoes were even more responsive where yield increases of 7-13t ha^{-1} were obtained (Simpson, 1986).

In a series of long-term experiments, 10-15tha^{-1} per year of well-decomposed FYM contributed 23-27% of the total grain yield response in rice obtained by combined use of the recommended dose of NPK fertilisers and FYM in different soils (Pillai and Kundu, 1993). Results of 293 on-farm trials showed that FYM increased paddy yield by 50 kgha^{-1} and on average, 20tha^{-1} FYM were required to raise paddy yield by one tha^{-1}

(Pillai and Kundu, 1993). Results with rainfed finger millet at Bangalore showed that annual application of $10tha^{-1}$ FYM increased grain yield by 1,040 $kgha^{-1}$ on an average and the combination of inorganic fertilisers + FYM not only produced the highest yield (3570 $kgha^{-1}$) but also resulted in greater yield stability (Tandon, 1992).

Research results from the combined use of fertiliser + FYM obtained from a nine-year experiment carried out on red soils of Bangalore indicated that rice grain yield of $2900kgha^{-1}$ with optimum NPK inorganic fertiliser application were similar with those from 50% NPK through fertiliser and 10 tonnes $FYMha^{-1}$ (Tandon, 1993). The yield increase of 630 $kgha^{-1}$ was obtained by adding the recommended NPK dose through fertiliser + 10t $FYMha^{-1}$ every year (Tandon, 1993). At Wellesbourne and Stockbridge House Horticultural Station in Yorkshire, U.K, both on light textured soils, annual dressings of FYM resulted in increased yields of vegetable crops that could not be achieved by mineral (inorganic) fertilisers alone (Davies *et al.*, 1993). At ADAS Rosemaund, on a silty soil, 30 tonnes per hectare of FYM applied for the potato crop from 1964 to 1966 raised yields by an average of over 5 tonnes per hectare as compared with the optimum fertiliser treatment (Davies *et al.*, 1993).

The results from 210 experiments conducted at 31 different locations in Kharif, India showed that, additions of 12.6t FYM ha^{-1} to irrigated wheat produced yield increases of 82-286 $kgha^{-1}$ with an average of $202kgha^{-1}$ or 1.6kg grain/t FYM (Gaur, 1992). Other results obtained from experiments with irrigated wheat and 71 experiments with rainfed wheat showed that FYM application at $12.6tha^{-1}$ increased yields, with an average yield response of 200 $kgha^{-1}$ (Lee and Wani, 1988).

Jain and Sharma (1993) reported that FYM is an effective source of nutrients and significantly increased the grain yield of maize. Highest grain yield of 4280 $kgha^{-1}$ was recorded when 12t FYM was applied along with 120-60-60 kg N + P_2O_5 + K_2O (Jain and Sharma, 1993). Slurry is most effective as a source of plant nutrients for potatoes, vegetables and late-sown crops such as maize. Its use for winter barley and winter wheat is not effective (Simpson, 1986). Probably this is due to leaching of some plant nutrients, particularly N. Kumpukul (1997) found that, use of water waste from the production of biogas of the animal fermentation residues is an effective natural fertiliser, which does not cause phytotoxicity. Using a mixture of water waste and chemical fertiliser (ratio 3:1) on kale, lettuce, chinese radishes and sunflowers, the yield were higher than using chemical fertiliser alone (Kumpukul, 1997). The yields were 329.6, 265.6, 166.4 and 34.7 kg ha^{-1} higher as compared to the controls, respectively (Kumpukul, 1997).

2.7 Use of farmyard manure and farmyard manure slurries with respect to the environment

Animal wastes like FYM are a valuable soil amendment, but when rates of application exceed crop nitrogen (N) requirements, N can leach into ground water or be lost to the atmosphere (Chang and Janzen, 1996). Crop N requirements are a key factor regulating the rate of waste application rates (Wen *et al.*, 1995). The high cost of transporting manure and slurry and the resulting tendency to apply high rates of manure close to its sources, make areas with intensive livestock production particularly vulnerable to environmental damage (Chang and Janzen, 1996).

Large manure piles are the common source of water pollution. Solutions oozing out of such manure piles may reach the farmer's wells and nearby stream and contaminate them. Eutrophication, that is increased growth of undesired vegetation such as algae resulting from an enriched supply of plant nutrients, will occur in backwater (Troeh and Thompson, 1993). The potential for contamination of ground and surface waters through improper handling and disposal of animal manure slurry from feedlots is considerable because most of feedlots have a relatively small land base and transport costs are high (Chang *et al.*, 1998). Schmitt *et al.* (1992) showed that injected bands of liquid manure at high levels have the potential to create localised environments that are not conducive and sometimes even toxic to plant root growth.

Application of piggery effluent in soil is under close scrutiny as a potential source of water resource contamination with phosphorus (P) (Redding, 2001). Eghball and Power (1994) observed that manure produced by beef cattle can potentially be a source of pollution for water, air, and land because of the potential for excess nitrate salts, undesirable micro-organisms, pathogens and green house gases. It is also a possible source of weed seeds. The management of nutrients, principally nitrogen (N) and phosphorus (P), to prevent possible contamination of groundwater and eutrophication of waterways is a key issue to the use of effluent-irrigated plantations for renovation of waste-water (Falkiner and Polglase, 1997).

CHAPTER THREE

MATERIALS AND METHODS

A glasshouse pot experiment was conducted at the Sokoine University of Agriculture Morogoro. Tanzania to evaluate the effect of FYM-slurry as a source of plant nutrients to short-term horticultural crops when applied to an acid soil. Chinese cabbage (*Brassica campestris* L) was used as the test crop in the glasshouse pot experiment.

3.1 Soil sampling and preparation for analysis

A composite soil sample for the pot experiment was collected from the central part of Sokoine University of Agriculture (SUA) farm. The farm is located at 6°51'S and 37°39'E, at an altitude of approximately 550m above sea level. The sampled area lies in the middle part of the Magadu plain with a slope of about 1% (Kaaya,1989). Twenty soil sub-samples from an area covering about 5ha were collected randomly at a depth of 0-20cm and composited. The composite soil was air-dried and grounded to pass through an 8mm sieve. A small sub-sample of the composite soil sample was ground and sieved to pass through a 2mm sieve for physical and chemical characterisation of the soil. The soil used in this study was classified as an Oxic Haplustults (Kaaya, 1989) equivalent to Dystric Nitosols (FAO, 1990).

3.2 Farmyard manure-slurry collection

Farmyard manure slurry (FYM-slurry) was collected from the Magadu Dairy Unity, SUA Morogoro. The slurry consisted mainly of the cow dung (faeces), urine, some feed wastage (stuff) and water used for cleaning/washing the dairy house. The slurry was collected in a lagoon where it was stirred properly and 80 litre of it was transferred to four twenty-litre capacity plastic buckets with airtight lids to prevent nutrient losses through volatization. Then half a litre was taken for laboratory analysis and the rest was used for pot experiment.

3.3 Laboratory analysis

3.3.1 Soil analysis

Soil characterisation was carried in the Department of Soil Science laboratory, SUA, Morogoro. The 2mm sieved composite soil sample was analysed for soil pH, particle size distribution, organic carbon, cation exchange capacity (CEC), total N, available P, exchangeable bases namely K, Ca, Na, and Mg and DTPA-extractable Cu, Zn, Fe and Mn. The soil pH was determined elecrometrically in 1:2.5 soil-water suspension as described by McLean (1982). The available P was determined by the Bray and Kurtz-1method (Olsen and Sommers, 1982). Organic carbon was determined by the wet digestion method of Walkley and Black (Nelson and Sommers, 1982). The total N was determined by the micro-Kjeldahl digestion-distillation method (Bremner and Mulvaney, 1982). The cation exchange capacity (CEC) was determined by the buffered ammonium acetate saturation method (Chapman, 1965). The quantities of exchangeable bases (K^+ and Na^+) in the NH_4OAC (CH_3COONH_4) filtrate were determined by Flame Photometer and Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometer (AAS) as described by Thomas (1982). Particle size distribution was determined by the hydrometer method (Juo, 1979) and textural classes by using the USDA textural triangle. Available Cu, Zn, Fe and Mn in the soil were extracted by the DTPA and the quantities of Cu, Zn, Fe and Mn in the DTPA extracts measured by AAS (Baker and Amacher, 1982).

3.3.2 FYM-Slurry analysis

The representative slurry sample from the 80 litres of slurry so collected was analysed for the essential plant nutrient element contents. The slurry in the storage plastic bucket was thoroughly stirred, and then 500ml sample was taken for laboratory analysis. The liquid portion of the sample was separated from the solid portion by filtration. The filtrate was stored in airtight plastic bottle and used for the determination of the essential nutrient elements of the liquid portion of slurry. The solid portion of the slurry was air dried, and used for the determination of the essential nutrient elements.

3.3.2.1 Analysis of the nutrient contents in the slurry filtrate

The filtrate from FYM-slurry was used for the determination of pH and soluble nutrients in the solution which included N, P, K, Ca, Na, Mg, Zn, Cu, Fe, and Mn. The pH of the filtrate was measured electrometrically (Mclean, 1982). Soluble N was determined by distillation of slurry filtrate following titration with 0.05N H_2SO_4 (Bremner and Mulvaney, 1982). P content was determined calorimetrically as described by Okalebo *et al.* (1993). Soluble K and Na in the filtrates were determined by Flame Photometer while Ca^{2+}, Mg^{2+}, Cu^{2+} Zn^{2+} Fe^{3+} and Mn^{2+} in the slurry filtrate were determined by AAS (Baker and Amacher, 1982).

3.3.2.2 Analysis of the nutrient contents in the solid slurry material

The available P was determined by the digestion method as described by Okalebo *et al.* (1993). Organic carbon was determined by the wet digestion method of Walkley and Black method (Nelson and Sommer, 1982). The total N was determined by the micro-Kjeldahl digestion and distillation method (Bremner and Mulvaney, 1982). Total K, Na, Ca and Mg were determined by digestion method as described by Okalebo *et al.* (1993). Total Cu, Zn, Fe and Mn in the solid slurry were determined by wet digestion using H_2OH-HNO_3-$HCLO_4$-HF mixture and measured by AAS according to Baker and Amacher (1982).

3.4 Raising of the chinese cabbage seedlings

A fine seedbed was prepared and the soil in the seedbed mixed with well-decomposed FYM. Chinese cabbage seeds were sown by broadcasting, followed by regular watering (twice a day) and weeding. Before transplanting the seedlings were hardened for three days to reduce the transplanting stress. The chinese cabbage seedlings were transplanted 21 days after sowing.

3.5 Glasshouse pot experiment

The glasshouse pot experiment study was conducted at SUA, Morogoro. Fifteen litre capacity plastic buckets with drainage holes at the bottom were used. Twelve kilograms soil sample portions were weighed into the eighteen plastic buckets. Each soil in the bucket was watered to field capacity. Four Chinese cabbage seedlings were transplanted to each bucket. Six-split application of FYM-slurry was done (Table 1) equivalent to 0, 166.67, 208.33, 250, 291.67, 333.33, 375, 416.67 and 500FYM-slurry m^3ha^{-1}. First application of FYM-slurry was done fourteen days after transplanting. Thorough stirring of the slurry in the twenty-litre (storage) buckets was done before it was applied to the soil in the buckets. Half a litre of FYM-slurry was applied uniformly to all treatments except for the control treatment (T1). Thereafter incorporation of FYM-slurry into soil was done followed by uniform application of water. The control received water alone.

The remaining five splits of FYM-slurry were applied ten days after the previous application following the same procedure but at different rates as shown in the Table 1.

Table 1: FYM-slurry application rates (ml/pot)

Treatment	First	Second	Third	Fourth	Fifth	Sixth	Total
0 (control)	-	-	-	-	-	-	-
1	500	100	100	100	100	100	1000
2	500	150	150	150	150	150	1250
3	500	200	200	200	200	200	1500
4	500	250	250	250	250	250	1750
5	500	300	300	300	300	300	2000
6	500	350	350	350	350	350	2250
7	500	400	400	400	400	400	2500
8	500	500	500	500	500	500	3000

The treatments were replicated two times. The pots were kept free from weeds throughout the experimental period. Mancozeb (fungicide) and decis (pesticide) were sprayed onto the plants to control fungi (damping-off) and pests (cut worm), respectively. The uniform application was done by making sure that each plant was wetted with fungicide/pesticide. This was done twice at an interval of seven days. Watering was done as necessary. Harvesting was done 66 days after transplanting by cutting the plant at soil level in the buckets. The plants were weighed immediately after harvesting to determine fresh weight, then washed to remove any adhering soil particles by using distilled water. The plant materials were then oven-dried at 70^0C to constant weight for dry matter yield determination. The oven dried plant materials were chopped to small pieces then ground into fine powder using a Tecator 1093 Cyclotec sample mill for laboratory analysis of N, P K, Mg, Ca, Zn, Fe, Cu and Mn. N determination was done following Micro Kjeldahl method (Bremner and Mulvaney, 1982). Total P, K, Ca, Zn, Cu, Fe, and Mn in the plant materials were determined by digestion using H_2OH-HNO_3-$HCLO_4$-HF mixture (Okalebo *et al.*, 1993). The quantities of K in the digest were measured by Flame Photometer and Ca, Mg, Cu, Zn, Fe and Mn by AAS (Baker and Amacher, 1982). Total P in the digests were determined colorimetrically (Okalebo *et al.*, 1993).

3.5 Statistical Analysis

Analysis of variance was used to asses treatment effects on fresh and dry matter yield, N, P K, Ca, Mg, Cu, Zn, Mn and Fe contents in the plant matterials using the MSTAT computer programme. The treatment means were separated using the Duncans' New Multiple Range Test (DNMRT) at 0.05 probability level. The statistical model used for the data analysis as described by Montgomery (1991) was

$Yij = \mu + Ai + Eij$

Where:

μ= Overall mean

Ai= Effect of i^{th} treatment

Eij= Random error test

CHAPTER FOUR

RESULTS AND DISCUSSION

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

Some of the physical and chemical properties of the soil used in the current study were as presented in Table 2. Based on the percentage sand, silt and clay content of the soil. the textural 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 the plant nutrient availability (Brady, 1990). 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. Most highly weathered tropical soils like *Oxic Haplustults* are dominated by 1:1 clay minerals and some considerable amounts of aluminium and iron oxide and hydroxides, hence low ability to retain plant nutrients and moisture (soil water).

The pH as determined in 1:2.5 soil: water suspension was 4.9, and categorised as low and the soil reaction as very strongly acid according to Landon (1991). The very low pH could be attributed to the extensive weathering of the soil, extensive leaching and predominance of exchangeable Al^{3+} and H^+ on the exchange sites and in the soil solution (Thomas and Hargrove, 1984). The pH of the soil was below the range favourable for optimum growth of chinese cabbage plant, as the optimum pH for chinese cabbage plant ranges between pH 6.0-6.8 (Maynard and Hochmuth, 1997). In acid soils Ca, P, Mg and Mo are the nutrients most likely to be deficient. The low pH of the soil will affect the magnitude of response of the chinese cabbage plants to the applied FYM-slurry.

The percentage total nitrogen in the soil was 0.09 and categorised as low according to Landon (1991) ratings. This level of total N conforms to the organic carbon and organic matter content in the soil. The low contents of total N, organic carbon and organic matter could be attributed to the high rates of decomposition, mineralisation and oxidation of the organic compounds and residues added to the soil, phenomena which are common in soils under tropical conditions (Smith and Sanchez, 1980; Uehara and Gillman, 1980) because of the high temperatures and humidities hence high microbial activities.

The Bray-1 extractable P for the soil was found to be 3.1mgkg-^{1} soil. According to the categorisation by Landon (1991), the extractable phosphorus for the soil was rated as low. The low level of plant available P in the *Oxic Haplustults* could probably be due to the inherent low phosphorus content in the parent material from which the soil was formed. Also it might be due to high fixation of the phosphorus by the aluminium and iron hydrous oxides into forms not extractable by the Bray1-reagents (Tisdale *et al.*, 1993; Troeh and Thompson, 1993).

The CEC of the *Oxic Haplustults* soil was low (Landon, 1991). This is in conformity to the soil's low pH (Brady, 1990) low organic matter content and probably the dominance of variable-charge soil colloids like 1:1 clay minerals and oxides of aluminium and iron, characteristics which are common in soils which are highly weathered and leached.

The amounts of exchangeable bases were generally low (except for K) according to Landon (1991). The low values of these bases particularly Ca, Mg and Na indicate that the soil is extensively weathered, consequently most of the bases have been leached out from the soil. Similarly the base saturation was 42.9% indicating low fertility status of the soil according to the categorisation made by Landon (1991), where, soils with PBS<50% are categorised as of low fertility status. The low fertility status of *Oxic Haplustults* corresponds to the low pH, total N, organic matter, Bray-P and relatively low amounts of exchangeable bases.

The exchangeable acidity was 1.82Cmo(+) kg^{-1} soil that is 1.75 and 0.25Cmo(+) kg^{-1} soil for Al and H, respectively and these values are generally low (Landon. 1991). Probably the low exchangeable acidity could have been caused by the accumulation of oxides of Al and Fe on the surface of the clay. Coleman *et al.* (1964) quoted by Thomas and Hargrove (1984) showed that both Al and Fe hydrous oxides reduce the exchangeable acidity, with Al oxide being more effective. It could assumed that the probable high amounts of Al in the soil could be in the form of aluminium oxide and hydroxide. High aluminium concentration can cause root injury to various crops because Al^{3+} tends to accumulate in the roots and impede translocation of calcium and phosphorus in plants (Thomas and Hargrove, 1984).

Plant available (DTPA extractable) micronutrients, that is Fe, Mn, Cu and Zn were 12.95, 28.44, 12.27 and 1.995$mgkg^{-1}$, respectively. According to Lindsay and Norvell (1978), the soil contained very high concentration of iron and manganese. Lindsay and Norvell (1978) suggested that 4.5-6$mgkg^{-1}$ Fe and 1$mgkg^{-1}$ Mn in the soil are adequate for plant growth. The high concentrations of Fe and Mn in the soil could be attributed to the low soil pH (Table 2) as low pH enhances solubility and availability of these elements in the soil. Lindsay and Norvell (1978) also suggested 0.2 and 0.5-1.0$mgkg^{-1}$ to be critical levels of Cu and Zn, respectively. The soil was found to have adequate levels of copper. Zn was low. and this was probably caused by the low pH and highly weathered nature of the soil. Thompson (1957) reported that the solubility of Zn decreases as the pH drops below5.25 or rises above 6.0. Also highly weathered soil have been reported to induce Zn deficiency (Marschner, 1995). Based on the data in Table 2, the soil used in this study could be rated as of low fertility status (Landon, 1991).

Table 2: Some of physical and chemical properties of acid soil (*Oxic Haplustults*)

Parameter	Unit
pH(water)	4.90
Bray I extractable phosphorus (mg Pkg^{-1} soil)	3.10
OC (%)	1.09
Total N(%)	0.09
CEC Cmol(+)kg^{-1} soil	12.30
Exchangeable bases (Cmol(+)kg^{-1}l)	
Na	0.31
Mg	2.10
Ca	2.45
K	0.47
%BS	41.35
Micronutrients (mgkg^{-1} soil)	
Fe	12.95
Mn	28.44
Cu	12.27
Zn	1.995
Exchangeable acidity (Cmol(+)kg^{-1} soil)	
Al	1.57
H	0.25
Particle size distribution	
%Clay	66.0
%Sand	28.0
%Silt	6.0
Textural class	Clay

4.2 Chemical properties of the FYM-slurry

Some of the chemical properties of the FYM-slurry used in this study are presented in Table 3. The results showed that large proportions of the nutrients contained in the FYM-slurry were found in the solid portion, except K, Na and Cu. Henriksen and Berthelsen (1989) reported the same trends of results. N content of the FYM-slurry in this study was low compared to that reported by Locomte (1980). Probably this could be attributed to the type of feed given to the animals, feed digestion efficiency of the animals and the amount of water used to wash the dairy house (dilution). However, Mathers *et al.* (1972) and Landon (1991) reported total N of FYM to range between 0.3-2.3 and 1.16-1.96%, respectively.

Total P of the FYM-slurry was higher than that reported by Kofoed and Nemming (1980) and this high value of total P was probably due to the feed given to animals and the treatment of the slurry before its collection. According to Landon (1991) (based on FYM) P content ranges between 0.04-0.12%, therefore the value obtained is within the range.

Total K of the FYM-slurry was high and corresponded to that reported by Simpson (1986). Probably this high content of K was due to the type of feed given to animals, particularly silage and roughage rations. Taiganides (1977) reported that vegetative plant parts have higher concentrations of K than the grains, therefore animals feeding on silage and roughage rations could consequently excrete more K than the same animals if fed with high concentrate rations. The reality was proved by the high K in this study where the slurry was from the Magadu dairy unit whose main ration is composed of roughage.

Total Ca and Na of the FYM-slurry were high when compared with the values reported by Kofoed and Nemming (1980). Mg content of the FYM-slurry was high and similar to those reported by Locomte (1980). The high content of Ca, Mg and Na observed could probably have resulted from weathering/disintegration of the materials particularly cement used in the construction of the animal shed which is made up of lime and gypsum and other chemically active materials which might have contained Ca and Mg.

With respect to total Cu, Zn, Mn and Fe the values were found to be 3.9, 12.3, 27.7,and 13.4mgkg^{-1}, respectively. These values of Cu and Zn were high according to Weller and Willetts (1977) and this was due to the type of the feed supplements given to the animals. For example Cu is used as antibiotic in some feed formulations for both preventive and therapeutic purpose (Taiganides, 1977). Mn and Fe were also high and corresponded to these reported by Kofoed and Nemming (1980).

The percentage organic carbon of the FYM-slurry was 41.6%. Locomte (1980) reported cattle slurry to contain 43.6% organic carbon and this value somehow corresponded to the value obtained in this study. The pH of the FYM-slurry was 7.1, which is within the range according to Skarda (1977) who reported that the pH of FYM and FYM-slurry ranges from 6.5 to 8.5. The C: N ratio of the FYM-slurry was 25:1 indicating somewhat slow mineralisation and hence slow release of plant nutrients from the FYM-slurry solid portion/part (Euroconsult, 1989).

Therefore based on the data in the Table 3, the FYM-slurry used in this study can be rated as of medium quality.

Table 3: Chemical properties of FYM-slurry

Parameter	Liquid portion of FYM-slurry	Solid portion of FYM-slurry	
Units	**(mg l^{-1})**	**(%)**	**(mg kg^{-1})**
Total nitrogen	119	1.61	-
Total phosphorus	600	0.17	-
Total potassium	37500	0.54	-
Total calcium	5300	3.11	-
Total magnesium	10300	3.02	-
Total sodium	10970	0.30	-
Cu	2.8	-	1.1
Zn	2.46	-	9.84
Mn	4.43	-	22.27
Fe	2.06	-	11.36
OC	-	41.6	-
C:N	-	25	-
pH	7.1	-	-

4.3 Glasshouse pot experiment

4.3.1 Response of chinese cabbage to FYM-slurry: Visual observations

During the whole growth period of the chinese cabbage (*Brassica campestris* L) in the glasshouse, visual observations were made. The response of chinese cabbage plants to the applied FYM-slurry was expressed by increase in plant vigor and decrease in nutrient deficiency symptoms, with increasing levels of added FYM-slurry. Two weeks after transplanting there were no differences observed among treatments in the growth pattern of chinese cabbage plants. This was because the plants had not recovered from the transplanting stress as the plant leaves were reduced to minimise the rate of transpiration. Severe stunted growth and yellowing (chlorosis) of older leaves in T1 were observed three weeks after transplanting. This was due to low soil fertility (Table 2) hence low ability of the soil to supply the essential nutrient elements for plant growth. In the fourth week the same symptoms were observed in T2 and T3 which received 166.67 and 208.33m^3ha^{-1} of FYM-slurry, respectively. This was attributed to the low amounts of FYM-slurry applied, which resulted into low nutrient supply to plants (Appendix 1a and 1b) with increase in plant growth. The performance of chinese cabbage plant was increasing with increasing level of FYM-slurry. No deficient symptoms were observed for plants in T4 to T9, which is an indication of adequate supply of the essential plant nutrients from the FYM-slurry.

Yellowing and drying of leaves decreased with increasing levels of applied FYM-slurry implying the increases in essential plant nutrients as levels of FYM-slurry applied increases. The chinese cabbage plants for T1 (0FYM-slurry m^3ha^{-1}) seemed to have less succulent, coarse leaves while the T9 (500FYM-slurry m^3ha^{-1}) had the softest and succulent leaves which are desirable qualities for leafy vegetables (Brady 1990). The tenderness of chinese cabbage plants increased with increasing levels of FYM-slurry.

4.3.2 Effect of FYM-slurry on fresh and dry matter yields of the chinese cabbage plants

The response of chinese cabbage plants to different levels of FYM-slurry applied to the *Oxic Haplustults* in terms of fresh and dry matter yields were as presented in Table 4 and Appendix 2. The fresh and dry matter yields of chinese cabbage plants increased with increasing levels of FYM-slurry, and the increase was statistically significant (Table 4). The result obtained in this study conforms to the observation made by Liu *et al.* (1997) who applied 560 to 2240kgNha^{-1} as FYM.

The increase in dry matter yield with increase in the levels of FYM-slurry followed a more defined trend as compared to the fresh matter yield (Appendix 4a). Probably this was due to different levels of water content in the fresh chinese cabbage plants. The increases in fresh and dry matter yields with increasing level FYM-slurry were due to decomposition of FYM-slurry solid portion thus release plant nutrients and the immediately available nutrients in the liquid portion of the FYM-slurry. This increased the availability of nutrients in the soil hence uptake by the chinese cabbage plants. The application of 500 FYM-slurry m^3 ha^{-1} increased the fresh and dry matter yields of chinese cabbage plants 1490.7% and 835.3%, respectively as compared to the control. This indicates the usefulness of using FYM-slurry as source of plant nutrients and also an indication of the very low fertility status of the soil used in the current study.

Table 4: Effect of FYM-slurry on the fresh and dry matter yields of chinese cabbage plants

Treatment	Fresh matter yield (g)	Dry matter yield (g)
T1	70.6^{f}	5.345^{h}
T2	249.5^{e}	15.77^{g}
T3	314.9^{e}	22.35^{f}
T4	504.5^{d}	29.80^{e}
T5	603.4^{cd}	33.15^{d}
T6	685.6^{c}	36.71^{c}
T7	646.5^{c}	38.52^{c}
T8	912.2^{b}	43.82^{b}
T9	1123.0^{a}	49.99^{a}

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

4.4 Effect of FYM-slurry on macronutrient contents of the chinese cabbage plants

The N, P, K, Ca and Mg contents of chinese cabbage plants at different levels of FYM-slurry applied to the soil were as presented in Table 5 and Appendix 3. The percentage N, P, K, Ca and Mg contents of the chinese cabbage plants increased with increasing levels of FYM-slurry, and the increases were significant compared to the control. However, the increase in nutrient contents in the chinese cabbage plants with increasing levels of FYM-slurry did not conform or follow well defined trends. This could be attributed to the speed of recovery and vigour of the chinese cabbage plants after transplanting, losses of some nutrients particularly N through volatilization during application of the FYM-slurry, nutrient imbalance and growth enhancement which lead into dilution of nutrient content in the chinese cabbage plants.

The proportionate increases in nutrient contents of the chinese cabbage plants with the increasing rates/levels of FYM-slurry over the control could be attributed to the readily available nutrients in the liquid portion of the FYM-slurry and the subsequent decomposition and mineralisation of the plant nutrients contained in the solid portion of the FYM-slurry. This increased the availability of the plant nutrients in the soil, hence their uptake by the plants. Also FYM-slurry increased the pH of the soil, thereby increasing the availability of the exchangeable cations in the soil.

4.4.1 Nitrogen

The N contents of the chinese cabbage plants in this study ranged between 1.732-3.762%. According to Maynard and Hochmuth (1997) <3.5, 3.5-4.0 and. >4.0% N contents of mature chinese cabbage plant leaves are regarded as deficient, adequate and high/excess, respectively. Therefore, the N contents of the chinese cabbage plants in this study ranged from deficiency to adequate. These values could even have been higher if the chinese cabbage plant leaves were used for N-determination instead of whole plants. Also the age of the plant (66days) might have contributed to the low N contents in the chinese cabbage plants as N is translocated from the older leaves to young leaves and to the productive portion (Tisdale *et al*., 1993). Yoshizawa *et al*. (1997) reported that the total N content of most leafy vegetable leaves collected two weeks after transplanting ranged from 4.8 to 5.3%.

However, the N content of the chinese cabbage plants in this study do not conform to the high rates of FYM-slurry applied to the soil (Appendix 4b). This could be due to losses of some N through volatilization, slow release of plant nutrients from the solid portion of FYM-slurry and probably due to interaction with other nutrients in the soil following the application of the FYM-slurry.

4.4.2 Phosphorus

The percentage P content of the chinese cabbage plants increased with increasing levels of FYM-slurry, although the increases in P contents in the plants were not so pronounced at the very high application rates/levels of FYM-slurry (Table 4). This result contradicts with the result obtained by Locomte (1980) and this might be caused by mineral imbalances resulting from the high levels of FYM-slurry application.

The P contents of the chinese cabbage plants ranged from 0.1211 to 0.5487%, that is from deficient to adequate according to Maynard and Hochmuth (1997) where <0.3, 0.3-0.6 and >0.6% P contents of chinese cabbage plants were deficient, adequate and high/toxic, respectively. The P contents of chinese cabbage plants was expected to be higher than the values obtained as the levels of FYM-slurry application increased. This was not observed because the whole plants were used in the analysis instead of the leaves which resulted into nutrient dilution. Also the acid nature of the soil might have played part in the observed P content of chinese cabbage plants (Table 2). Low pH causes poor availability of P through fixation of P by Al and Mn present in acid soils (Tisdale *et al.,* 1993). In addition most of P was in the solid portion of FYM-slurry, so the release was gradual, hence low P contents in the chinese cabbage plants.

4.4.3 Potassium

The percentage K content of chinese cabbage plants increased with increasing levels of FYM-slurry, however the increases did not correspond with high levels of FYM-slurry application (Table 4 and Appendix 4b). This could be caused by the amount of available N since K and N have synergistic relationships. K uptake increased with increasing N rate (Tisdale *et al.*, 1993). Therefore any factor affecting availability of N in the soil will also affect K uptake by plants.

The percentage K content of chinese cabbage plants was adequate according to Maynard and Hochmuth (1997) as critical deficiency is <0.3%. The adequate content of K in the chinese cabbage plants was attributed to the available amounts of exchangeable K in the soil (Table 2) and readily available K in the liquid portion of FYM-slurry (Table 3).

4.4.4 Calcium

Ca content of chinese cabbage plants ranged from o.46 to 0.93% in this study (Table 4). The adequate Ca content of chinese cabbage plants ranges between 3.7 to 6.0%, according to Maynard and Hochmuth (1997). This indicated that, plants in all treatments were deficient in Ca. Probably this was attributed to the low exchangeable Ca in the soil (Table 2) due to the acidic nature of the soil and nutrient imbalance. Normally concentration of Ca^{2+} and Mg^{2+} in acidic soils are low, which indicate low competition of Ca^{2+} and Mg^{2+} with K^{+}. Therefore increasing K in the soil will also increase K uptake, hence the uptake of $Ca^{2+}$and Mg^{2+} is reduced as the availability of K is increased (Tisdale *et al.*, 1993). Nutrient imbalance due to high amounts of K supplied by FYM-slurry contributed to the low Ca content in the plant materials.

Also it has been reported that, higher radiation intensity and higher temperatures promotes growth and consequently, cause imbalance in the nutrient supply to the plant tissue, Ca is particularly affected (Fritz and Weichmann, 1981). Low CEC is another factor that contributed to the low Ca content in the chinese cabbage plants (Table 2). It has been reported that, acid soils with low CEC can not provide sufficient available Ca^{2+} to crop (Marschner, 1995). Moreover, the low Ca content of chinese cabbage plants observed in this study might have resulted from the analysis of whole plant instead of leaves alone. Despite of the Ca deficiency, the yield of chinese cabbage plant was not affected, since Ca deficiencies rarely affect crop growth (Tisdale *et al.*, 1993).

4.4.5 Magnesium

The observed percentage Mg content of chinese cabbage plants in this study ranged from deficiency to adequacy (Table 4). According to Maynard and Hochmuch (1997) Mg value of <0.4, 0.4 to 0.5 and >0.7 are low, adequate and high/excess, respectively. Low Mg content in chinese cabbage plants was probably caused by low amount of Mg in the soil due to acidic nature of the soil (Table 2). In acid soils, the proportions of Al and Mn are high, this suppress Mg uptake in plants, as the availability of Mg depends on the activity or proportions of Mg relative to soluble and exchangeable amounts of K, Ca, Na, Al and Mn (Maynald and Wilkson, 1989).

Also nutrient imbalance caused by high amount of K supplied by the soil (Table2) and FYM-slurry (Table 3) contributed to the low Mg content in the plant materials. Due to nutrient imbalance it is assumed that plants in all treatments to be deficient in Mg (Tisdale *et al.*, 1993). Therefore the adequate content of Mg observed in some treatments was abnormal as high application of FYM-slurry on grazing herbage (grass) was reported to cause hypomagnesaemia, due to antagonistic relationship between K and Mg uptake by plants (Simpson, 1996). Also high rates of NH^{+}_{4} or K^{+} fertilizers may depress the Mg^{2+} level in plant tissue (Tisdale *et al.*, 1993). Generally FYM-slurry has high proportions of both NH^{+}_{4} and K^{+} (Simpson, 1986).

4.5 Effect of the FYM-slurry on micronutrient contents of the chinese cabbage plants

The Cu, Zn, Mg and Fe contents of chinese cabbage plants at different levels of FYM-slurry applied to the soil were as presented in Table 5 and Appendix 3. The Cu, Zn, Mn and Fe contents of chinese cabbage plants generally decreased with increasing levels of FYM-slurry, and the decreases were significant compared to the control (except Zn). This could be attributed the nutrient interaction/imbalance and probably increase in soil pH.

4.5.1 Copper

The data in Table 5 showed that, Cu content of chinese cabbage plants decreased with increasing levels of FYM-slurry application. According to Maynard and Hochmuth (1997) the adequate Cu content in chinese cabbage plants ranges between 4-6mgkg^{-1}. This indicates that plants in all treatments were deficient in Cu. However this was not observed visually due to the fact that, under low light intensities Cu deficiency is not severe (Board and Guire, 1990) as quoted by Marschner (1995). In the glasshouse where the experiment was conducted/based, the light intensity was low as compared to that in the field. The reason for Cu deficiency could be caused by low supply of Cu from the soil and added FYM-slurry, since absorption of trace element increases with the concentration of the element in soil (Stiles, 1961). Also nutrient imbalance affect Cu absorption like high concentration of K in the soil inhibit Cu absorption by plants (Brady, 1990).

4.5.2 Zinc

The data in Table 5 showed that, different levels of FYM-slurry application had no effect on zinc content of chinese cabbage plants. There was no significant difference among treatments. Plants in all treatments were zinc deficient except T3 according to Maynard and Hochmuth (1997) as <20, 20-40 and >40 of Zn are deficient, adequate and high, respectively. The reason for Zn deficiency could have bee caused by low supply of Zn from the soil (Table 2), since absorption of trace elements increases with the concentration of the element in soil (Stiles, 1961). Also the applied FYM-slurry increased the soil pH, this reduce the availability of micronutrients (Brady 1990). In addition highly weathered soil induce Zn deficiency (Marschner, 1995).

4.5.3 Manganese

The data in Table 5 indicate that Mn content of chinese cabbage plants decreased with increasing levels of FYM-slurry application. According to Maynard and Hochmuth (1997) Mn content of chinese cabbage plants in all treatments were adequate. This was due to adequate amount of Mn in the soil (Table 2). Under acid conditions micronutrients cations are more soluble and available in the soil (Brady, 1990). Also there is a synergistic relationship between Mn and K. Stiles (1961) reported an increase in Mn content of plant stem and petiole as K concentration increased. In addition the applied FYM-slurry provides adequate amount of Mn (Table 3).

4.5.4 Iron

The Fe content of chinese cabbage plants decreased with increasing levels of FYM-slurry application (Table 5). Like for Cu, the decrease differed significantly with the control. The decreased Fe content of chinese cabbage plants with increasing levels of FYM-slurry was caused by increase in pH enhanced by FYM-slurry application, since the solubility and availability of Fe to plant decreased with increasing soil pH (Brady, 1990). Also application of FYM-slurry increased soil humus which enhances reaction of Fe with humus to form complex compounds which reduces the availability of Fe to plants (Tisdale *et al.*, 1993).

Owing to the to acidic nature of the soil used in this study (Table 2), it was expected at least to have adequate micronutrient content of chinese cabbage plants in the control and in the treatments with low levels of FYM-slurry application due to high solubility and availability of micronutrients cations under acidic soil (Tisdale *et al.*, 1993). This was not observed because the categorisation of the nutrient contents of plant referred to are based on leaf analysis while in this study the whole plant was analysed. Probably this resulted into dilution of the nutrient contents of the chinese cabbage plants.

Table 5: Effect of FYM-slurry on N, P, K, Ca, Mg, Cu, Zn, Mn and Fe contents in chinese cabbage plants

Treatment	%N	%P	%K	%Ca	%Mg	Cu ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)	Mn ($mgkg^{-1}$)	Fe ($mgkg^{-1}$)
T1	1.732^{e}	0.1211^{d}	1.129^{d}	0.4602^{c}	0.2167^{c}	1.95^{a}	17.9^{a}	16.00^{a}	18.85^{a}
T2	2.170^{d}	0.3001^{c}	2.548^{c}	0.6312^{bc}	0.4433^{bc}	1.75^{b}	18.55^{a}	14.35^{b}	12.15^{bc}
T3	3.115^{c}	0.3669^{bc}	3.017^{b}	0.6653^{bc}	0.4617^{abc}	1.65^{b}	20.45^{a}	14.65^{ab}	13.20^{b}
T4	3.657^{ab}	0.5263^{ab}	3.489^{a}	0.7924^{ab}	0.5505^{ab}	1.65^{b}	20.00^{a}	13.55^{b}	11.50^{bcd}
T5	3.762^{a}	0.5487^{a}	3.615^{a}	0.9095^{a}	0.6606^{ab}	1.35^{cd}	18.25^{a}	14.00^{b}	11.40^{cd}
T6	3.250^{bc}	0.4852^{ab}	3.581^{a}	0.9063^{a}	0.5466^{ab}	1.45^{c}	19.35^{a}	14.45^{ab}	11.55^{bcd}
T7	3.500^{abc}	0.4162^{abc}	3.668^{a}	0.9341^{a}	0.6419^{ab}	1.25^{de}	17.55^{a}	13.35^{b}	10.85^{cd}
T8	3.307^{bc}	0.4886^{ab}	3.470^{a}	0.8004^{ab}	0.5054^{ab}	1.20^{e}	16.55^{a}	13.70^{b}	9.95^{de}
T9	3.342^{bc}	0.4699^{abc}	3.655^{a}	0.7803^{ab}	0.7171^{a}	1.20^{e}	17.35^{a}	14.05^{b}	8.4^{e}

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

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The FYM-slurry could fairly be used as a source of plant nutrients for short-term leafy horticultural crops, such as chinese cabbage plants. This is based on the observation that FYM-slurry contains all the essential plant nutrients required for plant growth and development. The plant nutrients contained in the liquid portion of FYM-slurry are immediately available to the plants, while those in the solid portion of the FYM-slurry are gradually available to the plants, hence increasing the efficiency of utilisation of the nutrients in the FYM-slurry by the growing plants. Because of the gradual release of the plant nutrients from the solid portion of the FYM-slurry, the residual effect of the FYM-slurry may be substantial. Further, the FYM-slurry modifies the chemical, physical and biological properties of the soil hence improving and enhancing soil fertility and productivity. However, one has to be cautions with the nutrient imbalances common in FYM-slurries. The nutrient imbalances are attributed to the feeds given to the animals, the conditions of animal-shed, storage of the slurry and the extent of dilution of the slurry.

In the current study, it was evident that FYM-slurry increases both the dry matter yield's and the nutrient concentrations in the chinese cabbage, hence improving the food quality of the chinese cabbage. The positive response of the chinese cabbage to the applied FYM-slurry indicates that the FYM-slurry can efficiently substitute the use of inorganic fertilisers in chinese cabbage production.

However, caution must be exercised/observed in the use of FYM-slurry so as to avoid pollution of the environment and consequently the spread of certain diseases. The amount of FYM-slurry to be applied, time and frequency of application and method of application must be given due consideration and attention.

6.2 RECOMMENDATIONS

The study suggests that, the optimal application rates of FYM-slurry could be between 250 and $300m^3ha^{-1}$. However, field studies are required to verify the response of chinese cabbage and other short-term horticultural crops to FYM-slurry so as to establish optimum application rates under field condition.

FYM-slurry should be applied through spreading (broadcasting) followed by incorporation into the soil to reduce losses of nutrients through volatilization.

The application of FYM-slurry should be after transplanting or germination of plants during the dry season or immediately after rains to avoid leaching of some nutrients particularly those in the liquid portion of the FYM-slurry.

Farmers keeping animals be sensitised to establish small horticultural/vegetable gardens and be encouraged to utilise the valuable resource, FYM-slurry, for vegetable production that would also reduce cost of production and simultaneously minimising environmental pollution.

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APPENDICES

Appendix 1a. Amounts of FYM-S applied per pot and per ha

Treatment	Amount of FYM-slurry(l/pot)	Amount of FYM-slurry(m^3ha^{-1})
1	0.00	0.00
2	1.00	166.67
3	1.25	208.33
4	1.50	250.00
5	1.75	291.67
6	2.00	333.33
7	2.25	375.00
8	2.50	416.67
9	3.00	500.00

Appendix 1b.Amount of N, P and K applied in the soil from FYM-slurry

Treatment	Amount of FYM-slurry(l/pot)	Amount of FYM-slurry(m^3ha^{-1})	Amount of N(g/pot)	Amount of P(g/pot)	Amount of K(g/pot)
1	0.00	0.00	0.000	0.000	0.00
2	1.00	166.67	1.143	0.180	3.584
3	1.25	208.33	1.429	0.225	4.470
4	1.50	250.00	1.715	0.270	5.376
5	1.75	291.67	2.001	0.315	6.282
6	2.00	333.33	2.286	0.360	7.168
7	2.25	375.00	2.572	0.405	8.054
8	2.50	416.67	2.858	0.450	8.054
9	3.00	500.00	3.430	0.480	9.752

Appendix 2. Raw data for the chinese cabbage fresh and dry matter yields

Treatment	Plants /pot	Fresh weight (g)/pot	Dry weight (g)/pot
1a	3	75.6	5.690
1b	3	65.6	5.000
2a	3	241.2	14.098
2b	3	257.8	17.440
3a	3	317.8	22.448
3b	3	312.0	22.250
4a	3	500.8	29.824
4b	3	508.2	29.772
5a	3	605.4	32.478
5b	3	601.4	33.830
6a	3	690.4	36.962
6b	3	680.8	36.466
7a	3	742.4	38.262
7b	3	550.6	38.784
8a	3	918.6	45.350
8b	3	905.8	42.286
9a	3	1114.4	49.708
9b	3	1131.2	50.280

Appendix 3. Raw data for macro and micronutrient contents of the chinese cabbage plants

Treatment	Total N (%)	P(%)	K (%)	Ca (%)	Mg (%)	Cu (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
1a	1.785	0.1249	1.120	0.4602	0.2136	1.9	18.1	19.0	16.2
1b	1.68	0.1173	1.138	0.4601	0.2198	2.0	17.7	19.7	15.8
2a	2.135	0.2812	2.580	0.7247	0.4774	1.7	16.6	12.8	13.6
2b	2.205	0.3191	2.515	0.6060	0.4094	1.6	20.5	11.5	15.1
3a	3.175	0.4339	3.194	0.6226	0.4966	1.8	22.9	14.3	14.6
3b	3.055	0.2998	2.840	0.7080	0.4268	1.6	18.0	12.1	14.7
4a	3.57	0.5277	3.320	0.7864	0.5356	1.4	19.4	11.5	13.6
4b	3.745	0.5249	3.658	0.7984	0.5654	1.7	20.6	11.5	13.5
5a	3.675	0.5847	3.446	0.8889	0.5842	1.7	18.8	11.1	14.4
5b	3.85	0.5127	3.785	0.9301	0.6172	1.3	17.7	11.7	13.6
6a	3.255	0.4945	3.340	0.8986	0.5236	1.5	18.7	11.1	15.4
6b	3.395	0.4760	3.822	0.9139	0.5698	1.4	20.0	12.0	13.5
7a	3.395	0.3777	3.577	0.9423	0.6422	1.3	17.3	10.6	13.8
7b	3.605	0.4548	3.760	0.9258	0.6516	1.2	17.4	11.1	12.9
8a	3.215	0.4550	3.373	0.8545	0.5116	1.2	15.5	10.4	13.5
8b	3.395	0.5222	3.566	0.7464	0.4992	1.2	17.6	9.5	13.9
9a	3.36	0.4579	3.566	0.8271	0.7718	1.2	17.0	8.6	14.3
9b	3.325	0.4818	3.745	0.7335	0.6626	1.2	17.0	8.2	13.8

Appendix 4a. Effect of the amounts of FYM-slurry applied to the soil on the yields of chinese cabbage plant (fresh and dry)

Treatment	Amount of FYM-slurry(l)/pot	Weight of CC plant (g)/pot	
		Fresh weight	Dry weight
1	0.00	70.6	5.345
2	1.00	249.5	15.769
3	1.25	314.9	22.349
4	1.50	504.5	29.798
5	1.75	603.4	33.154
6	2.00	685.6	36.714
7	2.25	646.5	38.523
8	2.50	912.2	43.818
9	3.00	1122.8	49.994

Appendix 4b. Effects of the FYM-slurry added to the soil on the N, P and K contents in the chinese cabbage plants

Treatment	Amount of FYM-slurry(l)/pot	%N content in plant	%P content in plant	%K content in plant
1	0.00	1.733	0.121	1.129
2	1.00	2.170	0.300	2.548
3	1.25	3.308	0.367	3.017
4	1.50	3.658	0.489	3.489
5	1.75	3.763	0.549	3.616
6	2.00	3.325	0.485	3.581
7	2.25	3.500	0.416	3.669
8	2.50	3.115	0.526	3.615
9	3.00	3.343	0.470	3.656