EFFECT OF COWDUNG MANAGEMENT AND UREA FERTILIZER ON SOME SOIL CHEMICAL PROPERTIES AND MAIZE (*Zea mays* L.) YIELD IN THE NORTHERN GUINEA SAVANNA OF NIGERIA.

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MAY, 2012.

DECLARATION

I declare that the work in the dissertation entitled 'Effect of cowdung management and urea fertilizer on some soil chemical properties and maize (*Zea mays* L.) yield in the Northern Guinea Savanna of Nigeria' has been performed by me in the Department of Soil Science under the supervision of Professors E.O. Uyovbisere, E.N.O. Iwuafor and J.O. Agbenin.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any University.

Joseph Tanimu	----------	----------
Name of Student	Signature	Date

CERTIFICATION

This dissertation titled "EFFECT OF COWDUNG MANAGEMENT AND UREA FERTILIZER ON SOME SOIL CHEMICAL PROPERTIES AND MAIZE (*Zea mays* L.) YIELD IN THE NORTHERN GUINEA SAVANNA OF NIGERIA." by Joseph Tanimu, meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This dissertation is dedicated to the following:

My late Father, Mallam Tanimu Shehu Kusheka,

My late Mother, Mrs. Matu Cecelia Tanimu

And

My late Grandmother, Mrs. Dije Shehu.

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ABSTRACT

Greenhouse and field studies were conducted at Samaru, Zaria (11^{o} 11" N, 7^{o} 38" E) in the Northern Guinea Savanna agro ecological zone of Nigeria to evaluate cowdung management options that could best conserve nutrients contained in the cowdung thereby improving its quality before application to the field, the effect of cowdung application to the field on nutrient content and availability to crops in the soil and the individual and combined effects of cowdung and urea fertilizer on soil chemical properties and the yield and yield components of maize. Treatments consisted of first incubating the cowdung material for one month under different management practices in the field and subjecting it to different storage times, from March (12 weeks) to June (0 week) in the various years of experimentation. Time of storage, from termination of incubation to field application provided another factor for evaluation of 0 to 12 weeks of storage. The cowdung was assessed in the greenhouse and field, using maize as a test crop. In the field, two locations (Institute for Agricultural Research, Samaru and Samaru College of Agriculture Farms) were used and the residual effect for each of the locations was also observed. In the greenhouse and field, the treatments consisted of three management methods (surface heaped uncovered, surface heaped covered and pit covered) four storage durations (12 weeks, 8 weeks, 4 weeks and 0 week) and two levels of N (0 and 45 kg N ha^{-1}) to give a total of twenty-four treatment combinations. Then, there were two control plots, where one of them no cow dung or N fertilizer was applied, while in the second one no cowdung was applied but NPK fertilizer was added at the rate of 120 kg N ha^{-1} (except that in the field trials the NPK fertilizer combination

was not included). This brings a total of 26 treatment combinations in the greenhouse and 25 in the field. The experiments were factorial experiments, 3 x 4 x 2, laid out in a randomized complete block design (RBCD), replicated three times. The results of analysis of the incubated cowdung material at termination of incubation and just before application as soil amendment in both field and greenhouse, showed that incubating cowdung in the pit covered gave higher values of total N. The control (untreated cowdung) was comparable to the pit covered method and it was lower by 4.46 %. After field storage of cowdung, the control treatment gave a higher total N value than the other management practices, surface heaped uncovered, surface heaped covered and pit covered. The pooled values of P at the termination of incubation and after field storage showed that the control treatment gave values that were higher than the various management practices. At the termination of incubation and after field storage for the two years pooled, the cowdung subjected to different management practices gave higher values of K, Ca and Mg compared to the control. The values of total N, exchangeable Ca and Mg were generally lower at just before use as soil amendment compared to at the termination of incubation. Subjecting cowdung to different management practices decreased the organic carbon content of cowdung at both the time of termination of incubation and at after field storage, making the control treatment to have higher values than the other treatments. Comparing the treatments at after incubation and field storage, the later gave lower organic carbon values. The 0 week field stored cowdung (June) generally gave higher values of total N which was comparable to the control and P, while the 12 weeks stored cowdung (March) gave

higher values of K. Cowdung management methods, duration of cowdung storage significantly($P < 0.05$) increased some of the soil chemical properties(soil pH, total N, available P and organic carbon) in the greenhouse and field. The application of 45 kg N ha^{-1} significantly ($P < 0.05$) gave higher values of yield and yield components of maize in both the greenhouse and field experiments. The highest maize grain yield of 2,545.8 kg ha^{-1} was obtained when 45 kg N ha^{-1} at surface heaped covered April direct effect, in 2003 season at the Institute for Agricultural Research farm. The application of N at 45 kg N ha^{-1} gave higher soil values for N and P than at 0 kg N ha^{-1} treatment (direct evaluation), while K values were higher at the 0 kg N ha^{-1} treatment than the 45 kg N ha^{-1} in the field. Total N, available P and organic C in most cases positively correlated with maize grain yield, dry matter yield and plant height. Grain yield was closely associated with stover yield and plant height. The positive correlation obtained between most of the soil parameters and the yield and growth parameters, indicates that there were positive benefits of the cowdung treatments and the yield components of maize.

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CHAPTER ONE

INTRODUCTION

The moist savanna (Guinea savanna) region of sub-Sahara Africa (SSA) with 42 % of the SSA human population has been recognized to have the potential for increased crop and livestock production (McIntire *et al.,* 1992; Winrock, 1992; Jabbar, 1996). Increasing agricultural productivity in the region without due attention to natural resource management or the fragile soil resource of the region could impose negative consequences. It is estimated that as much as 85% of the land in this region is threatened by degradation (IFPRI, 1995).

The Nigerian savanna covers about three quarters of the country's total land area (Kowal and Knabe, 1972). The soils are derived from aeolian deposits (Jones and Wild, 1975) and kaolinite dominates the clay fraction (Ojanuga, 1979). The soils are low in organic matter (OM), basic cations, available phosphorus and nitrogen (N). This low level of OM has made the savanna soils susceptible to major chemical, physical and biological limitations which reduce crop yields (Jones and Wild, 1975). With intensification of cropping , organic matter and N are readily depleted, while phosphorus (P) and other nutrient reserves are slowly but steadily being depleted. The increasing pressure on land, with the traditional practices employed to restore the fertility of these soils, have been rendered unsuitable, as quick fertility restorative practices are needed to meet the increasing demand for food crop production (Kang *et al.,* 1986). About 70 % of the Nigerian population depends on farming for their livelihood and 90

% of these groups are constrained by resources (Heathcote, 1970; Jones and Stockinger, 1976).

The current global move for sustainable agricultural systems that optimize use of low inputs, require close monitoring of soil quality (FAO, 1989). Integrated soil fertility management systems, by combining the use of chemical amendment, biological and local organic resources, such as crop residues, green manure, biological N- fixation and agro-forestry for low activity clays of the savanna soil have been suggested (Kang and Wilson, 1987). The critical factor for the success of improved farming systems seem to be the efficient recycling of organic materials (Kang and Duguma, 1985).

In recent years, with increasing cost of inorganic fertilizers, scientific interest has turned toward the evaluation of organic fertilizers based on locally available resources, including crop residues, animal manure and green manures (Reijntjes *et al.,* 1992). The focus of soil fertility research has been shifted towards the combined application of organic matter and mineral fertilizers as a way to arrest the on going soil fertility decline in sub Saharan Africa (Vanlauwe *et al*., 2001c). The organic sources can reduced the dependency on costly fertilizers by providing nutrients that are either prevented from being lost (recycling) or more truly added to the system (biological N-fixation). When applied repeatedly, the organic matter leads to build-up of soil organic matter, thus providing a capital of nutrients that are slowly released (Giller *et al*., 1997) and at the same time increasing the soils buffering capacity for water, cations

and acidity (de Ridder and van Keulen, 1990). The beneficial role of animal manure in crop production has long been recognized (Schlecht *et al*., 1995; Karanja *et al.,* 1997; Harris *et al.,* 1997). They further explained that, manure is now used by over 95% of all small holder farmers in the Kenya Highlands. The utilization of cattle manure as a soil amendment is an integral part of the Nigerian guinea savanna (Harris and Yusuf, 2001; Iwuafor *et al*., 2002). However, the information that is lacking to most of the farmers is the methods of manure management practices for optimal quality before field application and time of application of animal manure for optimum crop production. Also, Iwuafor *et al*.(2002) observed that, the results of trials conducted in the northern guinea savanna showed the need to investigate the high variability in manure quality across different farmers/sites, and to look for ways to avoid losses during manure storage, or at least to establish ranges of N contents for manures with different origins and storage methods. Therefore, the general objectives are to determine the effects of cow dung management and Urea fertilizer on some soil chemical properties and maize yield in the Northern Guinea Savanna of Nigeria. The specific objectives of this study are:

1. To study cowdung management options and time of application that could best conserve nutrients in the cowdung thereby improving the cowdung quality.
2. To determine the separate and combined effects of urea fertilizer with cowdung on N and P content.

3. To determine the separate and combined effects of urea fertilizer with cowdung on soil exchangeable cations (K, Ca and Mg).
4. To determine the separate and combined effects of urea fertilizer with cowdung on the yield and yield components of maize.

CHAPTER TWO

LITERATURE REVIEW

2.1 Manure.

Animal manure (called manure) according to Defoer *et al.,* (2000) is an organic fertilizer consisting of partly decomposed mixture of dung and urine. Manure is recognized as a key resource in sustaining soil fertility in the tropics, supplying the soil with a range of macro- and micro- nutrients and organic matter (Defoer *et al.* 2000). However, the management of this resource raises several questions:

- What is the nutrient content of manure?
- What are the losses during storage and how can they be reduced?
- How much manure is produce by cattle?

2.1.1 Nutrient content of manure.

According to Camberato *et al.* (1996) and Fulhage (2000) the nutrients content of manure varies widely with animal species, age, ration quality and feed consumption, as well as with different methods of storage, handling methods, housing type, temperature and moisture content, treatment and land application. According to Fulhage (2000), manure contains the three major plant nutrients: nitrogen, phosphorus and potassium (NPK), as well as many essential nutrients such as Ca, Mg, S, Zn, B, Cu, Mn. In addition to supplying plant nutrients, Fulhage (2000) further explained that, manure generally improves soil tilth,

aeration, and water holding capacity of the soil and promotes growth of beneficial soil organisms. Manure applied in the proper amounts at the appropriate time can supply some, if not all, of the nutrient requirements of many crops.

Although much work had been done in northern Nigeria during colonial period on the value of manure to various crops (Hertley and Greenwood, 1933; Hertley 1937; and Dennison, 1961), faeces of the various groups of livestock were not characterized as to their contents of plant nutrients (Kallah and Adamu, 1989). They further explained that, chemical composition can be used to compare different sources and forms of animal faeces. It is a fair index for estimating the kind and potential amount of fertilizer elements being recycled on application. Kallah and Adamu (1989) reported the analysis of the plant macro- and micro- nutrients of faeces from different livestock. The results of some of the macro- nutrients showed that, cattle dung had 1.55 % N, 0.37 % P and 0.65 % K, sheep dung, 2.15 % N, 0.27 % P and 0.89 % K; goats dung, 2.57 % N, 0.33 % P and 0.82 % K and chicken droppings, 2.53 % N, 0.21 % P and 0.74 % K on dry matter basis.

Fresh cow dung in India has an average N content of 0.3 %. This contributes almost 50 kg of N per hectare of crop land (Jaiswal *et al.* 1971). Renard (1997) and Riviere (1991) reported nutrient content ranges of fresh cattle manure as follows: N 1.4-2.8 %, P 0.5-1.01 %, and K 0.5-0.6 %. According to Defoer *et al.* (2000),the nutrient content of manure is highly variable and it is

difficult to make useful comparisons. Muller-samann and Kotschi (1997) stated that, in practice, such values can only rarely be achieved, since a large part of the manure and the nutrients it contains may be lost depending on the type of agricultural practices. Defoer *et al.* (2000) explained that, the N content of manure is affected by the way it decomposes. In aerobic conditions (which are prevalent in most cattle pens) N may be high, and ammonia volatilization from aerated manure can remove up to 60 % of its total N content. These losses increase with prolonged storage and greater moisture content. In anaerobic conditions N may be lost through denitrification. Substantial amounts of mineral and organic material can be lost through surface water run-off and leaching, which increases with high rainfall and prolonged storage. Muller-samann and Kotschi (1997) explained that, exactly how much is lost depends on the form of animal husbandry, the method of storage and the way manure is used. They further explained that, within the same animal species, the composition of dung and urine varied according to fodder (site, season) and water supply, as well as the age of the animal and how it is used. For example, young animals and good milk producing cows excrete less N than working or old animals because of their more efficient use of protein. However, except in the case of poultry, the proportion of soluble N in fresh dung is relatively low. In fresh cattle, horse or sheep dung, this is about 0.05 – 0.06 %, this means that only some 10 % of the total N is immediately available. Storing and rotting the dung increases the content of available N. The composition of urine varies even more widely than

that of dung. The average chemical composition of the urine of some livestock species as reported by Jaiswal *et al*, (1971) and Flaig *et al,* (1978) showed that, urine is especially rich in K and N, whereas dung contains Ca, N, P and Mg. The N in urine is present in soluble form and is readily available to plants. However, liquid manure made from urine should be applied with care, as undiluted urine causes plant burns.

It is obviously difficult to generalize concerning the nutrient contents of manures (or dry dung) obtained in different ways. Through on-site analysis, it should be possible to calculate the nutrient contents that can be expected from each method of storage. The nutrient ratio of cattle manure is approximately 10: 5: 13 (N: P_2O_5: K_2O). For nitrogen, some 30 % to 60 % of the total can be regarded as available, depending on soil and climate (McCalla 1975, Flaig *et al.,* 1978). The availability of P and K corresponds to that of mineral fertilizers. The effect of the P may even be better, because not so much P is soluble at one time as, for example, with super phosphate, so less fixation takes place. Studies by Flaig *et al.,* (1978) revealed that the finer the spread, the better the fertilizing effect of farmyard manure, the higher the N content and the smaller the C/N ratio. The proportion of soluble N can be substantially improved through proper storage (Musa, 1975). Dung stored in deep pits contain six times as much N after four months as dung stored above ground (30 cm stack height), but the C/N ratio was high (42:1) indicating slower decomposition rate or rate of mineralization in the pits.

Muller-Samann and Kotschi (1997) observed that besides the main nutrients, manure also contains a wide range of micro-nutrients. However, large differences in micro-nutrient contents may be observed, depending on the soil and the diet of the animals. Because the contents of trace elements in farmyard manure are primarily determined by the fodder, and the fodder by the site, any deficits of such nutrients cannot be alleviated with organic fertilizer alone. They further explained that, while availability is usually improved to some extent with organic fertilizers, a marked improvement can only be achieved when the nutrients that are lacking are introduced through better mineral nutrition of the animals or through additives (e.g. stone-meal).

Although conserving nutrients is a very important aspect of farmyard manure management, farmyard manure is not just a vehicle for nutrients. Manure is also an important source of humus and has a beneficial long-term effect on the structure and carbon-economy of the soil. Moreover, farmyard manure contain hormones, vitamins, and anti-biotics, and their stimulating effects on root growth and on the growth of micro-organisms (yeast cultures) has been demonstrated experimentally (Sauerlandt and Tietjen, 1970; Fulhage, 2000)

2.1.2 Quantity of manure produced.

The quantity of manure accumulated in a livestock enterprise would be a function of factors intrinsic to the animal and factors related to the management.

The amount can be determined by species, breed, age and size of the animal, number of animals in the enterprise, the type and nature of food ingested, seasonal variation, length of kraaling time, and whether or not bedding is used (Kalla and Adamu, 1989).

Kalla and Adamu (1989) have also reported daily feaces excreted as dry matter (DM) for four agro pastoral livestock as follows: cattle, 1500 g / head; sheep, 200 g / head; goat, 240 g / head; and poultry, 39 g / bird. Expressed on tropical livestock unit (TLU) basis, the daily and yearly feacal recoveries as will be available to the farmer are: cattle, 1.50 kg; sheep, 2.87 kg; goats, 3.76 kg and poultry, 9.67 kg; and cattle, 550 kg; sheep, 1050 kg; goats, 1370 kg; and poultry, 3530 kg respectively. It is worth noting that per TLU, poultry has the highest output of faeces among the four species of livestock, follow by goats, sheep and cattle in that order.

The average agro pastoral cattle of 250 kg live weight (LW) excretes 1.5 kg DM of faeces daily during the kraaling period. Omaliko (1981) reported a daily dung deposition of 1.1 to 2.2 kg DM / head for cattle grazing tropical grassland range. For livestock under confinement feeding system, where all faeces voided remain in place, it is likely that more than double the quantity stated above would be expected. Comparative figures on feacal output by various species and classes of livestock under feedlot system had been presented by Runov (1977). Figures vary from 0.05kg / head / day for broilers to 60kg / head / day for horses and dairy cattle.

The amount of animal manure produced world wide is enormous. In India alone, where one-fifth of the world's cattle are raised, it is estimated that 1762 million tons of manure are produced yearly (Balasubramanian and Nnadi, 1980). For the individual farmer, it is important to know approximately how much faecal matter and urine is theoretically available to him or her, that is, how much does each kind of domestic animal produce per day or per year. Rough estimates can serve as a guide, but it must be remembered that there are wide regional and seasonal differences owing to changes in the animals feed supply, water regime etc. as stated earlier in this section above.

2.1.3 Calculation of the quantity of manure produced.

According to Defoer *et al.,* (2000) the daily amount of fodder (dry weight) consumed by a ruminant can be expressed as a percentage of its live weight. For cattle, this averages out at 2.5% (1.8-3.2%), while for small livestock the average is 3.2% (2.4- 4.0%). A standard animal with a live weight of 250 kg is called a Tropical Livestock Unit (TLU). On average, a TLU consumes 250 x 0.025 = 6.25 kg of dry matter per day. A sheep with an average weight of 25 kg consumes about 25 x 0.032 = 0.8 kg of dry matter per day.

One TLU consumes 250 x 365 x 0.025 = 2,280 kg dry matter per year.

The average digestibility of dry matter for cattle is estimated at 55%.

So, one TLU will produce $\frac{(100 - 55)}{100}$ x 2280 = 1,026 kg dry feaces per year.

One small ruminant weighing 25 kg consumes 25 x 365 x 0.032 = 292 kg dry matter per year.

The average digestibility of dry matter for small ruminants is estimated at 60 %.

So, one small 25 kg ruminant will produce approximately $\frac{(100 - 60)}{100}$ x 292 = 116.8 kg dry feaces.

Defoer et al. (2000) reported that as a rough estimate we can say that, one TLU produces one ton of dry faeces per year.

According to this formula, 10 goats would produce about 7 tons of manure (naturally moist, containing 3 kg of litter per day). The amount of manure produced annually by a dairy cow kept all day in the stable is roughly 10 tons (naturally moist). In Africa 7 tons is a realistic estimate per TLU with permanent stabling and litter (Ministere de la cooperation, 1980). The amount of manure that a farm can produce in practice is usually considerably less than the estimates given here (Muller-samann and Kotschi, 1997).

In northern Cote de Ivoire, Schleich (1985) studied draft oxen stabled with litter overnight. He measured an output of 2.2 – 4.4 tons of fresh manure per animal per year (average 3.3 tons) or 1.0 to 2.2 tons of dry dung. This is about a third to half the theoretical amount. Far smaller amounts of dry dung were obtained when the animals were kept on the savanna and driven into a pen with no roof for the night. Kotschi *et al* (1991) reported 6 tons / TLU for semi-permanent deep litter stabling in Rwanda.

2.2 Handling and management of cowdung

Farmyard manure is the most commonly used and readily available organic fertilizer world wide. However, it is not commonly used in many regions of the world, since it is both impossible and unnecessary to use cattle dung on extensively grazed pasture land (Burnett, 1975).

Crop and livestock production are not separate agricultural activities. In many parts of the world, including much of Africa, integration is the norm, not the exception. In India, Pakistan and Bangladesh, mixed farming is widely practiced, such that the exploitation of dung is easier (Muller-Samann and Kotschi, 1997). They further explained that, vast amounts of organic matter and nutrients are still lost to agriculture through lack of care in the collection of dung and through burning as fuel. Ministry of Agriculture, New Delhi (1975) explained that, the problems that arise in connection with handling and using animal dung are complex. Often, dung is inappropriately prepared and processed. The labour required to process it properly may be regarded as unacceptable. In some places, farmers refuse to have manure heaps in their farmyards (Lenzner and Kempf, 1982).

Other social and cultural conditions may present obstacles to the use of manure. For example, the raising of livestock on communal rangeland practiced in many parts of Africa makes it more difficult to utilize dung (Muller-Samann and Kotschi, 1997). Despite the many positive aspects of manure application Lenzner and Kempf (1982) and Schleich (1983) point out that, even in areas

where livestock production is traditional, it is often difficult to improve the care and conservation of manure. Manure heaps may not be tolerated in the farmyard on hygiene ground. The handling of manure may be regarded as an inferior task. Farmers may be unwilling to devote labour to storing and applying manure. The technical problems should not be under estimated. Musa (1975) regarded the lack of information and training for farmers on efficient methods of conserving and storing manure as a major problem. Additional losses may occur when manure is brought to the fields, if it is left for long periods unprotected from the sun or rain. As a result of these short comings, farmers may fail to recognize the potential of using farmyard manure. For these and other reasons (e.g. transport problem), the use of manure is often confined to the home gardens. Muller-Samann and Kotschi (1997) summarized by saying that, the more widespread use of farm yard manure depends greatly on proper preparation methods. Proper preparation, storage and application increased the value of farmyard manure, reduce costs, and enhance effectiveness, thereby increasing acceptability.

2.3 Storage and stacking of manure.

Storage of livestock waste involves accumulating manure and waste water in an environmentally sound manner until they can be applied to land or otherwise utilized (Collins and Younos, 1996). They further explained that, manure storage facilities allow farmers to spread manure when conditions are right for nutrient use by crops. Storing manure in a concentrated area, however increases risk to

the environment to human and animal health. Feacal bacteria in livestock waste can contaminate ground water, causing such infectious diseases as dysentery, typhoid and hepatitis (Collins and Younos, 1996).

According to Muller-Samann and Kotschi (1997) the simplest method of manure preparation is to do nothing with the dung at all but store it directly on the fields. Two arguments against this practice are that it is cumbersome from an operational point of view, that often there is no field available to accommodate the manure. Sauerlandt and Tietjen (1970) pointed out in addition, that fresh stable manure is prone to form organic acids. These are rapidly processed by soil organisms, which can lead to an over load of oxygen and nitrogen in freshly manured soils. The C: N ratio of fresh manure is often too high. This can result in a temporary N immobilization, such that hardly any manure nitrogen will be available in the following growing period (Flaig *et al*, 1978). In addition, the content of lactate soluble phosphates in cropped soils is increased only by decomposed manure, not by fresh manure (Sauerlandt and Tietjen, 1970). Storing manure is therefore preferable to using it fresh. Fresh manure can inhibit crop growth considerably (Muller-Samann and Kotschi, 1997), however there are exceptions. Fresh farmyard manure can be used successfully on light, sandy soils provided the litter content is sufficiently low (Musa, 1975). Augstburger (1983) achieved good results on acid mountain soils in the highlands of Bolivia, where fresh chicken manure (pH = 9.0) gave better results than stored manure. Almost all methods of manure conservation and preparation involve stacking the

manure in one form or another. In addition to saving space, stacking should achieve the following aims: It should narrow the C/N ratio (this will improve the fertilizing effect) and enrich the humic matter and build permanent forms of humus. Many factors that determine value, act only as the manure ages, which is why decomposition though associated with the loss of organic matter, is recognized as positive by increasing the proportion of beneficial components and breaking down harmful elements. Whereas little or no humus is formed when manure is spread fresh, formation is promoted by the special chemical and physical conditions prevailing in a manure pile (pH, gaseous balance etc). Many of the humic compounds formed in this way are more resistant to decomposition than those present in fresh manure. Other benefits of stacking are, mineralization of nutrients will take place with as little loss as possible, weed seeds that may later germinate will be destroyed (or reduced to a minimum) and the physical, biological and chemical properties of the manure will be improved (i.e. it should become more convenient to handle and more effective).

Lekasi *et al.* (2005) stated that, mineral nutrients are largely concentrated during composting as the carbon compounds are oxidized by micro organisms. This implies that, the lower the percentage organic carbon of the manure after incubation the more mineralization of the manure had taken place and the higher the nutrient content of the manure. Eghball *et al.* (1997) reported a similar result, that composting beef cattle manure leads to the loss of 46 -62 % of total carbon.

Muller-Samann and Kotschi (1997) pointed out that, storage places for manure, like those for composting, should ensure its protection from sun, wind, rain (perhaps including a roof or cover). Stagnant moisture caused by seeping liquid should be avoided. The best place is on firm, impermeable, slightly sloping ground (2 % gradient), so that liquid manure can flow out to be collected (with the urine from the stable) in an air tight pit. A base wall surrounding the manure pile prevents the semi-liquid from running out and rain water from flowing in.

Fresh manure for stacking should have a moisture content of 60 – 70 % (i.e. it should be quite moist). In the case of sheep dung, goat dung and perhaps also horse dung, it may be advisable to water the manure before stacking. It is even better to pour urine onto it (Jaiswal *et al.,* 1971). Losses occur if the manure is too dry and decomposition is hindered. White mycelia in the heap are a sign that it is too dry. Manure that is stored too wet exhibits yellow green discolouration. A well stored manure should be an even brown to black colour. This is the easiest way of recognizing that it is well stored (Muller-Samann Kotschi, 1997).

2.4 Methods of composting/stacking manure.

According to Muller-samann and Kotschi (1997), dung is placed on manure heap daily or every two days. It is better to build the heap up in sections and to stack up a small section quickly than to spread manure over the whole

farmyard. They further explained that, small scale farmers are advised to build a heap 1.5 – 2.0 m high with a wooden board or low wall surrounding it for protection. The section is then covered with a layer of earth (15 – 20 m) to reduce drying and loss of ammonia. If it contains a high proportion of litter, the manure should be trampled down firmly. This step can be omitted only for densely compacted manure that is poor in litter. Heaps should be firmly reinforced round the edges to give them the necessary stability and to limit the exchange of gases. The manure heap is thus filled and stamped down section by section. It is a good idea to organize the heap in such away as to allow access to older sections before newer ones, so that decomposed manure is always made available.

Haga (1998) reported that, the objectives in composting are to stabilize the biodegradable organic matter in raw wastes, to reduce offensive odours, to kill weed seeds and pathogenic organisms and finally, to produce a uniform organic fertilizer suitable for land application.

2.5 Management/handling of manure to conserve nutrients.

There are many pathways that lead to nutrient loss, especially N, from composting manure heaps. These include gaseous and leaching losses (Dewes, 1994). There is a need to apply collection and storage management strategies that minimizes these losses so that efficient nutrient cycling can be achieved. Such strategies are essential if small holders are to reap the full benefit from the

extra resources invested in a manner that is cost effective. Lekasi *et al.* (1998) conducted two surveys and reported that, farmers were able to suggest many ways in which management of livestock and manures might improve manure quality as opposed to quantity. The suggestions covered aspects such as better feed, capturing urine, mixing manures from different species, composting, storing in a covered pit, adding ash and inorganic fertilizer, adding green biomass, and roofing the cattle pen. In both the earlier survey and the survey described above, it was difficult to ascribed manure quality differences to individual management practice.

Lekasi *et al.* (1998) further explained that, five manure types were composted on-station which had known history of source and chemical composition of the constituents from which manure were derived, but considerable variation in chemical properties of the finished product was observed, which could be attributed to the different manure management strategies during composting. Differences in manure quality, derived from the different collection practices, influenced crop response over two seasons, even when the manure was applied at the same rate of total nitrogen. A variety of parameters may have influenced the efficacy of the different manures, other than total nitrogen applied, which was measured but did not correlate with yield performance (Lekasi *et al.,*1998). They further explained that the factors could include, among others, relative supply of other unmeasured, macro- or micro-

nutrients effects on the soil physical, chemical or biological properties, and chemical properties of the manure that influence nutrient mineralization.

In a later work, Lekasi *et al* (2001) reported that, most farmers preferred to store their manure in a heap, or pit (67 %) rather than by deep littering (33 %), and 90 % did not cover the manure. Forty-six percent of farmers kept the manure under shade. Farmers who did not turn, infrequently turned and frequently turned the manure during storage represented 45, 51 and 4 % respectively. The reported age of the manure heaps at sampling time ranged from 1 to 8 months with 5 months being the most common age. Eight months (4 %), 7 months (1 %), 6 months (13 %), 5 months (42 %), 4 months (13 %), 3 months (12 %), 2 months (10 %), 1 month (5 %). They explained that, relatively few of the management practices could as a single factor, be shown to significantly affect the nutrient content of the manure. However, percentage P was higher in zero grazing units (0.42 %) than in improved bomas (0.30 %) or traditional bomas (0.24 %); higher with a full roof (0.34 %), than with a partial roof (0.31 %) or no roof (0.25 %); higher when concentrates were fed (0.31 %) than when not (0.28 %); and higher when manure was stored in a pit or heap (0.31 %) than when stored as deep litter (0.28 %) (Lekasi *et al.,* 2001).

The inclusion of bedding significantly decreased the mineral N concentration (420 mg kg^{-1} compared with 804 mg kg^{-1} without bedding) and significantly increased the C:N ratio (23.9 compared with 21.1 without bedding). Turning the heaps significantly increased the mineral N concentration (667 mg

kg $^{-1}$ compared with 362 mg kg $^{-1}$ without turning) and decreased the C:N ratio (21.5 compared with 24.9 without turning). Turning the heaps significantly increased the mineral N concentration (667 mg kg $^{-1}$ compared with 362mg kg $^{-1}$ without turning), and decreased the C :N ratio (21.5 compared with 24.9 without turning) (Lekasi *et al.,* 1998).

Results suggest that modification of traditional livestock housing (boma) to the zero - grazing system may have beneficial effects on some aspects of manure quality. It is important to note that these beneficial effects may arise as an interaction between number of livestock and manure management factors and that the analysis of main factors only, presented above, may have overlooked these. However, in defense of this analytical approach, the aim of this study was to identify simple management factors that have significant influence on manure quality. Interacting factors may indeed influence quality but expressions of these interrelationships lend themselves to complex extension messages (Lekasi *et al.,* 2001). They further explained that, similarities between the current and earlier surveys confirm that management factors have the greatest positive influence upon P content increasing as a result of feeding on concentrates. This is an important finding given that P is considered the primary limiting nutrient in Kenya highland soils. No clear agreement was found between the two surveys regarding the best practice for producing manures with high N concentration. The present results suggest that inclusion of bedding and turning affect the C: N

ratio and N mineralization of the manure and this could have an impact on compost maturity and synchronization of nutrient release with crop growth.

Lekasi *et al.,* (2001), reported that although nutrient concentrations are valuable indicators of manure quality, these measurements do not reflect the total amount of nutrients that could be potentially available in the farms. It is quite possible that manures with low nutrient concentration could also have high heap mass, resulting in potentially higher nutrient cycling capacity. The full impact of livestock and manure management practices on nutrient cycling can only be determined if mass balances are recorded.

According to Fulhage (2000) a good manure management plan covers all aspects of manure management on a farm, from feeding the animal to eventual field application. The USDA-EPA unified national strategy for animal feeding operations released in 1999, requires that comprehensive nutrient management plans (CNMP) be developed for all animal feeding operations by the year 2009. According to the strategy, the CNMP should address feed management, manure handling and storage, land application of manure, land management, record keeping and other options for making use of manure. The plan should address liquid and solid manure produced in the operation as well as run off and erosion control from areas where manure is stored or applied. The scope of the plan should include manure collection and storage at the point of production and appropriate use of manure on crop and pasture land. The overall purpose of the plan was to guide animal manure management in a manner that prevents

degradation of water, soil and air resources and protects public health and the environment.

2.6 Quantity of manure to be applied.

Muller-Samann and Kotschi (1997) reported that, there is some controversy as to how often and in what quantities farmyard manure should be applied. Whereas, it was once assumed that small, frequent applications (4- 8 t ha $^{-1}$) were more effective than heavier applications (150 – 250 t ha $^{-1}$) at long intervals, opinion today is different. Results were reported in Europe, where Sauerlandt and Tietjen (1970) showed that larger applications of fermented manure given every 3 years had a better humus effect (+ 0.2 % in 12 years) and, with regard to humification, were therefore superior to other forms of application (fresh manure and/or yearly application). Results from Rwanda suggest that it is more effective to fertilize with farmyard manure at longer intervals than to treat all areas more frequently with small amounts (Egger, 1982). This is borne out by practices in the indigenous cropping systems of the Kofyar in Nigeria and the Wakara in Tanzania. They too apply farmyard manure or manure compost at longer intervals in their rotation, choosing crops that respond well to it (primarily Pennisetum). Usually a legume occupies a slot in the rotation between applications (Muller-Samann and Kotschi, 1997).

Applying manure at less frequent intervals also has advantages from a labour and organizational point of view. Covering large areas with small

amounts require more effort than covering small areas with large amounts. Muller–Samann and Kotschi (1997) further explained that the amount of manure applied should be determined by the effect sought. If the main aim is to make up for nutrient deficiencies, enough should be applied to achieve a rough nutrient balance. As experimental results show, even small amounts of farmyard manure (2.5 t ha^{-1}) are often sufficient to make a considerable impact on yields. This happens when a specific deficit (a single nutrient or macro nutrient) is alleviated or when an important chemical, physical or biological property of the soil is changed (Muller–Samann and Kotschi,1997).

If the humus level of a cropped soil is to be increased, application of 5 – 10 t ha^{-1} per year is necessary, according to trials in the West African savanna (Jones 1971). Young (1976), regards applications of at least l0 t ha^{-1} per year as necessary if satisfactory yields are to be sustained over time on permanently cultivated Luvisols. Other authors recommend minimum applications of 5 – 9 t ha^{-1} (Rodel *et al.,* 1980). Larger applications appear necessary in the permanently humid tropics (Godefroy, 1979), where at least 40 – 50 % more is recommended (Jaiswal *et al.,* 1971).When larger amounts of manure are applied, they should be accompanied by certain measures to protect the soil (Agboola *et al.,* 1975). The question of how a soil utilizes different doses of stable manure naturally depends to a large degree on the soil itself. An active well aerated soil, for instance, “digest” a larger application of stable manure with more ease than a poorly aerated soil (Muller- Samann and Kotschi, 1997).

According to Fulhage (2000) applying too much manure, at the wrong time, or improperly handling it in other ways releases nutrients into the air or into ground or surface waters. Thus, instead of nourishing crops, nutrients become pollutants. Excess nitrogen can leach through soil into ground water. Manure contamination can increase nitrate levels in ground water and caused bacterial contamination and the death of fish in surface waters. Excess phosphorus can be contained in erosion or runoff from fields and accumulate in surface water impoundments, such as ponds and lakes. This phosphorus can stimulate unwanted plant growth, such as algae, which causes turbidity and other undesirable conditions in water. Fulhage (2000) further stated that, a common misuse of manure is to spread it on a field and then, in addition, apply commercial fertilizer to supply a crop's nutrient needs with no consideration for the manure's nutrient value. An efficient manure management and application system meets, but does not exceed, nutrient needs of the crop, thereby minimizing pollution.

2.7 Methods and time of manure application.

Having obtained good, nutrient-rich manure through careful collection, storage and transport and knowing how much quantity of manure to apply, it is important to apply it to the fields in the most effective way. It should be spread carefully and evenly (no clumps) without disturbing the root area of the crops. This is easier to achieve with decomposed manure and manure composts than

with fresh manure containing crop straw. Once spread, manure should be worked into the soil as soon as possible, since long exposure on the surface causes loss of nutrients and fertilizing effect (Muller- Samann and Kotschi, 1997). According to Collins and Younos (1996), solid manure can be incorporated by tillage immediately following its application, and liquid manure slurry can be injected into the soil. Manure application should be applied close to time of planting to maximize N uptake by crops and minimize the loss of N through run-off or leaching down the soil profile. Liquid manure and lagoon effluent can also be applied to land areas by irrigation over growing crops. Care must be taken, however to prevent burning of some plants by the waste materials and to avoid excessive run-off.

As observed in some studies carried out in Ohio, USA, 50 % of the nitrogen was lost after 4 days of storage in the field (McCalla, 1975). Incorporating the manure close to the surface is better than deep incorporation. The lighter the soil, the deeper the manure should be incorporated (> 20 cm). Highly decomposed or fermented manure can be ploughed in deeper than relatively fresh manure. The manure should be well mixed with the soil and no dense clumps should be left in the subsoil. A special form of manure application is as surface compost mulch. In heavy soils, surface application of this kind can contribute to physical improvement of the site by stimulating soil life (Jaiswal *et al.,* 1971). However, the loss of nutrients with this method is high, and the nutrient effect becomes secondary to the mulching effect. Surface compost

mulch is only recommended on good soils well supplied with nutrients or farms with large supplies of manure, and where the aim is to achieve soil physical improvements, for example in combination with sowing green manure.

2.8 Effect of farmyard manure on humus balance.

The effect of farmyard manure on humus is evident in the tropics. On the ferrallitic loamy soils of Cote d Ivoire, where bananas and pineapples are grown, applications of 10-50 t ha $^{-1}$ of farmyard manure every two years resulted in an increase in C content by 30-46 % (Godefroy, 1979). Agboola *et al.* (1975) reported that a moderate application of farmyard manure on a crop soil in the rain forest zone was sufficient to slow down humus decomposition, which progresses only half as fast as with mineral fertilizers. On a savanna site at Samaru, Nigeria (1000 mm/year rainfall), crop land (ferric luvisols, sandy loam) had 50 % and 90 % more humus than the control plots after 15 years of applying 2.5 t ha $^{-1}$ of farmyard manure per year. Relatively small doses had a marked effect, acting as a strong check on the decomposition of soil humus and other fertility limiting soil properties (Bache and Heathcote, 1969). Trials on this site by Jones (1971) showed, the yearly loss of humus in the control plot was still 3.5 % even after 18 years of cropping. With farmyard manure (5 t ha $^{-1}$) the loss was greatly reduced to 0.7- 0.8 %. Applications of 12.5 t ha $^{-1}$ of manure increased the humus content. After 12 years of manuring, the humus content was nearly equal to that of a natural environment (1.5 %). Similar results were achieved in

long-term trials on red loams in Bihar, India (1400 mm yr $^{-1}$). Here 20 t ha $^{-1}$ of farmyard manure applied over 20 years increased the C content of a sandy loam from 0.6 to 1.1 % (90 % increase) (Muller-samann and Kotschi, 1997). As in temperate climates, the humus effect is strongly influenced by soils and site and only emerges clearly after many years of manure application.

2.9 Effect of farmyard manure on other soil properties.

The capacity of manure to provide nutrients, especially N, P and K is one of such benefit. Other benefits that have been demonstrated include an increase in CEC, pH, water holding capacity, hydraulic conductivity and infiltration rate and decrease bulk density (Lekasi *et al*., 2005; Dudal and Roy, 1995) and more recently biological properties and soil organic matter dynamics have attracted some interest (Kapkiyai *et al*., 1999) .

The sorption power, that is the soils capacity to store nutrients is also improved by manure application. Impressive results in this area have been obtained by applying manure to wetland rice. Regular applications of farmyard manure (10 and 20 t ha^{-1}) over 27years improved the cation exchange capacity (CEC) from 15 me/100g soil to 19 and 20 me/100g soil respectively (Egawa, 1975). Acidification is greatly reduced or reversed, the contents of exchangeable calcium are increased, the contents of free aluminium and manganese can be reduced through regular applications and root growth and the uptake of P are promoted (Agboola *et al.,* 1975 and Charreau, 1975). In many experiments, the

amount of available iron found when farmyard manure was used, was little different from that in mineral fertilizer amended fields. Nevertheless, the danger of iron toxicity appears to be considerably less with manure. For example, Agboola *et al.,* (1975), working in West Africa, reported that iron toxicity could be reduced by applying decomposed organic fertilizer.

Physical soil properties such as water holding capacity, erosion stability and gas exchange are also improved by applying farmyard manure. This means that after only a few years, yield stability may be markedly higher than in fields where mineral fertilizers alone have been used. Thus in five year trials in Zimbabwe by Rodel *et al.,* (1980) the yield from fields fertilized with farmyard manure was higher in the dry year of 1968 – 69, with only 350 mm of rainfall, than in the previous year when 800 mm fell. In the next dry year, 1968 – 69, the differences were even more pronounced. As all trial plots had received a complete cover of green manure, this effect must be attributed to physical soil improvement. Moreover, it was observed that, compared with mineral N fertilizers, the effect with manure improved with each succeeding year. In trials, physical improvements in the soil appeared to be the reason why fields receiving 7.5 t ha $^{-1}$ of farmyard manure for many years achieved higher yields than soils that had had large applications of mineral fertilizer, but were under supplied with organic matter (Mokwunye, 1980). Many physical properties of soils (for example infiltration capacity) can be more quickly improved with straw manuring (Somani and Saxena, 1975). Farmyard manure works more slowly, but

as the length of time over which it is regularly applied increases, so is the long term effectiveness.

2.10 Effects of farmyard manure on nutrients and crop yields.

The fertilizing effect, and especially the nitrogen effect, of farmyard manure usually lags behind that of corresponding amounts of soluble mineral fertilizers at first, because in the first growing period only about 30 – 60 % of the farmyard manure N becomes available. The rest is fixed at first, or is serving to build up the soils humus and nutrient supplies. The nutrient supply later starts to increase significantly with regular applications of farmyard manure (Prasad and Singh, 1980). After two or three applications, both the immediate effect and the delayed effects of earlier applications coincide, and the manure starts to have its maximum impact on yields (Jones, 1971).

Murwira *et al.* (2002) in an experiment to determine the fertilizer equivalence (F.E.), values of organic materials of differing quality reported that, from seven cluster sites in Zimbabwe, there was a positive effect of using N-poor manures at Chinonda, Manjoro, Chiteme and Mukudu. At three of the four sites, the manure effects were pronounced. Addition of 5000 kg manure increased yield by 1000 kg ha^{-1} of grain yield compared with the control except at Chisunga site. The incremental levels of inorganic nitrogen applied also resulted in an increase in yield levels achieved. At Chinonda, supplementation of 5000 kg ha^{-1} manure with at least 40 kg N ha^{-1} of inorganic fertilizers resulted in

a statistically significant yield increase was only obtained after applying 100 kg N ha^{-1} of inorganic N fertilizer. The percentage fertilizer equivalency of manure at Chinonda, Majoro, Chiteme, Makudu and Mapira 2 sites were calculated to be 30 %, 30%, 10 %, 20 % and 35 % respectively.

Still in the same experiment at Chisunga and Mapira in Zimbabwe, Murwira *et al.,* (2002) reported that the N poor manure treatment only caused a yield reduction even though there were no statistically significant treatment differences. Negative fertilizer N equivalency values of 100 kg N and 90 kg N respectively were obtained from three sites. These values were equal to the minimum amount of inorganic N fertilizers required to over come the negative effects of the manure used at each of the sites. The depression in yields can be attributed to the immobilization effect of the low quality manure used. Reports from work done by other workers (Mugwira, 1985; Murwira *et al.,* 1993) have also shown that use of low quality materials with a C:N ratio greater than 23, resulted in immobilization. Contrary to these reports, however, manure from Chisunga with a C:N ratio of 12 and that from Mapira with a C:N ratio of 15, both immobilized resulting in yield depression. This shows that prediction of decomposition behaviour of manure based on the C:N ratios were sometimes not accurate enough. The relationship between the initial N contents of manure and the N fertilizer equivalency values ($Y = 49.6 X - 56.4$) was weak with an R^2 value of 0.28. This means that the initial N content on its own could not fully explain

the observed responses, and other parameters which affect the decomposition processes of organic materials should be investigated.

Murwira *et al.* (2002) concluded that, the manures had nitrogen F.E. values of less than 30 %. The initial N content of the manures could not explain the observed trend of N fertilizer equivalencies. From the manure studies, it can also be concluded that not all manure with C:N values less than 23 result in net N mineralization when added to the soil. The results suggest that other indices of manure quality have to be investigated to improve the prediction of the effects of manure application on N availability and crop yields. A lot of the manure samples were not pure dung, but rather a mixture of dung and maize residues and therefore they may not be a simple index for predicting N mineralization patterns and fertilizer equivalency values.

Murwira *et al.* (2002) observed the relationships obtained between N content and percentage F.E. values for manure samples and plant materials were different, hence separate decision trees should be considered for the two types of organic material. More data points including a broader range of organic materials and sites from different agro climatic zones are required to improve the predictability of the relationship between percentage N content of organic inputs and further test the decision tree. It is from such information that we can have same guide lines on the use and the management of organic inputs, as we have for inorganic fertilizer (Murwira *et al.,* 2002).

Quite noticeable in tropical sites are the effects of manure as a P fertilizer and the improved effectiveness of mineral P fertilizers when combined with manure (Mokwunye, 1980). Agboola *et al.,* (1975) described a typical case of this on an extremely acidic, humid tropical site, where they found that mineral P fertilizer had no effect on cowpea. But, when the fertilizer was applied with relatively small amounts of farmyard manure (2.5 t ha^{-1}), increasing the amount of P applied also increased yields.

A deficit of P or a decrease in its availability on cultivated soils can be counteracted by fertilizing with farmyard manure (Godefroy, 1979; Prasad and Singh, 1980). The reasons why manure brings about an increase in available P are both chemical and physical in nature due to higher pH, lower C/P ratio and biological (heightened biological activity, increased mineralization of P compounds, increased root activity etc). Ofori (1980) suggested the following additional reasons for P availability due to manure application in the soil: organic colloids prevent dissolved phosphate from coming into contact with free aluminium and iron; when organic matter decays, the carbonic acid then forms dissolved phosphate; organic phosphorus is less strongly fixed by the soil and microorganisms mineralized organic phosphate compounds.

The impact of farmyard manure on yields depends strongly on the site, that is, on the primary effect on soils (as N or P fertilizer, biological, physical) and on the state of the soil. On a dry savanna site in the Sudan, yields of sorghum were increased from 1.3 t ha^{-1} to 2.4 t ha^{-1} (i.e. by over 80 %) by using

just 4.0 t manure ha $^{-1}$ (Musa, 1975). In contrast, 15.0 t ha $^{-1}$ had little effect on a site in highland of Rwanda. The maize yield increased by only 30 % to 1.3 t ha $^{-1}$. On a neighbouring degraded site in the same country, the maize yield was increased from 0.6 to 1.3 t ha $^{-1}$. The effect here, with a rise of 116 %, was very definite. Altogether, the results from Rwanda show that farmyard manure can positively affect yields in the second and sometimes even in the third subsequent cropping season (Pietrowiez and Neumann, 1987).

2.11 Residual effects of manure application in the soil.

According to Camberato *et al.* (1996), the organic N in manure that is not mineralized to ammonium in the first cropping season may be released in subsequent seasons. Unfortunately, there is lack of information, and not enough data on which to make recommendations on how much eventually becomes available. There is probably little N released after the first season from one-time applications of manure at rates to provide the crop N requirement in the first season. However, for fields with long term manure history of annual applications for five years or more, the amount of N released from previous season's applications may be significant. To assess the full effect of manure on yields, it is vital that the delayed effects be taken into account (Muller-samann and Kotschi, 1997).

In temperate climates the residual effects of fertilizing with farmyard manure last well into the third or even the fourth year (Sauerlandt and Tietjen,

1970), in the tropics they will subside more quickly. The results from the residual manure treatments showed that, the residual effect of manure could last at least seven years (Kihanda *et al*., 2008). Manure provides nutrients to crops for several years (Camberato *et al*., 1996). Pratt *et al.* (1973) developed a decay series (based on best judgments and some laboratory data) to estimate N availability in the first, second, third and fourth year after manure application. The decay series was different for each manure type. For example, the decay of beef cattle manure (1.5 % N) was 0.35, 0.10, 0.05, and 0.02, indicating that 35% of total manure N was available in the first year of application, 10%, 5% and 2% in second , third and fourth years of application respectively.

2.12 Effects of manuring in combination with mineral fertilizers.

The complimentary effect of farmyard manure and mineral fertilizers is known for temperate climates and also been confirmed in the tropics (Mokwunye, 1980). As observed by Charreau (1975), the combined effect of farmyard manure and mineral fertilizers showed that, higher yields were achieved with the same amount of nutrients when these were in combined form (mineral and organic) than when mineral fertilizer alone was applied. This was especially true in the long term and when the level of mineral fertilizer was relatively low.

In Samaru, Nigeria, cultivated soil that had been independently supplied with nutrients for 20 years possessed a substantially lower yield capacity than

soils receiving regular applications of farmyard manure. Even the largest doses of mineral fertilizer did not achieve the effect of moderate applications of farmyard manure and mineral fertilizers in combined form. The synergistic effect of combined manure and P fertilizer, already mentioned above, was confirmed by the results from Samaru (Jones, 1971; Prasad and Singh, 1980).

2.13 Manure mineralization.

Nitrogen is undoubtedly the most intensively studied plant nutrient in both natural and managed ecosystems. Despite its importance to plant growth and ecosystem productivity, there is still no reliable soil test for nitrogen availability (Stanford, 1982). Soil nitrogen for the most part is in the organic form and unavailable to plants. Organic nitrogen is mineralized to ammonium, a plant available form, by microbial processes. Net nitrogen mineralization, has been considered as a measure of nitrogen availability of organically bound N in soils. The amount of N mineralized or immobilized from manure and compost depends on soil mineralogy (Beckwith and Parsons, 1980), organic material, chemical and physical characteristics (Catellanos and Pratt, 1981; Janssen, 1996) and environmental conditions (Adriano *et al.,* 1974; and Kissel, 1995). The rate of mineralization depends on many factors including temperature and rainfall, the quality of the soil organic nitrogen, and the quality of organic inputs to the system (Palm *et al.,* 1997). Since mineralization is microbially driven, it is influenced by many factors, including temperature, soil moisture, soil properties,

and manure characteristics. Nitrogen mineralization increases with increasing temperature under conditions found in agricultural soils (Cassman and Munns 1980; Eghball 2000). Growing degree day, which is a function of temperature, has been used to predict N availability from applied manure (Griffin and Honeycutt 2000). Mineralization is greatest when soil moisture is near field capacity and declines with soil drying (Cassman and Munns 1980)

Good manure should synchronise mineral nitrogen release and plant demand such that the peak mineral nitrogen release coincides with peak plant biomass development and hence peak nitrogen requirements (Myers *et al.,* 1994). Also, Lekasi *et al*. (2005) reported that it is advantageous if the organic materials added to the soil mineralize nutrients slowly and the rate of nutrient mineralization increases as the plant growth progresses. As the plant matures, it is expected that a good soil will have released adequate nutrients for optimum plant growth. Closer synchronization of nutrient demand ensures efficient utilization of organic inputs applied to the soil. Organic materials that mineralize too readily subject mineralized nutrients to losses through processes such as leaching and volatilization. On the other hand, organic materials that release nutrients later in the season will not benefit the plant or crop as it will have matured with inadequate availability of nutrients during the critical growing stages. This example is most applicable to annual crops because perennials require a steady supply of nutrients during seasons with adequate moisture availability.

The overall amount of nutrients released from organic amendments for crop uptake depends on the quality, the rate of application, the nutrient release pattern and the environmental conditions (Mugwira and Mukurumbira, 1986; Murwira and Kirchmann, 1993). Unfortunately, for many trials, there has been lack of crucial information on nutrient content and quality of organic inputs; therefore, it has not been possible to establish quantitative recommendations on the amounts of organic materials needed to obtain similar crop yields as a given amount of fertilizer nitrogen (Murwira *et al.,* 2002).

Research over the past century has related nitrogen release patterns to the resource quality, or chemical characteristics of organic materials (Heal *et al.,* 1997). The nitrogen concentration and the C:N ratio of the material still probably serve as the most robust indices when all plant materials are considered (Constantinides and Fownes, 1994).

2.14 Socio- economic consideration for adopting the use of manure.

Despite the many positive aspects of manure application; Lenzner and Kempf (1982) and Schleich (1983), pointed out that, even in areas where livestock production is traditional, it is often difficult to improve the care and conservation of manure. Manure heaps may not be tolerated in the farmyard on hygienic grounds. The handling of manure may be regarded as an inferior task. Farmers may be unwilling to devote labour to storing and applying manure. Where extensionist recommend subsidized mineral fertilizers, it becomes

extremely difficult to promote the use of farmyard manure. In many areas, the shortage of firewood means that dung is dried and used as fuel for cooking, rather than being applied to crops. Where population pressure is high, increasing land scarcity and the curtailing or elimination of fallow periods are leading to declining soil fertility and to increased risk of erosion, forcing farmers to turn to some form of soil fertility management other than fallow. As grazing areas shrink, stabling and fodder cropping become more attractive and farmyard manure assumes a more important role in the maintenance of soil fertility.

2.15 Soil Microbial Population as indices of soil fertility.

Microbiological analyses of soil are used as indices of soil fertility and land use (Fauci and Dick, 1994; Ndiaye *et al.*, 2002). Other workers have used microbial population and ratios to assessed the modification of the soil ecological environment brought about by land use changes (Mendes *et al.*, 1999 and Ndiaye *et al.*, 2002). For example according to Isirimah *et al.* (2006) waste disposal from large livestock feedlots and oil palm bunch processing mills is a major problem of agro-industrial operations. A common traditional method of disposal is to dump or spread the waste or effluent sludge on wetlands or nearby croplands at unrestricted high concentrations. At such dumping rates the soil condition, crop growth and quality could be negatively imparted. Incorporating large amounts of livestock waste and other agricultural waste into surface soil alter the microbial population of soil quantitatively and qualitatively (Mendes *et*

al., 1999). The data on soil microorganisms in several tropical soil are very limited and grossly underestimated (Ayanaba and Sanders, 1981). Most of the available reports did not consider the effects of some soil properties, cropping history and system and waste disposal on the microbial population (Isirimah *et al.*, 2006). In their work in 2006, crop residues and animal waste incorporated into the soil for different land use affected the rate of organic matter decomposition as indicated by the population of microorganisms.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location and description of experimental site.

The study consisted of collection and incubation of cowdung and subsequent evaluation using both greenhouse and field experiments. The greenhouse experiment was conducted at the screen house of Institute for Agricultural Research (IAR) Ahmadu Bello University, Samaru, Zaria (Lat. 11^{o} 11" N and Long. 7^{o} 33" E) located in the Northern Guinea Savanna zone of Nigeria. The field studies were also carried out at Samaru at two different locations within the same zone at the IAR Research Farms and the Samaru College of Agriculture (SCA) Farm, Samaru.

3.2 Climate, vegetation and soils of the experimental site.

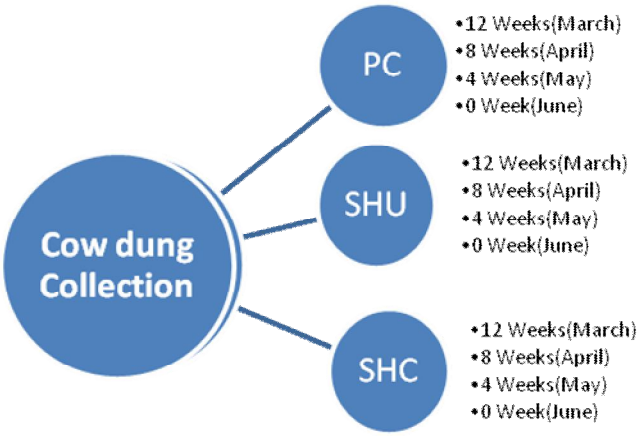
Samaru has mean annual rainfall of about 1050 mm, spanning the periods from May to September, while the dry season starts from October to April with a mean daily temperature of 24^{o} C (Kowal and Knabe, 1972). The hottest months are those that precede the rains (March to April) and coldest months occur in November to January, October and February are considered as transition months. The global radiation is evenly distributed throughout the year, ranging from 440 cal. cm^2 day^{-1} in August to 550 cal. cm^2 day^{-1} in April to May (Kowal, 1972). Samaru is located at the Northern Guinea Savanna zone. The vegetation of the zone is similar to the southern Guinea savanna zone except that the grass growth

is shorter and consist mainly of *Hyperrhenia/Andropogon* spp. The main trees are *Isoberlinia* spp which characteristically flushes during the middle of the dry season (Kowal and Knabe, 1972).

The soils of Samaru were developed on aeolian drift materials, overlaying basement complex (Klinkiberg and Higgins, 1968), and are broadly classified as Alfisols (Awujoola, 1979). These are less leached, slightly acid (pH 5.5 to near 7.0) soils derived from Precambrian crystalline basement complex rocks Harpstead (1973) and are more commonly found in the Guinea and derived savanna zones. They are well drained and shallow, with texture consisting of loamy sand to sandy loam top soils (0 – 20 cm) over argillic subsoils which are sand loam to sandy clay loam with evidence of manganiferrous concretions and quartz/feldspathic fragments (Ayotade, *et al*., 1989). They further explained that, organic matter content of the surface soils in the entire zone is very low, the value being less than 2 % and the total N content never exceeding 0.1 %. Kaolinite is the dominant clay type which explains why the cationic nutrients and water holding capacities are low and soils poorly structured.

3.3 Cowdung collection and subjected to management practices.

The cowdung that was used for these experiments (both greenhouse and field experiments) were collected from the National Animal Production Research Institute (NAPRI), Shika-Zaria in years 2003 and 2004. The cow dung collected was subjected to different management practices as described below.



Stage 1= Cow dung Collection
Stage 2=Management Practices(composting or incubation) for four weeks
Stage 3= Field Storage (Exposure)before use in the field

Figure 3.1: Diagrammatic presentation of Experimental set up.

Fresh cowdung was collected early in the morning from pens and piled into a heap. The cowdung was then mixed thoroughly with a shovel with the aim of harmonizing it. After mixing it thoroughly, it was then subjected to the various management schedules as follows: (i) cowdung placed in a pit of 2 x 2 m and 75 cm deep and covered with a polythene sheet, (ii) cowdung heaped on the ground surface and covered with a polythene sheet, and (iii) cowdung heaped on the ground surface and left uncovered. The collection of the cowdung and its distribution to the 3 different management practices was repeated for the next 2-

3 days as described above until enough cowdung was gathered. The cowdung was then allowed to decompose for four weeks (one month, the ageing period) without any disturbance before it was removed and stored in the field.

This experiment started in February, 2003 with the collection of cowdung and allowing it to decompose (composting) for 4 weeks which means the field storage (exposure) of the cow dung was in March to May (12 weeks of field storage before application to the soil as amendment). The same cowdung treatment as described for February above was repeated in March against April to May (8 weeks of field storage before application to the soil as amendment), April against May (4 weeks of field storage before application to the soil as amendment) and May against June (0 week) where cowdung was collected at the termination of composting (incubation) and applied to the field immediately, without field storage (the moisture content was taken into consideration). The same procedure was repeated in the second year (2004).

3.4 Cowdung sampling.

Three types of cowdung sampling were carried out in each of the two years. First, fresh cowdung samples (untreated) were taken after mixing thoroughly before subjecting them to any management practice. These samples were oven-dried immediately after collection at 65^{o}C for 3 days and stored for analysis. Secondly, samples were taken after subjecting the cowdung to the three different management practices (already discussed above) but before taking them to the

field for storage. This set of cowdung after collection was air dried and stored for analysis. The third sampling of the cowdung was done at the time of application and incorporation into the soil {at this stage, the cowdung treatments must have been exposed at the field in storage after the 1 month of composting (ageing period) for different time durations of 12 weeks, 8 weeks, 4 weeks and 0 week}. These were all carefully processed and kept for analysis and for use in the greenhouse and field.

3.5 Cowdung analysis

3.5.1 Cowdung chemical analysis

Cowdung samples were digested using wet oxidation method. Potassium in digest was determined by flame photometer, while Ca and Mg were determined using atomic absorption spectrophotometer. Phosphorus was determined by the vanadomolybdate yellow colour method (Juo, 1979); while N was determined by the micro-kjedahl wet digestion method outlined by Bremner (1982). Organic carbon was determined by the Walkley-Black method (Nelson and Sommers, 1982).

3.5.2 Cowdung microbial analysis.

Soil-dilution plate technique and media was used for microbial analysis. A 10 fold dilution of sample was done by adding 10 g of manure sample to 90 ml of sterile distilled water in 250 ml screw capped bottle. After shaking to mix

thoroughly, a ten fold serial dilution up to 10^{-9} was made by transferring 1 ml to universal bottle containing 9 ml of sterile distilled water. Aliquots (0.5ml) of the 10^{-9} dilutions were transferred in duplicate into soil extract agar (SEA) and potato dextrose agar (PDA) plates and spread by means of a flamed bent glass spreaders.

The soil extract agar was reconstituted according to the specific instruction of the manufacturer, while the potato dextrose agar was prepared as described by Harrigan and McCance (1990). The inoculated plates were placed in an incubator then incubated at ambient temperature (30 ^{o} C) for seven days and colonies of bacteria and fungi were counted.

3.6 Soil sampling and preparation.

Before the commencement of the greenhouse experiment surface soil sample (0 to 30 cm depth) was collected from the field where the field experiment was going to be conducted at SCA farm. The soil was air-dried and sieved to pass through the 2 mm sieve.

3.7 Greenhouse experiment.

3.7.1 Treatments and experimental design.

The treatments consisted of three cowdung management methods, surface heaped uncovered (SHU), surface heaped and covered (SHC) and cowdung placed in a pit and covered with polythene sheet (PC), four storage periods, after

1 month ageing: 12 weeks, 8 weeks, 4 weeks and 0 week and two levels of N: 0 kg N ha^{-1} and 45 kg N ha^{-1}.

The experiment was a factorial experiment, 3 x 4 x 2, laid out in a Randomized complete block design (RBCD) and replicated three times.

3.7.2 Pot preparation and Sowing.

Each pot was filled with 3 kg of the soil sample. The cowdung samples which were carefully ground and sieve to pass through a 2 mm sieve and were added at the rate of 5.0 t ha^{-1} (7.50 g) to each pot and thoroughly mixed with the soil, watered at field capacity for two weeks before maize (var. Oba super II) was sown. Samples of soil and the cowdung before mixing were taken and kept for chemical analysis. Three seeds were sown per pot and later thinned to two plants per pot at two weeks after planting (WAP).

3.7.3 Observations and measurements made during the experiment.

Observations were made on weekly basis, from the 2 weeks after planting(WAP).

3.7.3.1 Plant height.

Plant height was measured from the soil surface to the leaves whorl using a meter rule.

3.7.3.2 Harvesting.

The plants were harvested after 4 weeks of growth in the greenhouse. Each pot was harvested by cutting the plants at the soil level. The plant shoots harvested were washed thoroughly with water and dried for 48 hours in an oven set at 65^{o} C and weighed for dry matter yield(DMY).

3.7.3.3 Soil analysis.

The surface soil samples for both greenhouse and field studies were analyzed by the following methods: for particle size distribution the standard hydrometer method (Klute, 1986) was used. The soil pH was determined in water and 0.01 M $CaCl_2$ with a pH glass electrode using a soil: solution ratio of 1:2.5. Organic Carbon was determined by wet oxidation method of Walkley–Black (Nelson and Sommers,1982).

Exchangeable bases were determined by extraction with neutral 1 N NH_4O AC saturation method. Potassium in the extract was determined by the flame photometer, while Ca and Mg were determined by atomic absorption spectrophotometer (Juo, 1979). Available P was extracted by the Bray 1 method. The P concentration in the extract was determined colorimetrically using the spectronic 70 spectrophotometer. Total N was determined by the Kjeldahl procedure (Bremner and Mulvaney, 1982 and Bremner, 1982).

3.8 Field Experiments.

The field experiments were conducted at two locations. The first trial was carried out at the IAR Farm, Samaru in the year 2003, and 2004 seasons. The second trial was established at the SCA Farm, Samaru in 2004 and 2005 seasons. In all the experiments, the same treatment combinations, experimental design, observations and procedures were maintained as in the greenhouse experiment, except that the NPK combination was not included.

3.8.1 Soil sampling and preparation.

An initial bulk soil sample was collected in each of the two sites that were used before land preparation. Soil samples were taken from 15 points across the field along each of the blocks (replicates) in each site and each was bulked to produce 3 composite samples representing the 3 replicates. After the experiment had been established, soil samples were collected at two stages of plant growth with a soil auger at 0 to 30 cm. The first sampling was at 4 WAP and the second sampling was at harvest. Samples were taken from each plot in the 3 replicates. Soil samples were collected at 3 different points diagonally across the plot and bulked together and a subsample taken. In each case the samples were carefully air dried, sieved with a 2 mm sieve and stored for analysis.

3.8.2 Treatments and experimental design

The treatments and experimental design in the field were the same as described in the greenhouse experiment in section 3.7.1. These were; 3 cowdung management practices, 4 different storage times after 1 month ageing of each month's cowdung collection before application in the field, 2 levels of N. However there was a control treatment where no cowdung or nitrogen fertilizer was applied. These gave a total of 25 treatment combinations (NPK treatment was not included).

The experiment was a factorial experiment with 3 factors, laid out in a randomized complete block design replicated three times.

3.8.3 Land preparation.

The land was plowed and harrowed and the field was mapped out into plots in the first year of the experiment. The plot sizes were 4 x 5 m ($20m^2$) and each plot was separated from the other by one meter. The plots were then ridged manually at 75 cm between ridges and immediately after cowdung application to avoid the transfer of the manure from one plot to another and to also incorporate the manure into the soil.

In the second year of the experiment, when the residual effect was to be observed, the same plots were maintained and the ridging was also done manually to avoid the transfer of soil from one plot to another.

3.8.4 Cowdung application.

Cowdung subjected to different management practices which had been conveyed and stored in the field at different times (March for 12 weeks, April for 8 weeks, May for 4 weeks and June for 0 week) were applied manually at 5.0 t ha $^{-1}$ on dry matter weight basis in the first year of the experiment. The plots were then immediately ridged manually with the hand hoe to incorporate the cowdung. In the second year of the experiment, the residual effect of the first year applications was observed. That is, there was no application of cowdung in the second year.

3.8.5 Planting.

In both years (direct and residual trials) of the experimentation, maize (Var. Oba super II) dressed with Fernasand D was sown at two seeds per hole, at a spacing of 25 cm within the row. The seedlings were later thinned to one plant per hill at two weeks after planting. The same procedure was repeated in the second year, when the residual effect was to be observed.

3.8.6 Fertilizer application.

A blanket application of P was applied as single super phosphate (SSP) at the rate of 60 kg P_2O_5 ha^{-1} and at 45 kg N ha^{-1} as urea was applied in two split equal doses to the appropriate plots. The first application was done immediately after the first weeding. The second dose was applied at the time of second

weeding. In each case the fertilizer was applied by single band about 5 cm deep, made along the ridge, 5-8 cm away from the plant stand and covered immediately. All methods carried out in the first year were repeated in the second year of evaluating the residual effect.

3.8.7 Weeding.

This operation was carried out at the third and sixth weeks after planting. Remolding was carried out at 8-9 WAP to ensure proper weed control and a clean field at the time of harvesting.

3.8.8 Plant height.

During the first and the second years of the trials, when the maize was fully matured at the time of full cob formation, the plant height of five randomly sampled plants in each plot were measured and the mean calculated.

3.8.9 Harvesting.

The net plots (four inner rows) were harvested when the crop was fully matured and dry. Ears for each net plot were dehusked and the fresh weight of the cobs was taken immediately. The number of cobs plot $^{-1}$ was also counted. Fifteen cobs plot $^{-1}$ were randomly selected and weighed.

3.8.10 Grain yields.

After sun drying, the cobs were shelled using the manual sheller. The dry grain weight for each treatment was recorded.

3.8.11 Stover yield.

After harvesting, the maize stover was cut and left in the field to dry and the dry stover weight was taken for each treatment.

3.9 Statistical Analysis

The data collected from the greenhouse and the field studies were subjected to analysis of variance (ANOVA) using the SAS package (SAS Inst., 1999). The means where significant were separated using the Duncan's Multiple Range Test (DMRT) at 5% level of probability, except otherwise stated. Simple correlation analysis were also run for some selected parameters.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Site Characterization (Physical and Chemical Properties)

Some selected physical and chemical properties of the two sites are shown in Table 4.1. The results of the IAR experimental farm, showed that the texture of the soil was sandy loam; while that of SCA farm was silt loam. The soil reaction was slightly acidic 5.9 (H_2O) for both sites, and 5.1 and 5.2 for IAR and SCA farms respectively for ($CaCl_2$). The soil organic carbon for IAR farm was 7.40 g kg^{-1} and 4.40 g kg^{-1} for SCA farm. The total N for IAR farm was 0.53 g kg^{-1}, while for SCA was 0.70 g kg^{-1} .Both were low, a characteristic of the Nigerian savanna soils, a situation which has been attributed largely to the rapid mineralization rate of organic matter under the high temperature and rainfall conditions that exists in the tropics. The available P for IAR farm was 7.0 mg kg^{-1}, while for SCA farm it was 2 mg kg^{-1}. The exchangeable cations, Ca^{2+} (2.00 cmol kg^{-1}), Mg^{2+} (0.80 cmol kg^{-1}) and K^{+} (1.84 cmol kg^{-1}) and Na^{+} (1.87 cmol kg^{-1}) were for IAR farm, while SCA farm had exchangeable Ca^{2+} (1.6 cmol kg^{-1}), Mg^{2+} (1.0 cmol kg^{-1}), K^{+} (0.49 cmol kg^{-1}) and Na^{+} (1.13 cmol kg^{-1}) all were classified as medium according to the modified FAO Suitability Classification System, which makes the soil to be moderate in fertility status (Young, 1976). According to the modified FAO Suitability Classification System, the soils can be classified as moderately suitable for the cultivation of most crops.

Table 4.1 Some physical and chemical properties of the soil of the first and second experimental sites at commencement of study.

Parameters	IAR Farm	SCA Farm
Sand (g kg^{-1})	640	360
Silt (g kg^{-1})	210	540
Clay (g kg^{-1})	150	100
Texture	Sandy loam	Silt loam
pH 1:2.5 (H_2O)	5.90	5.90
pH 1:2.5 ($CaCl_2$)	5.10	5.20
Organic Carbon (g kg^{-1})	7.40	4.40
Total N (g kg^{-1})	0.53	0.70
C/N ratio	14.00	6.29
Bray 1 P (mg kg^{-1})	7.00	2.00
Exchangeable Calcium (cmol kg^{-1})	2.00	1.60
Exchangeable Magnesium (cmol kg^{-1})	0.80	1.00
Exchangeable Potassium (cmol kg^{-1})	1.84	0.49
Exchangeable Sodium (cmol kg^{-1})	1.87	1.13

IAR = Institute for Agricultural Research
SCA = Samaru College of Agriculture

4.2 Characteristics of the cowdung used for the study.

4.2.1 Basic properties of the cowdung

The characterization of the untreated (fresh) cowdung before they were subjected to different management practices at different months in years 2003 and 2004 are presented in Tables 4.2 and 4.3. The analysis of the cowdung provided the information on the kind and potential amount of fertilizer elements contained in the material before use. The results showed that, in the 2003 season, the results were total N (1.58 %), P (0.75 %), K (1.65 %) Ca (0.22 %) Mg (0.38 %), organic carbon (48.2 %) and the total microbial count (4.75 cfu), while in the 2004 season, total N was (1.55 %), P (0.73 %), K (1.50 %), Ca (0.27 %) Mg (0.35 %) organic carbon (45.5 %) and the total microbial count (0.30 cfu). These results corroborate works of some scientist on these materials (Kallah and Adamu, 1989) who also reported cowdung had 1.55 % N, 0.37 % P, 0.65 % K, 2.80 % Ca, 0.30 % Mg and 86.57 % organic matter for cowdung in this same ecological zone. The results showed that, the nutrient content of the 2004 season cowdung (Table 4.2) was generally lower than that of 2003 season. This may be attributed to the difference in the diet of the animals at the two seasons. Camberato *et al*. (1996) and Fulhage (2000) reported that the nutrients content of manure may vary with animal species, age, ration feed consumption, among other factors.

Table 4.2 Characteristics of the cowdung (NPK and organic carbon) used for greenhouse and field studies.

Management practices (one month incubation)	Time of cowdung (storage) exposure in the field before use (weeks)	N (%)			P (%)			K(%)			Org.C. (%)		
		a	b	Diff.	A	b	Diff.	a	b	Diff.	a	b	Diff.
2003 Season													
SHUM	12	1.05	1.40	+0.35	0.75	0.25	-0.50	5.48	1.65	-3.83	48.2	38.4	-9.8
SHUA	8	1.40	1.40	0	0.39	0.39	0	1.43	1.65	+0.22	55.6	22.7	-32.9
SHUY	4	1.40	1.58	+0.18	0.60	0.50	-0.10	1.35	1.35	0	38.6	20.6	-18.0
SHUJ	0	1.75	1.75	0	0.53	0.75	+0.22	1.25	2.25	+2.00	47.5	60.8	+13.3
SHCM	12	1.23	1.40	+0.17	0.75	0.67	-0.08	1.35	1.75	+0.40	48.2	52.0	+3.8
SHCA	8	1.40	1.05	-0.35	0.83	0.39	-0.44	1.50	1.28	-0.22	41.5	28.2	-13.3
SHCY	4	1.23	1.23	0	0.67	0.32	-0.35	1.65	1.43	-0.22	41.5	37.1	-4.4
SHCJ	0	2.10	1.93	-0.17	0.91	0.75	-0.16	1.50	3.08	+1.58	44.5	34.9	-9.6
PCM	12	1.75	1.45	-0.29	0.79	0.39	-0.40	3.15	1.98	-1.17	38.3	35.6	-2.7
PCA	8	1.75	1.05	-0.70	0.60	0.32	-0.28	5.25	1.20	-4.05	38.4	14.1	-24.3
PCY	4	1.58	1.75	+0.17	0.67	0.49	-0.18	3.68	1.58	-2.10	50.5	29.7	-20.8
PCJ	0	1.75	1.58	-0.17	0.83	0.53	-0.30	4.28	1.58	-2.70	53.4	32.6	-20.80
Untreated control.	-	1.58			0.75			1.65			48.2		
2004 Season													
SHUM	12	0.88	1.00	+0.12	0.67	0.64	-0.03	3.60	2.78	-0.82	31.9	11.4	-20.5
SHUA	8	1.23	1.08	-0.15	0.60	0.67	+0.07	3.30	3.08	-0.22	27.7	13.5	-14.2
SHUY	4	1.23	1.20	-0.03	0.60	0.91	+0.31	2.55	6.08	+3.53	17.7	25.5	+7.8
SHUJ	0	1.20	1.23	+0.03	0.67	0.71	+0.04	3.68	2.63	-1.05	34.1	28.4	-5.7
SHCM	12	1.05	1.08	+0.03	0.39	0.51	+0.12	1.73	2.10	+0.37	24.1	29.7	+5.6
SHCA	8	1.23	1.10	-0.13	0.46	0.60	+0.14	0.98	4.65	+3.67	24.8	34.1	+9.3
SHCY	4	1.23	1.58	+0.35	0.53	0.71	+0.18	1.88	3.53	+1.65	25.5	16.3	-9.2
SHCJ	0	1.23	1.25	+0.02	0.53	0.60	+0.07	0.98	2.55	+1.57	29.8	31.2	+1.4
PCM	12	1.05	1.05	0	0.80	0.60	-0.20	4.88	1.58	-3.30	29.8	18.5	-11.3
PCA	8	1.58	1.58	0	0.53	0.53	0	4.28	1.80	-2.48	54.6	31.9	-22.7
PCY	4	1.98	1.05	-0.93	0.53	0.71	+0.18	3.15	2.63	-0.52	45.4	18.5	-26.9
PCJ	0	1.70	1.70	0	0.58	0.53	-0.05	3.60	1.73	-1.87	27.0	11.4	-15.6
Untreated control		1.55			0.73			1.50			45.5		

a = At termination of 1 month incubation
b = At time of application to field trial

SHUM = Surface heaped uncovered March, SHUA = Surface heaped uncovered April, SHUY = Surface heaped uncovered May, SHUJ = Surface heaped uncovered June

SHCM = Surface heaped covered March, SHCA = Surface heaped covered April, SHCY = Surface heaped covered May, SHCJ = Surface heaped covered June

PCM = Pit covered March, PCA = Pit covered April, PCY = Pit covered May, PCJ = Pit covered June

Table 4.3 Characteristics of the cowdung (Ca, Mg and total microbial count) used for greenhouse and field studies

Management practices (one month incubation)	Time of cowdung (storage) exposure in the field before use (weeks)	Ca (%)			Mg (%)			Total Microbial count (cfu)		
		a	b	Diff.	a	b	Diff.	a	b	Diff.
2003 Season										
SHUM	12	0.27	0.27	0	0.43	0.18	-0.25	0.60	2.30	+1.70
SHUA	8	1.65	0.45	-1.20	1.75	0.33	-1.42	4.90	4.40	-0.50
SHUY	4	1.20	0.21	-0.99	1.45	0.33	-1.12	1.10	44.50	+43.40
SHUJ	0	0.75	1.15	+0.40	0.40	0.98	+0.58	4.30	1.90	-2.40
SHCM	12	0.39	1.12	+0.73	0.23	0.99	+0.76	0.60	1.05	+0.45
SHCA	8	0.60	0.44	-0.16	0.30	0.30	0	6.65	32.50	+25.85
SHCY	4	1.50	1.40	-0.10	1.45	1.30	-0.15	2.40	6.00	+3.60
SHCJ	0	0.41	1.55	+1.14	0.28	1.93	+1.65	0.90	33.00	+32.10
PCM	12	0.15	1.10	+0.95	0.30	0.95	+0.65	1.80	2.30	+0.50
PCA	8	0.75	0.88	+0.13	0.88	0.35	-0.53	11.10	36.50	+25.40
PCY	4	1.25	0.85	-0.40	1.20	1.05	-0.15	55.00	4.25	-50.75
PCJ	0	0.24	0.49	+0.25	0.45	0.90	+0.45	8.75	9.50	+0.75
Untreated control.		0.22			0.38			4.75		
2004 Season										
SHUM	12	1.15	0.38	-0.77	0.65	0.65	0	13.50	50.50	+37.00
SHUA	8	1.10	0.28	-0.82	0.55	0.65	-0.20	4.25	66.00	+61.75
SHUY	4	0.31	0.85	+0.54	0.35	0.33	-0.02	11.50	6.50	-5.00
SHUJ	0	1.13	0.43	-0.70	0.98	0.33	-0.65	87.00	15.30	-71.70
SHCM	12	0.31	0.65	+0.34	0.28	0.88	+0.60	2.25	4.05	+1.80
SHCA	8	0.31	0.99	+0.68	0.22	0.33	+0.11	0.30	91.50	+91.20
SHCY	4	1.00	0.28	-0.72	0.98	0.35	-0.63	3.40	87.00	+83.60
SHCJ	0	0.27	0.40	-0.13	0.23	0.40	+0.17	3.20	4.40	+1.20
PCM	12	0.45	0.84	+0.39	0.48	0.33	-0.15	14.25	3.10	-11.15
PCA	8	1.20	0.28	-0.92	0.40	0.33	-0.07	2.35	43.50	+41.15
PCY	4	0.84	0.31	-0.53	0.35	0.30	-0.05	11.05	36.00	+24.95
PCJ	0	1.28	0.39	+0.89	0.90	0.40	-0.58	1.00	67.50	+66.50
Untreated control.		0.27			0.35			0.30		

a = At termination of 1 month incubation
b = At time of application to field trial

SHUM = Surface heaped uncovered March,
SHUA = Surface heaped uncovered April,
SHUY = Surface heaped uncovered May
SHUJ = Surface heaped uncovered June

SHCM = Surface heaped covered March,
SHCA = Surface heaped covered April,
SHCY = Surface heaped covered May
SHCJ = Surface heaped covered June

PCM = Pit covered March,
PCA = Pit covered April,
PCY = Pit covered May
PCJ = Pit covered June

4.3 Quality of Cow dung after one month of incubation (composting)

4.3.1 Nitrogen

The results of the cowdung management practices and the months of incubation at termination of one month incubation in each month are also shown in Tables 4.2 and 4.3. The results showed that, the surface heaped covered at the month of June gave the highest content of total nitrogen (2.01 %) in year 2003, while in year 2004, it was the pit covered treatment in the month of May that gave the highest total nitrogen value (1.98 %). At both 2003 and 2004 seasons, the surface heaped uncovered in the month of March treatments gave the least value of total nitrogen (1.05 % and 0.88 % respectively). The high total nitrogen observed in year 2003 on the surface heaped covered in the month of June and pit covered in the month of May, 2004, was probably due to the treatment of containment by covering that reduced loss of nitrogen through volatilization and probably by leaching. Just as well, the low temperatures observed for the months of May and June, due apparently to the on-set of rains could have helped in lowering the temperatures of the incubating materials, and protected the manure from excessive volatilization which could caused considerable loss of nutrients from the materials. Comparing the May and June treatments to the March and April treatments that were not covered and left under very high temperatures, an act that would normally encourage high rate of volatilization, the March and April values were lower, suggesting the factor of temperature and effect on N

volatilization as relevant in manure management practices. Dewes (1994) had reported that, there were many part-ways that lead to nutrient loss, especially nitrogen, from composting manure heaps. These could be gaseous and leaching losses. Lekasi *et al.,* (1998) conducted two surveys and reported that, farmers were able to suggest many ways in which the management of livestock and manures could improve manure quality. The suggestions included storage of manure in covered pits, as well as roofing the cattle pens among other factors. Though the authors concluded that it was difficult to ascribed manure quality differences to any individual practice.

Assessing the mean effects of the individual management practices and the control in both years of study, at the termination of the one month incubation in each month, the pit covered treatment gave the highest total N, which was slightly higher than the control (fresh cow dung) by 4.46 %, while the surface heaped covered and surface heaped uncovered treatments decreased the total N content of the cow dung by up to 19.12-23.57 % respectively (Figure 4.1). At the time of field application of the incubated and stored cowdung, the results showed that in 2003, there was no difference among the treatments, however the control treatment (fresh cowdung collected and oven dried immediately without incubation) gave a slightly higher value than all other treatments (Figure 4.2). But in 2004, the control treatment gave a higher value than the uncovered treatment. This was followed by the pit and covered treatments. When the results were pooled together the control gave a

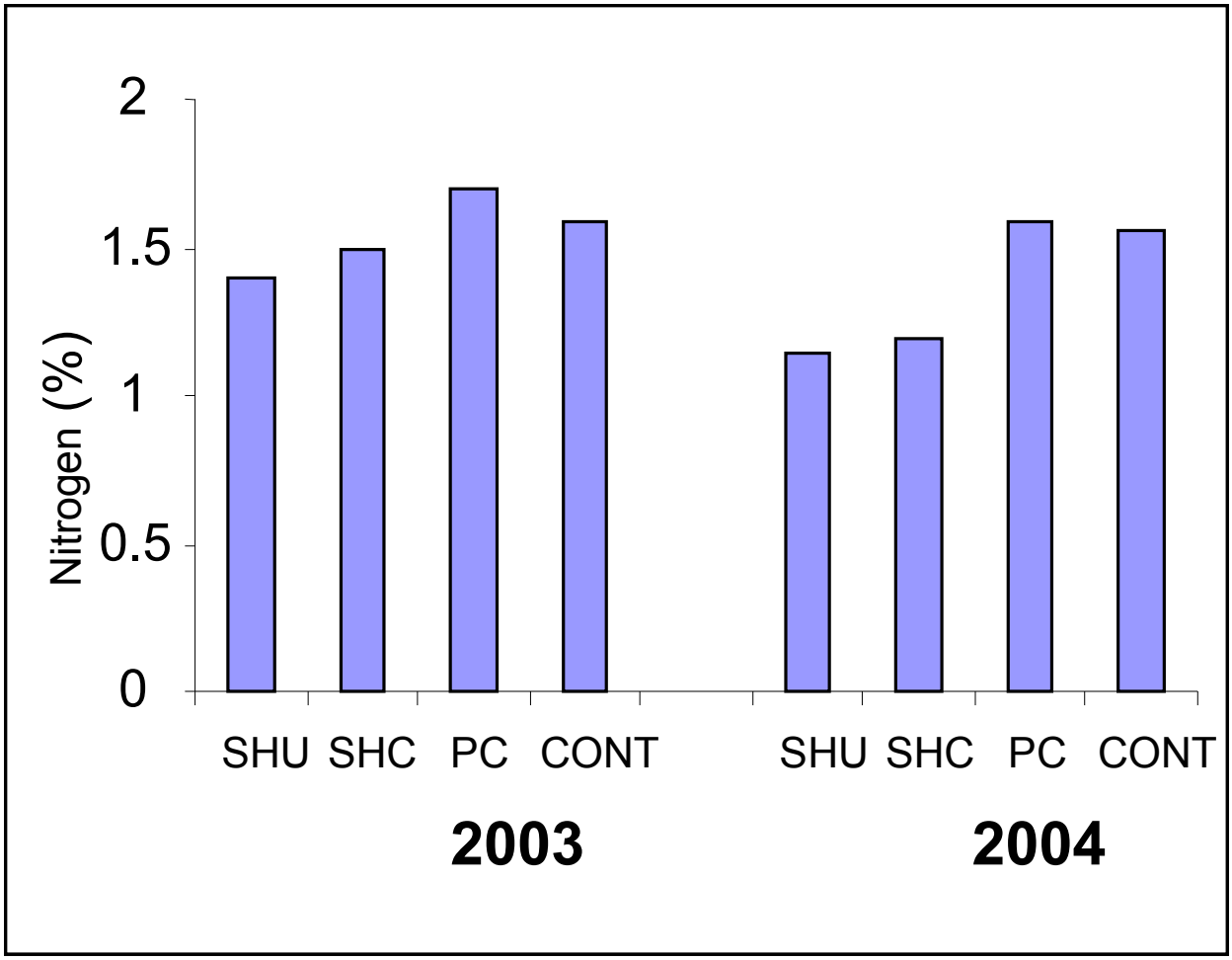


Fig.4.1: Nitrogen content of cowdung at termination of one month incubation

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

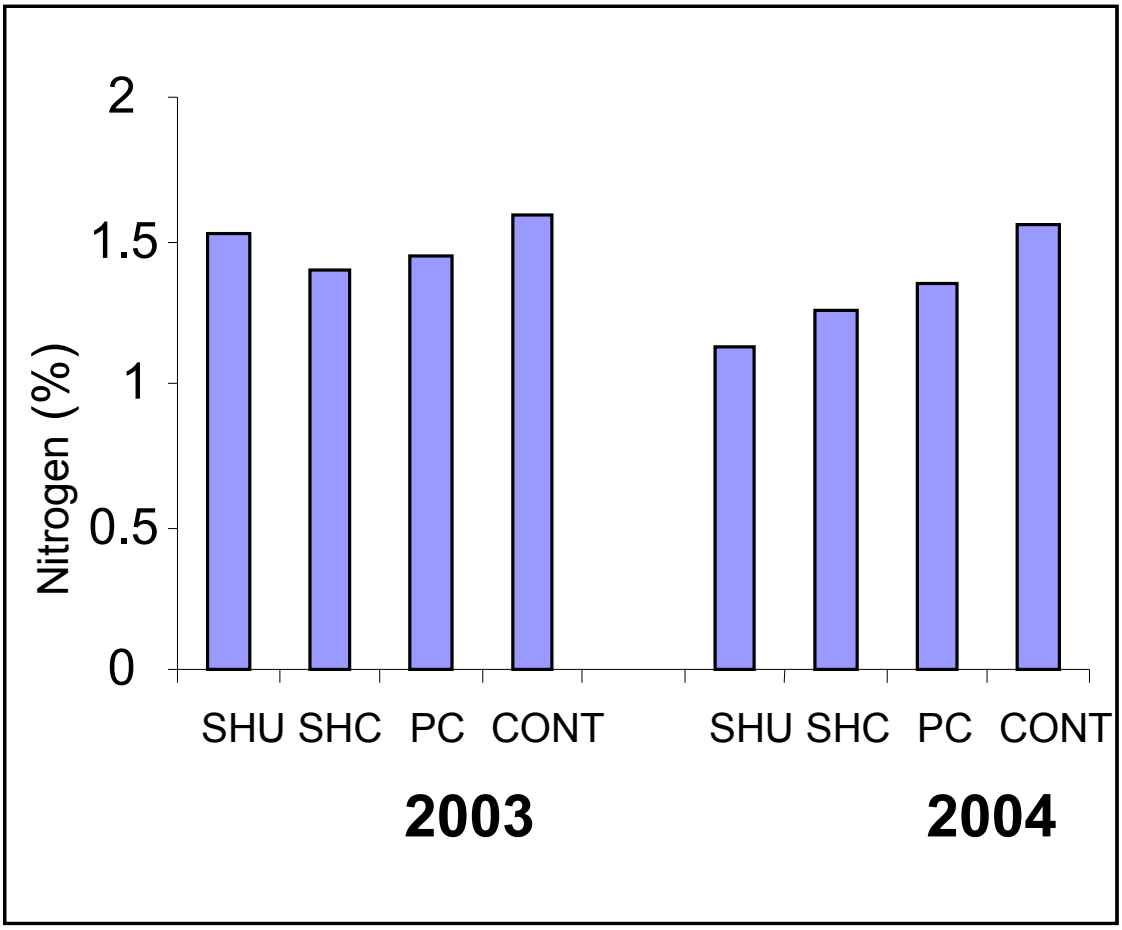


Fig.4.2: Nitrogen content of cowdung after storage in the field.

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

value that was higher than the other treatments (surface heaped uncover, surface heaped cover and pit covered) that ranged from10.83-15.29 % respectively. The values of surface heaped uncover and surface heaped cover were at par with each other. These results agreed with those of Kwakye (1980) and Nzuma *et al.,* (1998) who reported that, composting manure in pit was superior to surface composting. This may still be attributed to the reasons already stated above, that is, lowering of temperature and covering the cowdung may greatly reduce the volatilization and leaching of nutrients.

4.3.2 Phosphorus

The P contents of the manure at the termination of one month incubation are shown in Table 4.2. The surface heaped covered treatment in June gave the highest P content (0.91 %), while the surface heaped uncovered in April treatment gave the least P value (0.39 %) in year 2003. These showed that, the surface heaped covered treatment still favours high P content in the cowdung as it was with N in year 2003. In the 2004 season, the pit covered in the month of March gave the highest value (0.80 %), while the least value was observed in the surface heaped covered treatment in March (0.39 %).

Considering the mean values of the management practices in year 2003, at the termination of one month incubation, the results showed that the surface heaped covered treatment was superior to the other management practices in terms of P content of the cowdung (Figure 4.3). Probably the mineralization of

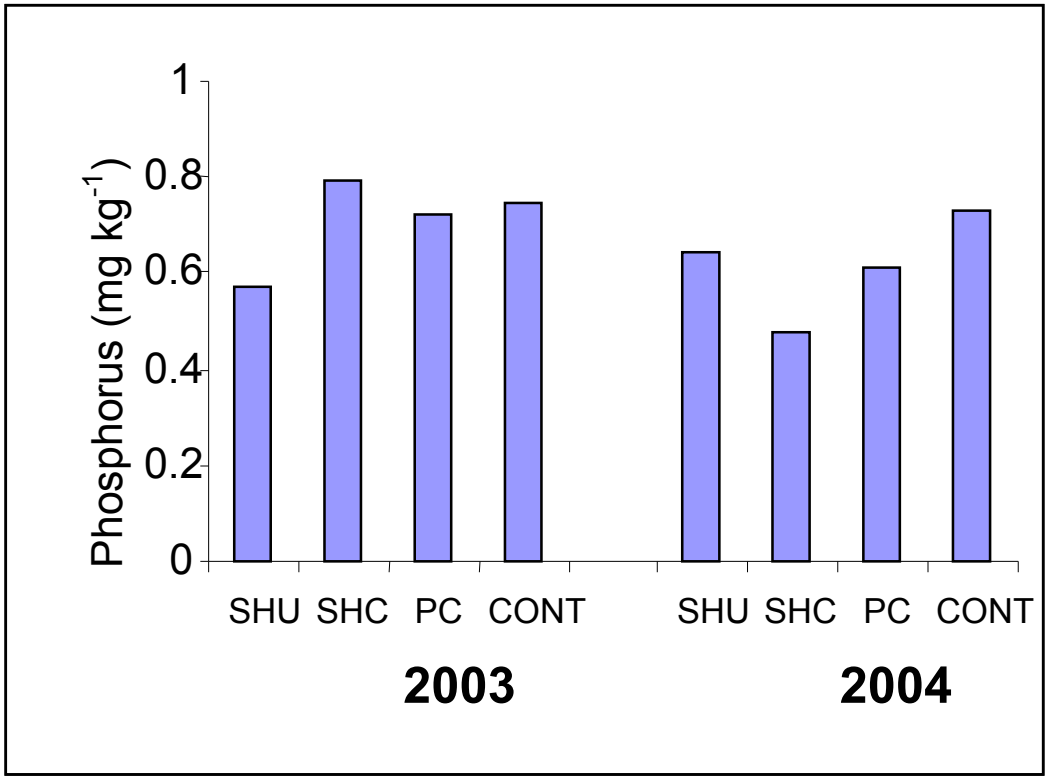


Fig.4.3: Phosphorus content of cowdung at termination of one month incubation

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

P is enhanced when the cowdung is heaped on the surface and covered. Lekasi *et al*. (2001) reported higher percentage of P when manure was stored in pit or heaped, than when stored as deep litter. However, comparing the mean values with the untreated cowdung, the results showed that incubating the cowdung for one month decreased the P content of the cowdung for each of the management practices and the values decreased from 9.45-18.91 %.

Observing the difference between the manure values at termination of one month incubation and at time of field application (Figure 4.4), the results showed a general decrease of P content. But when the values of the two years were pooled together, the control treatment was still superior to the other treatments by up to between 18.91-31.08 %.

4.3.3 Potassium

The concentration of K at the termination of incubation are presented in Table 4.2. Observing the K values in year 2003, it was the surface heaped uncovered March treatment that gave the highest K content of cowdung (5.48 %), while the surface heaped uncovered in June gave the least K value (1.25 %). The results also showed that, the pit treatment in March in year 2004 gave a better K content of cowdung (4.88 %), while the surface heaped covered in the months of April and June gave the least K content (0.98 %).

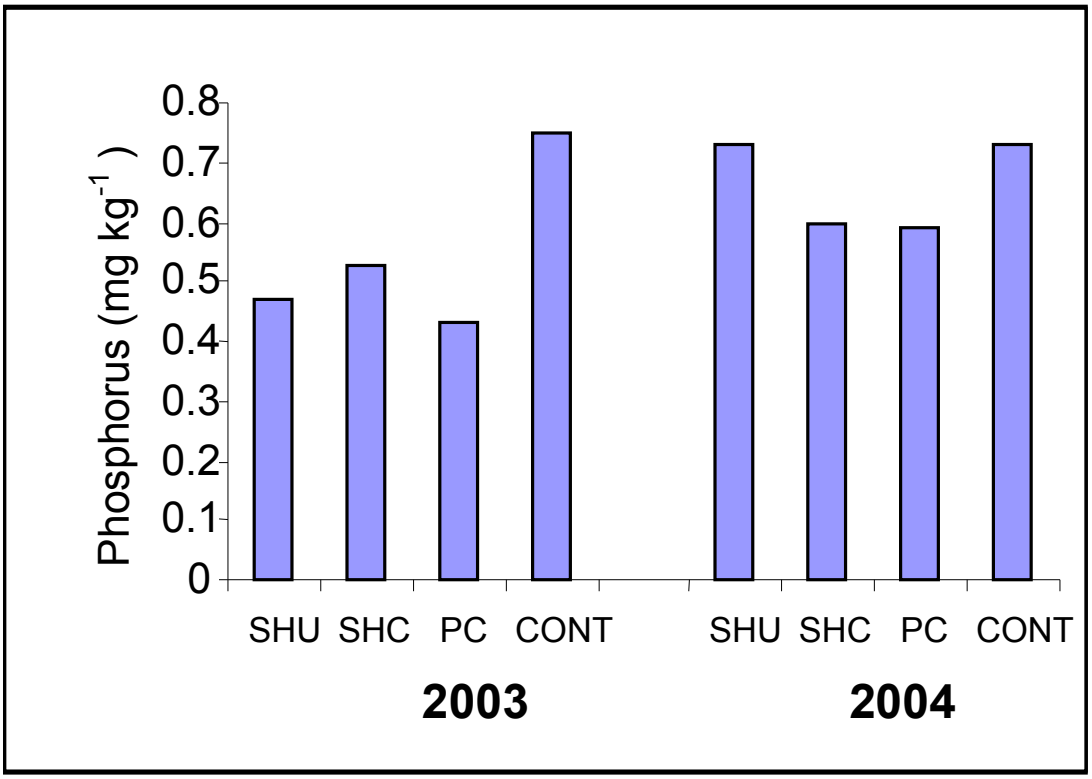


Fig. 4.4: Phosphorus content of cowdung after storage in the field.

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

The mean values of the management practices for the two years pooled together, showed that the pit covered treatments were generally higher than the other treatments after one month of incubation (Figure 4.5). Incubating the cowdung generally increase the K content, since most of the treatments gave values that were higher than those observed for the untreated control. Incubation increased the K content of surface heaped uncovered up to 78.48 % and for pit covered up to 155.06 %. However, it was the surface heaped covered that slightly decreased by up to 8.23 %. Fulhage (2000) reported that, manure K is in soluble form and is considered to be immediately and completely available to plants when applied.

The mean values of the management practices at the time of field application showed that the surface heaped uncovered and the surface heaped covered gave higher values than the control and pit methods (Figure 4.6). Storing the cowdung in the field increased the values of K for all the management practices between 11.92 to 62.03 % than the control treatment..

4.3.4 Soil organic carbon

The percentage organic carbon values for the 2003 and 2004 seasons are presented in Table 4.2. In 2003 season, the surface heaped uncovered April treatment gave the highest value of 55.6 %, while the pit covered in March gave the least value (38.3 %). The 2004 season, the pit covered in April

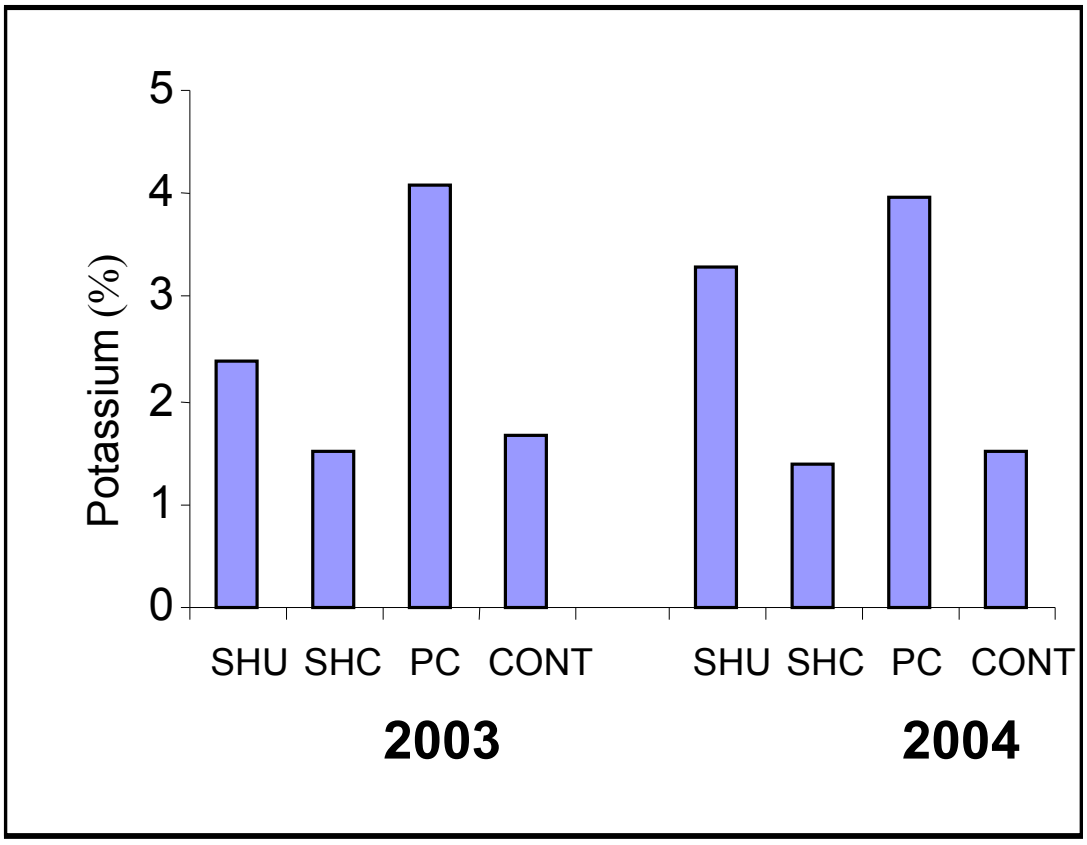


Fig. 4.5: Potassium content of cowdung at termination of one month incubation

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

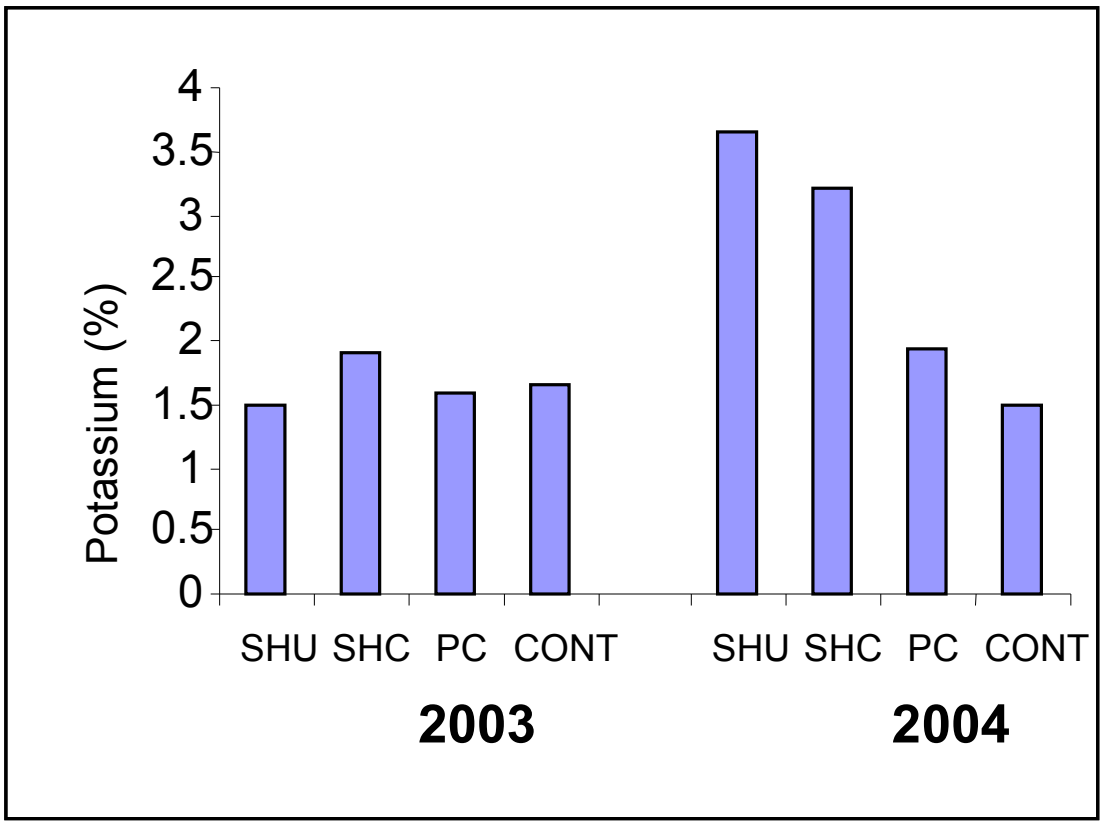


Fig.4.6: Potassium content of cowdung after storge in the field.

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

treatment gave the highest organic carbon values (54.6 %), while the surface heaped uncovered May treatment gave the least value (17.7 %).

The mean values for the management practices for the two seasons pooled together at termination of one month incubation revealed that, the pit covered treatment was higher in organic carbon content compared to the other treatment, and all these other treatments gave values that were lower than the control treatments. The values were lower than the control treatment between 9.97 % for pit covered to 25.29 % for surface heaped covered, while the surface heaped covered gave the least value (Figure 4.7). This means that the rate of carbon oxidation was higher in this particular treatment that gave the lowest value (SHC). Also the untreated control gave higher values than any of the treatments. Lekasi *et al.* (2005) stated that, mineral nutrients are largely concentrated during composting as the carbon compounds are oxidized by micro organisms. This implies that, the lower the percentage organic carbon of the cow dung after incubation the more mineralization of the cowdung would have taken place and the higher the nutrient content of the cowdung. Eghball *et al.* (1997) reported a similar result, that composting beef cattle manure led to the loss of 40-46 % of total carbon.

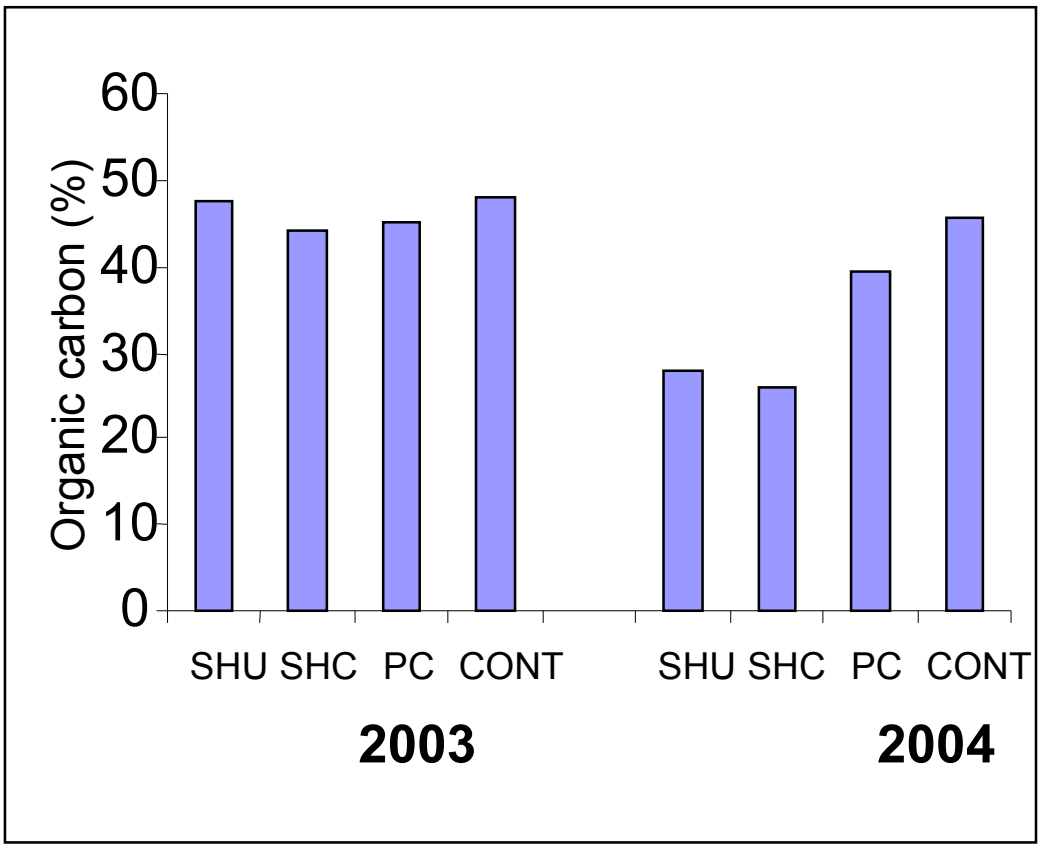


Fig. 4.7: Organic Carbon content of cowdung at termination of one month incubation

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

At the time of field application, the values of the organic carbon at their equivalent levels of comparison were generally lower (Figure 4.8). The control treatment still gave the highest value of organic carbon in the two years. The least values of organic carbon were observed at the pit covered treatments at the time of cow dung incorporation into the soil. The treatments gave values that were lower than the control treatments that ranged between 29.69 % to 48.69 %.

4.3.5 Calcium

The calcium content of cowdung at the end of one month incubation for 2003 and 2004 seasons are presented in Table 4.3. The 2003 season showed that, surface heaped uncovered in April gave the highest value (1.65 %) , while the lowest value was observed for the pit covered June treatment (0.24 %). The low value observed for the pit covered June treatment could be attributed to leaching , being the month of heavy rains, when compared to the other months.

The Ca values for the 2004 season showed that, the pit covered June treatment gave the highest value (1.28 %) and the surface heaped covered June treatment gave the least value (0.27 %). All the treatment values were higher than the value of the untreated control, which further agrees with the work of Lekasi *et al*. (2005), that mineral nutrients are concentrated during composting as the carbon compounds are oxidized by microorganisms.

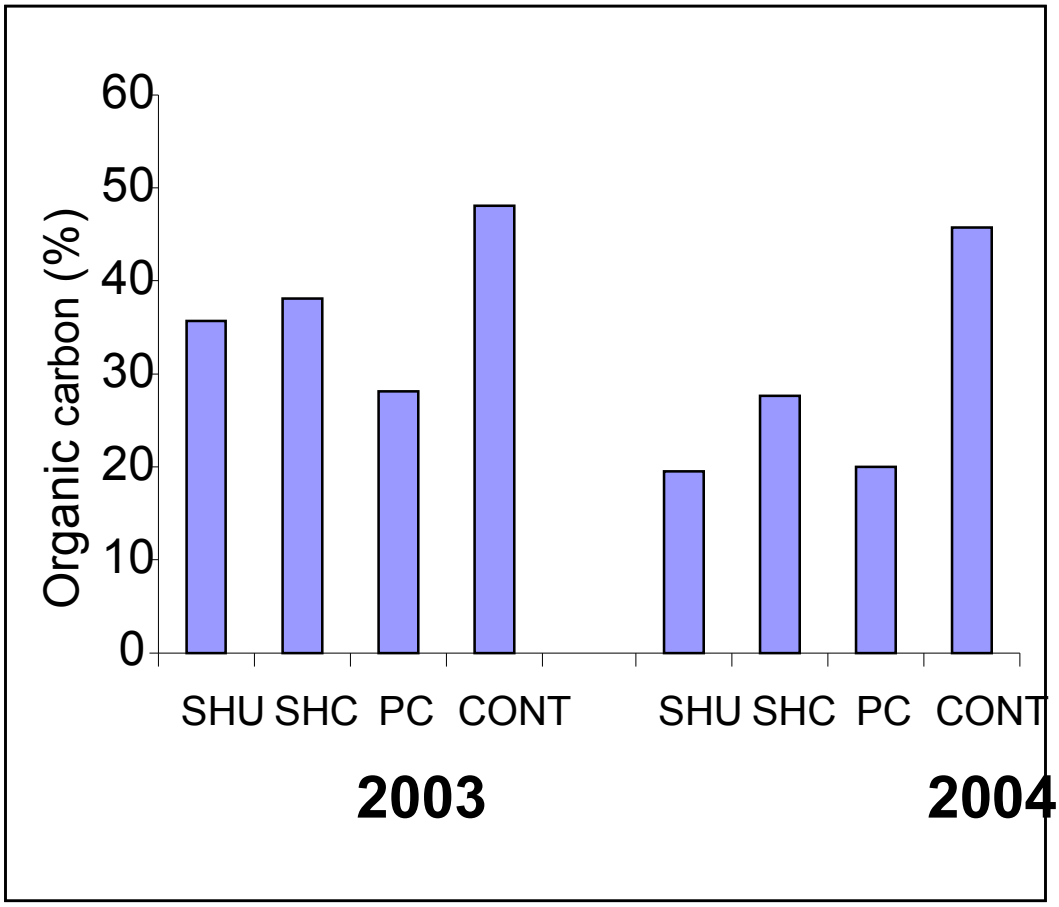


Fig. 4.8: Organic carbon content of cowdung after storage in the field.

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

When the mean values of the management practices were pooled together for the two years, at termination of one month incubation, the surface heaped uncovered treatments gave the highest Ca value (0.95 %) and all the other treatments gave values that were also higher than the untreated control (Figure 4.9). This increase in K of the cowdung, when converted to percentage ranged from 152.17 to 280.00 % more than the untreated control.

At the time of field application, the values of the surface heaped uncovered treatments were greatly reduced for the two years, while for the surface covered and pit covered, there were increases in some instances (Figure 4.10). This showed that exposing the manure to the surface uncovered must have resulted in leaching of Ca ions as the rain had started before the cowdung was incorporated into the soil. However, the increases of the treatments over the control for the pooled values was still much, ranging from 100-240 %

4.3.6 Magnesium

The Mg content of the cowdung for 2003 and 2004 seasons are presented in Table 4.3. The highest value of Mg on the cowdung was observed in year 2003, on the surface heaped uncovered treatment in April (1.75 %), while the surface heaped covered in March gave the lowest value (0.23 %). But in 2004, it was the surface heaped covered in June and surfaced

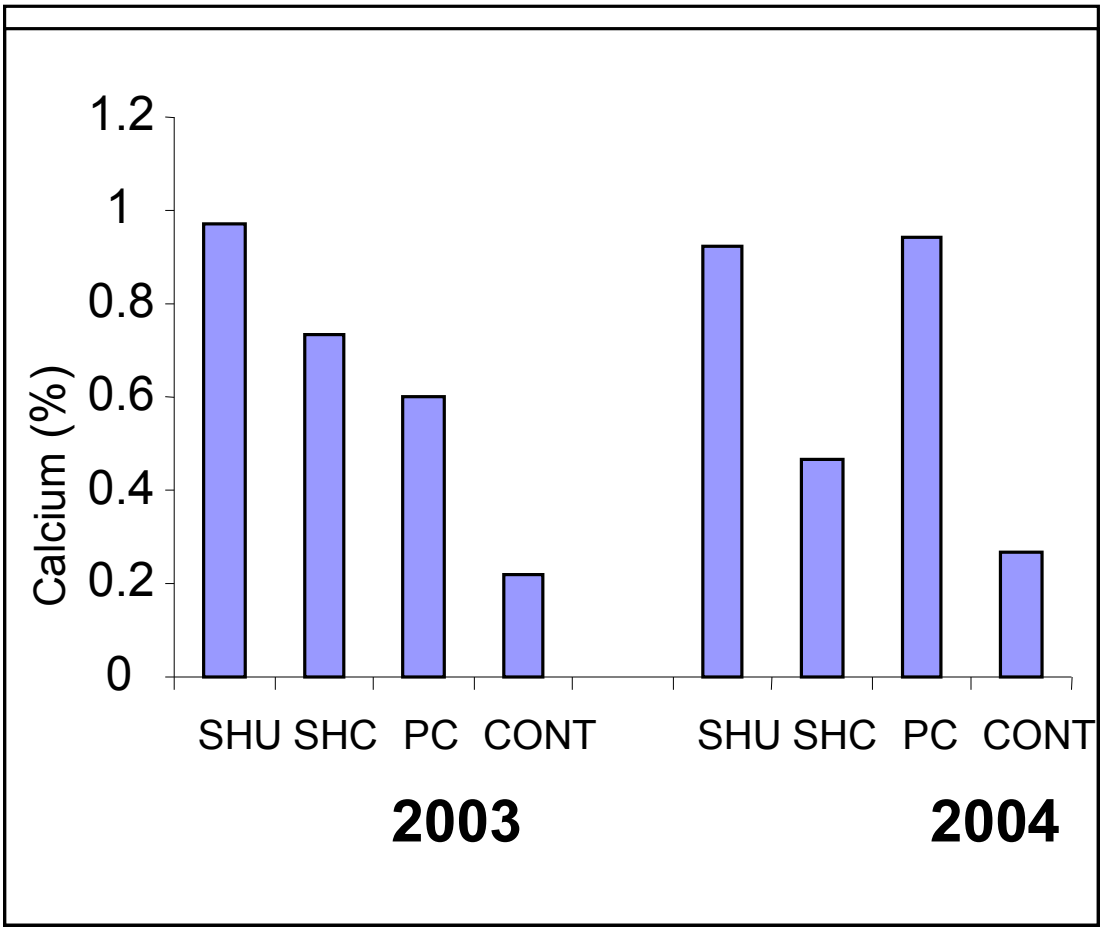


Fig.4.9: Calcium content of cowdung at termination of one month incubation

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

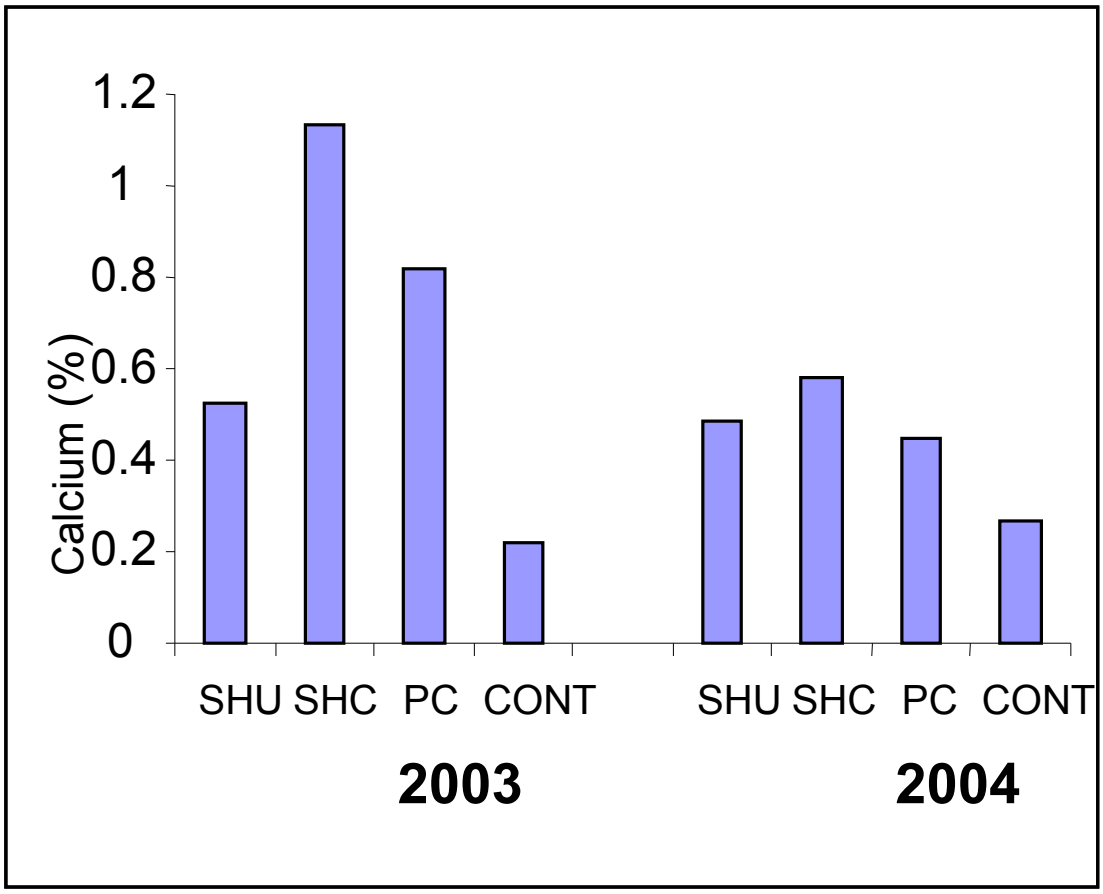


Fig. 4.10: Calcium content of cowdung after storage in the field.

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

heaped covered in May treatments that gave the highest values (0.98 %). The least values were observed on surface heaped covered in April (0.22 %).

Though the pattern for the two years was not consistent, however, when the values for the management practices for the two years were pooled together, the surface heaped uncovered treatment gave the highest mean values with the untreated control having the least value (Figure 4.11). These values when converted to percentages ranged from 35.14 to 121.64 % higher than the control treatment. At the time of field application, as it was for Ca, the surface heaped uncovered values decreased substantially (Figure.4.12). This may also be attributed to leaching as a result of leaving the manure on the surface of the ground uncovered as the rain had started before the before it was incorporated into the soil. However, pooled values of the treatments for the two years were still higher than the control and ranged from 18.92 to 118.92 %.

4.3.7 Total microbial population

The total microbial population values for year 2003 and 2004 seasons are shown in Table 4.3. The results revealed that at the termination of one month incubation in 2003, the pit covered May treatment gave the highest microbial population in the manure (55.00 cfu), while the least value was

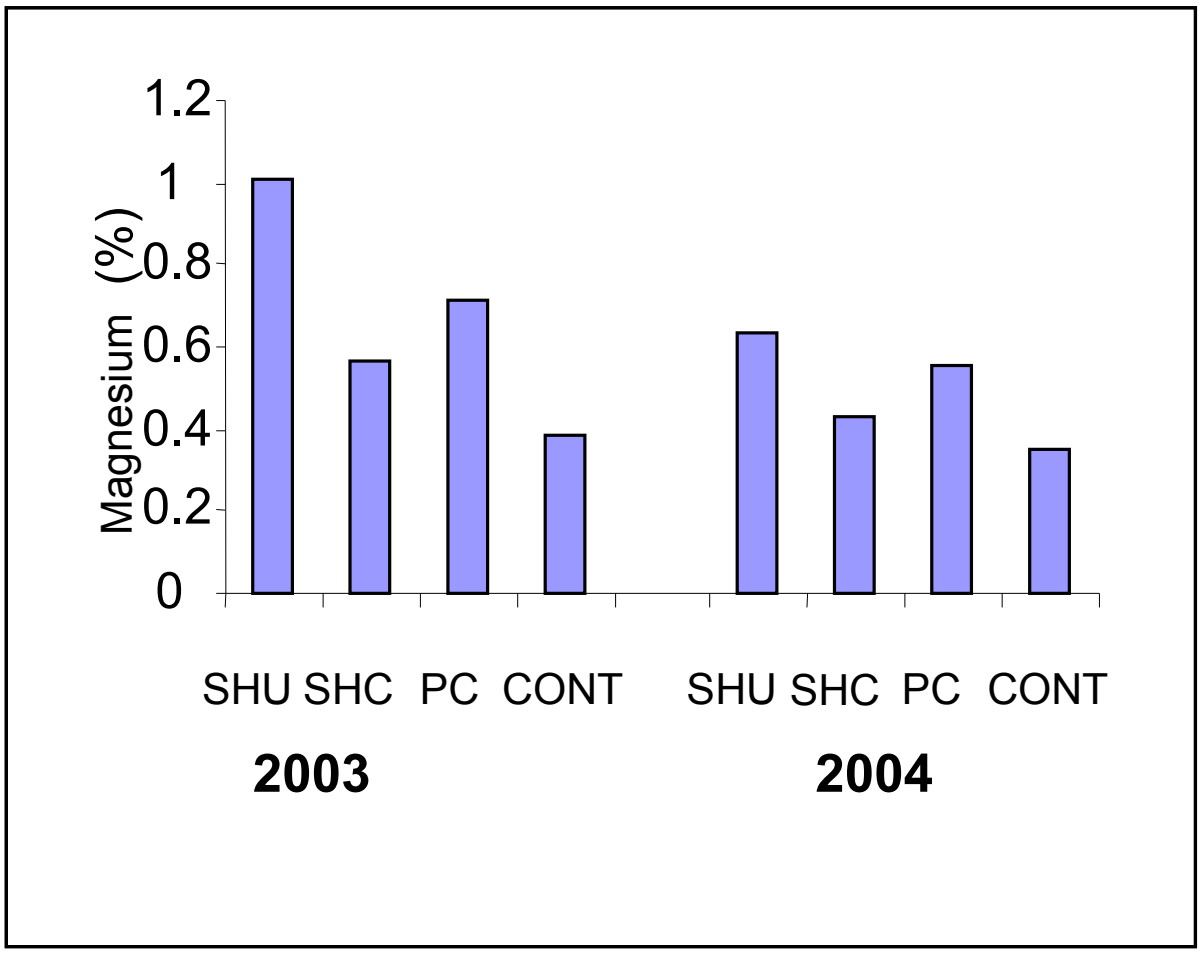


Fig.4.11: Magnesium content of cowdung at termination of one month incubation

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

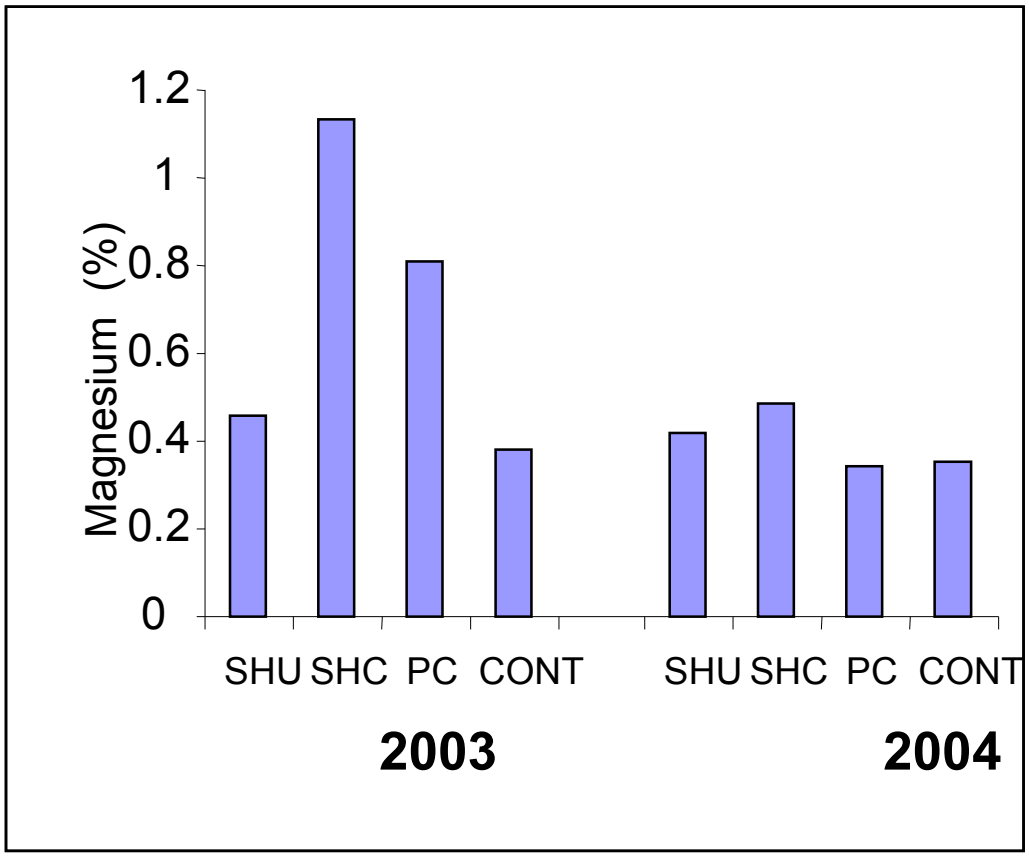


Fig. 4.12: Magnesium content of cowdung after storage in the field.

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

observed for the surface heaped uncovered March and surface heaped covered March treatments (0.60 cfu). In year 2004, at the termination of one month incubation, the highest microbial population was observed in surface heaped covered April (91.50 cfu) and the lowest was in the untreated control (0.30 cfu).

The mean values of the two years for the management practices showed that the surface heaped uncovered was higher than all other treatments particularly the 2004 treatment, while the untreated control gave the least values (Figures 4.13 and 4.14). This showed that, subjecting cowdung to the different management practices increased the microbial population, that was why the values of the treatments were all higher than that of the control, when the values of the two years are pooled together. At the termination of incubation, the management practices gave values that were higher than the control treatment, between the range of 1.98 % and 468.38 %. The oven drying of the control treatment must have responsible wide range of difference in the population of the micro organism. This agrees with the work of Mendes (1999), that incorporating large amounts of livestock waste into surface soil alter the microbial population of soil quantitatively and qualitatively. Isirimah *et al.* (2006), also stated that, the population of bacteria and fungi at the site where oil palm effluent was deposited were high, indicating that the soil was biologically active. Isirimah *et al.* (2006), reported that, crop residues and animal waste incorporated into the soil for different land uses affected the rate

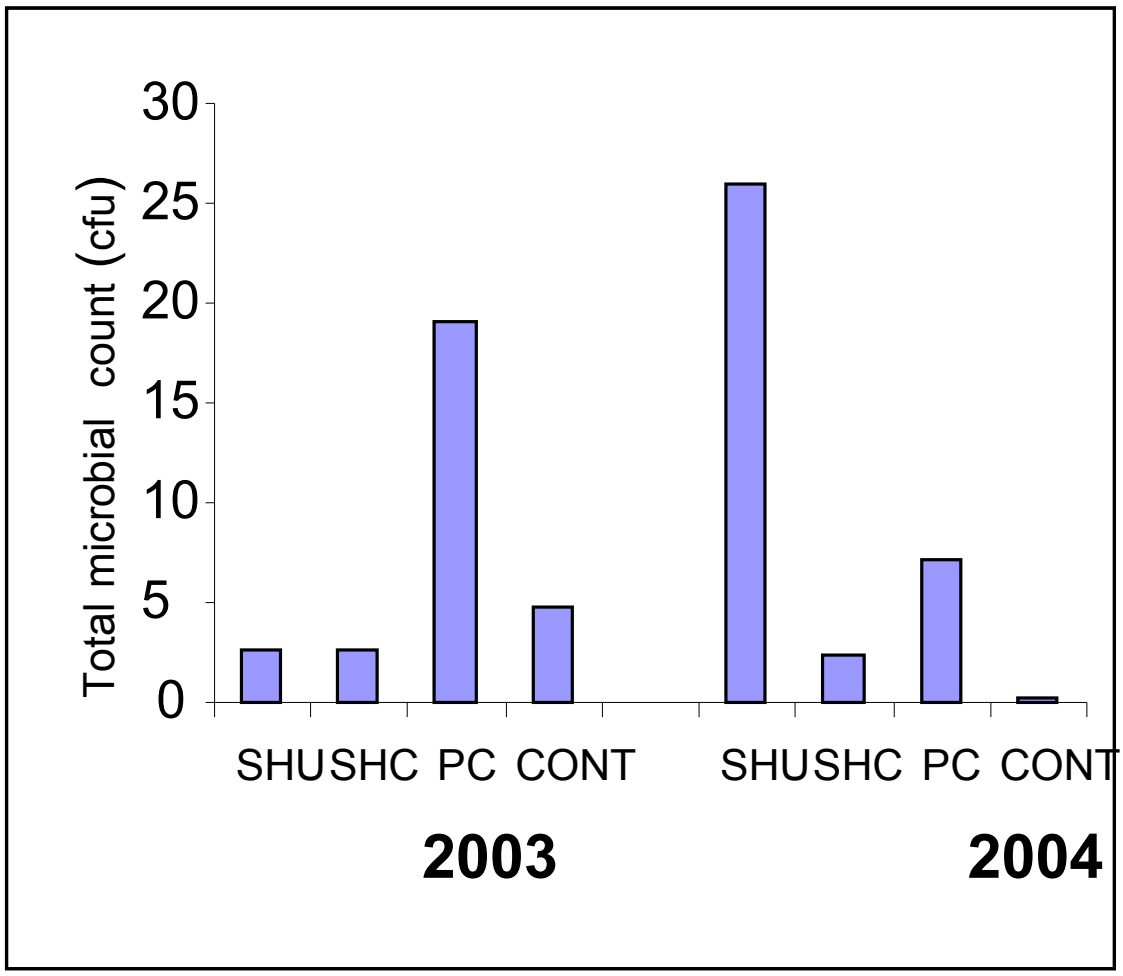


Fig. 4.13: Total microbial count of cowdung at termination of one month incubation

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

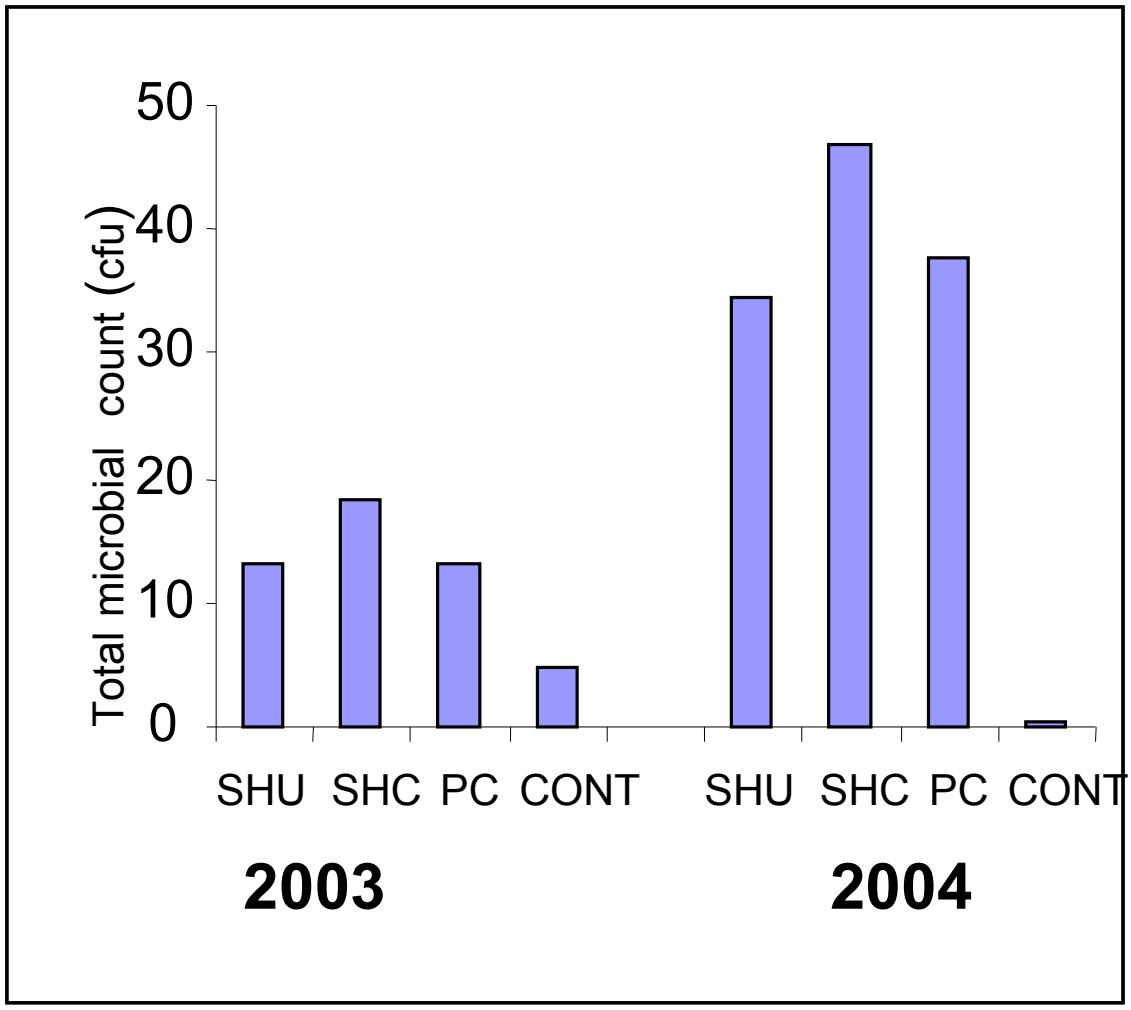


Fig.4.14: Total microbial count of cowdung after storage in the field.

Key

SHU = Surface heaped uncovered
SHC = Surface heaped covered
PC = Pit covered
CONT= Control

of organic matter decomposition as indicated by the population of microorganisms. In other words, the higher the population of micro-organisms the better the soil, because there will be more decomposition and more nutrient release processes on going in the soil.

At the time of incorporation into the soil, the treatments gave even a higher microbial population than the control. The increase in population ranged from 844.60 % to 1,182.21 % more than the control. This may still be as a result of oven drying of the control treatment which must have completely destroyed the micro organisms in the cow dung.

4.3 Effect of time of storage on the quality of cowdung

The duration of storage (exposure) of the cowdung in the field after incubation affected the quality of the cowdung. The results of cowdung quality assessment on the various nutrients as affected by time of exposure are presented in Table 4.2.

4.3.1 Nitrogen

The total N was affected by the months of cowdung storage in the field, with June (zero week) giving the highest N content in year 2003 at the termination of one month incubation and the March (12 weeks) having the lowest cowdung N content. In year 2004, the May (8 weeks) treatment gave

the highest N content of the cowdung, while the lowest was again still in the March treatment (Figure 4.15).

At the time of cowdung application in the field, in years 2003 and 2004 pooled together, the June treatments that had a shorter time of storage after incubation in the field (zero week) gave the highest N content compared to the12 weeks storage treatments from March (Figure 4.16). Storing the cowdung in the field for a longer duration encourages more loss of N through volatilization and leaching during the time of high temperatures and rainfall respectively. This work agrees with the work of many scientists. Atia (2008) reported that solar radiation increases the temperature of the manure, and as manure temperature increases, ammonia volatilization also increases, especially within the first few hours (24 hours) after manure is applied to the soil. He also reported that, 50 % of total N is volatilized as ammonia at a temperature of 30^{o} C, compared to 35 % loss when the temperature is 25^{o} C. The timing of application is an important consideration affecting the release of manure N to the atmosphere.

4.3.2 Phosphorus

Observing the P values at termination of one month incubation in year 2003, the June treatment gave the higher P value, as it was with N and was the

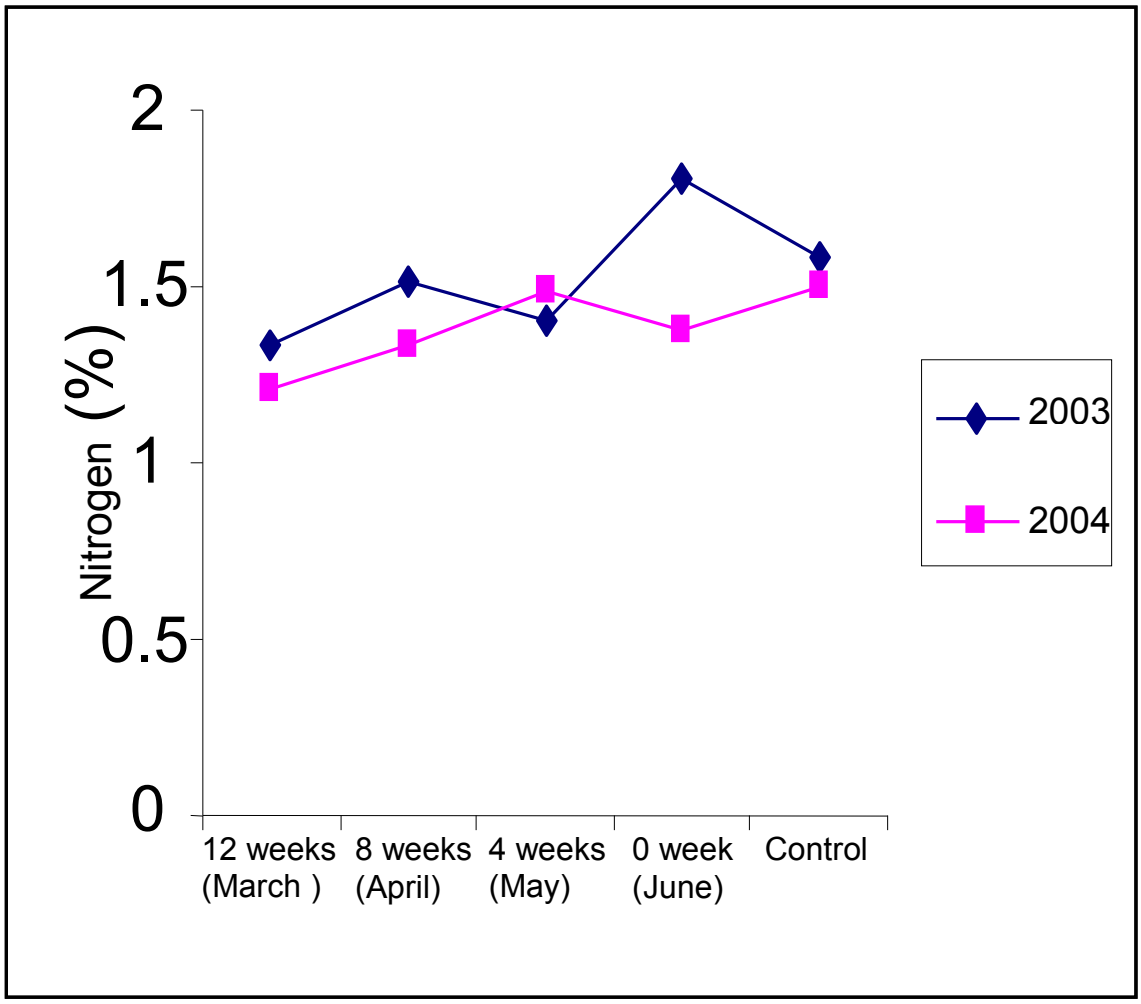


Fig.4.15: Nitrogen content of cowdung at termination of one month incubation.

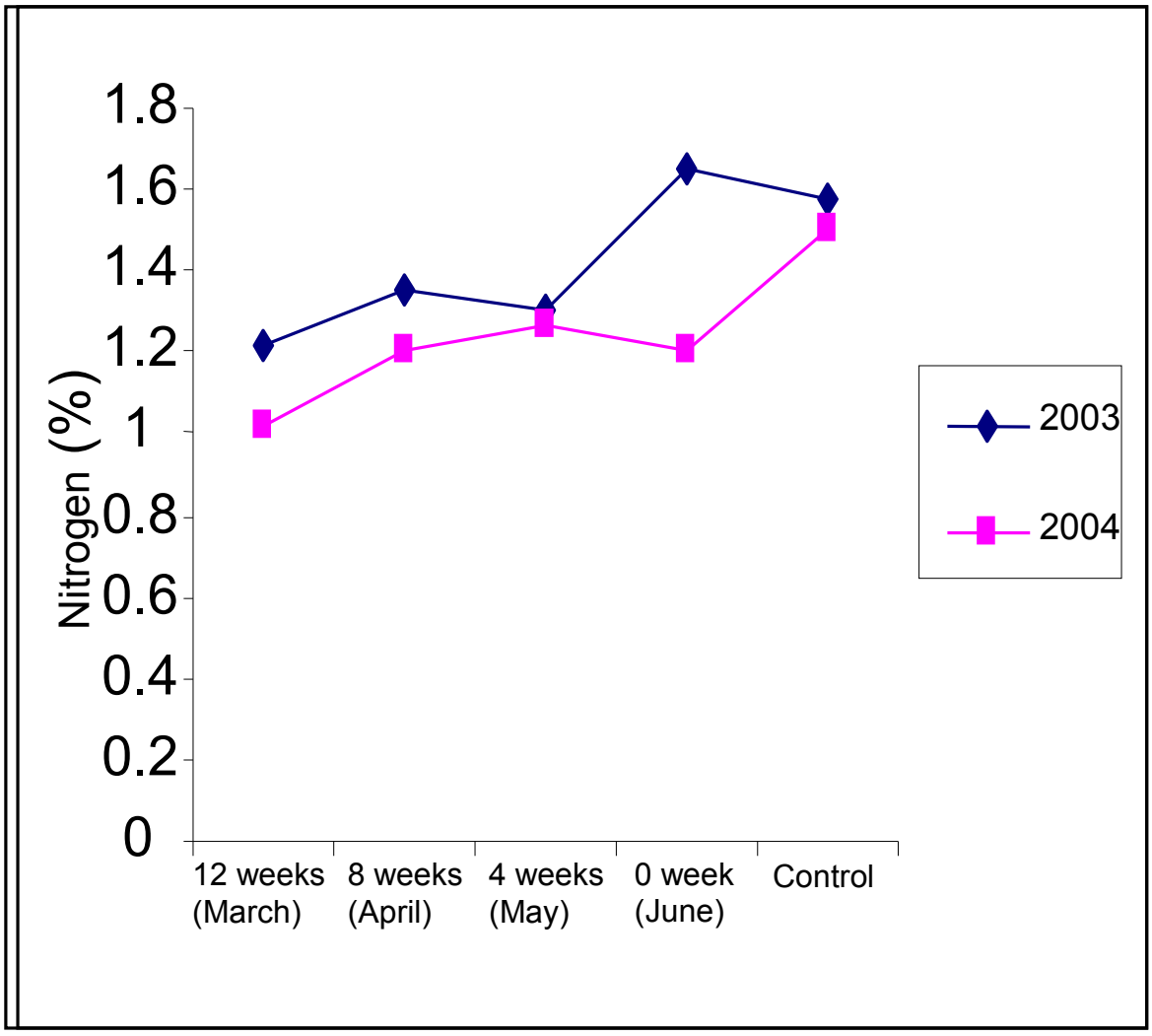


Fig. 4.16: Nitrogen content of cowdung after storage in the field.

same with that of the untreated control (Figure 4.17). The lowest P value was observed in the April (4 weeks) treatment. In year 2004, the highest P value was the control followed by the June treatment, while the lowest value was the April treatment. At the time of cowdung application for the field trial, the control treatment was superior to other treatments for the two years, while the lowest was still the April treatments in the two years (Figure 4.18). This showed that, the time of exposure of the cowdung in the field affected the P content of the manure in the two years. The control and June treatments appears to be consistently higher in the two years. Lekasi *et al.* (2001) reported that no single management practice could be shown to significantly affect nutrient contents of stored manure.

The means of time of exposure showed that, the control tended to give higher P values in the cowdung, compared to those that were expose for longer durations (8 and 12 weeks) which gave lower cowdung P values (Figures 4.17 and 4.18). Lekasi *et al.* (2001) also reported that certain management practices could affect the P content of cowdung. That, the P content was higher when manure was stored in a pit or heaped (0.31 %) than when stored as deep litter (0.28 %), higher with full roof (0.34 %) than with a partial roof (0.31 %) or no roof (0.25 %).

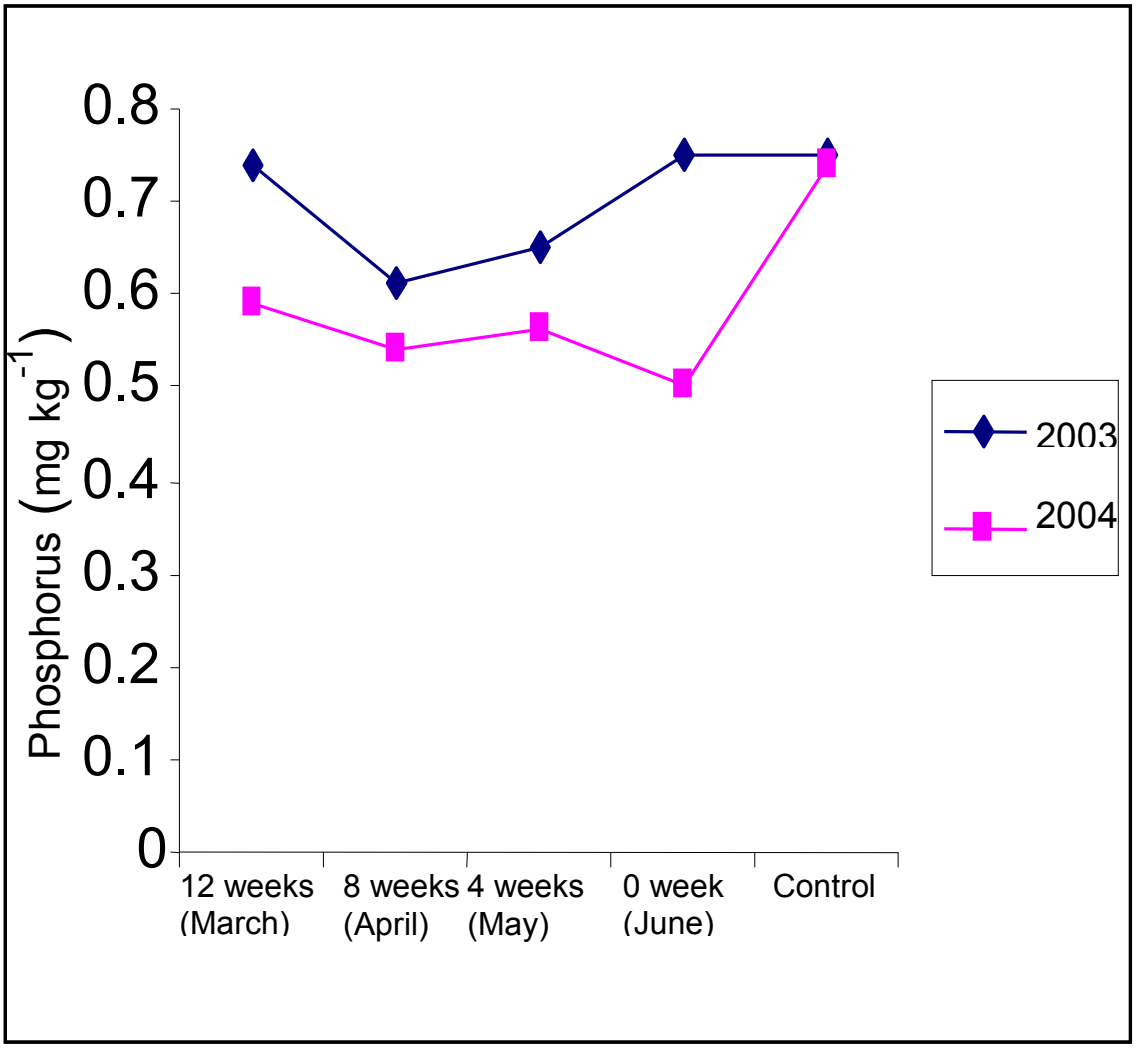


Fig. 4.17: Phosphorus content of cowdung at termination of one month incubation.

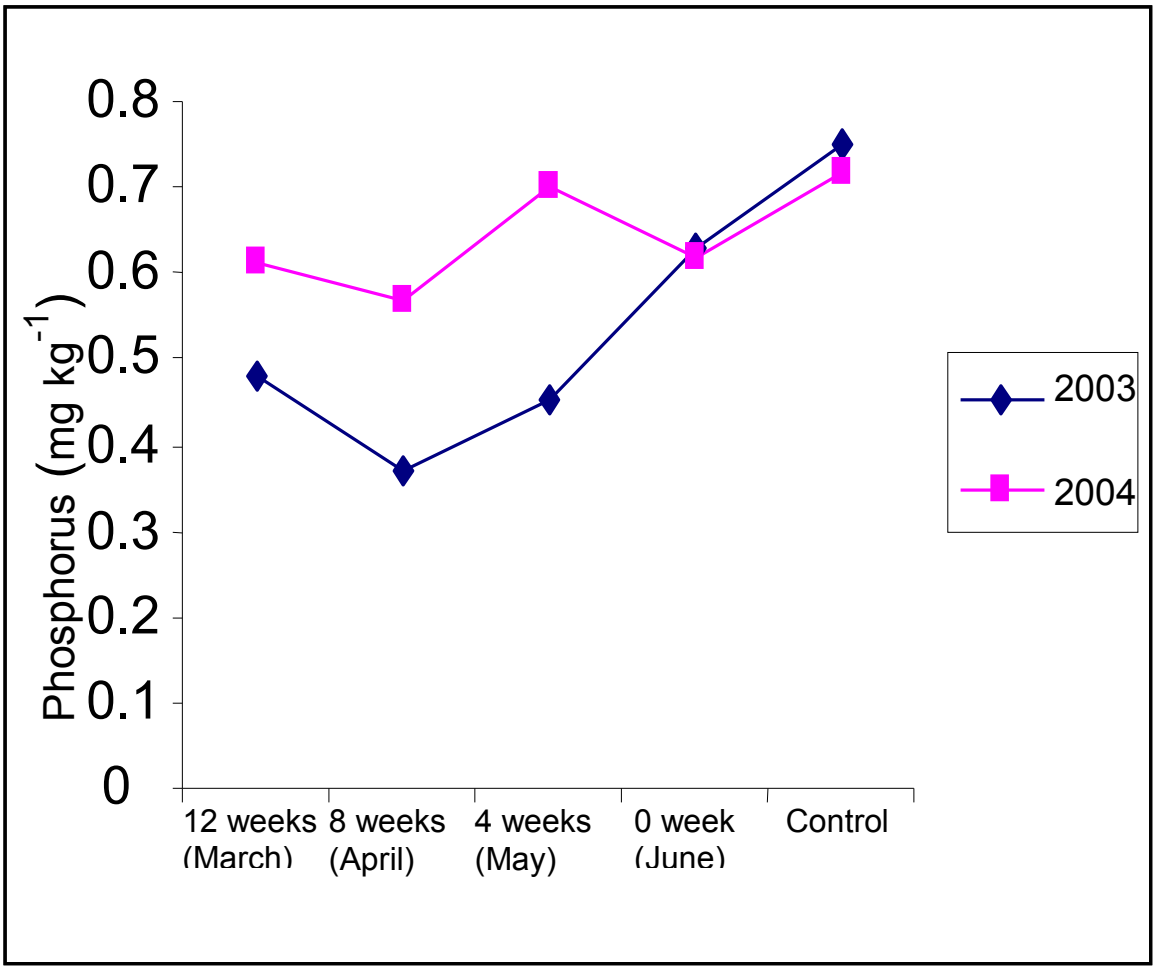


Fig. 4.18: Phosphorus content of cowdung after storage in the field.

4.3.3. Potassium

The manure K content at the termination of one month of incubation was high in the months of March (12 weeks) and lowest in the control for the two years (Figure 4.19). The lower values among the treatments were observed in May (4 weeks) in 2003 and 2004. The results revealed that incubating the cowdung greatly increases its K content. This agrees with the work of Lekasi (2005), that decomposing the manure results in concentrating the nutrient content of the manure. After exposing the cowdung in the field at different durations, at the time of field application in June, the June (zero week) treatment gave a higher value in year 2003, while in year 2004, the May (4 weeks) treatment gave the highest value (Figure 4.20). The control was higher than the April and May treatments in 2003, but it was the lowest in year 2004. The results showed that exposing the manure before field application negatively affected the K content in 2003, but in 2004 the K values appreciated in the April and May treatments. This may be attributed to the differences in the climatic conditions of the two years.

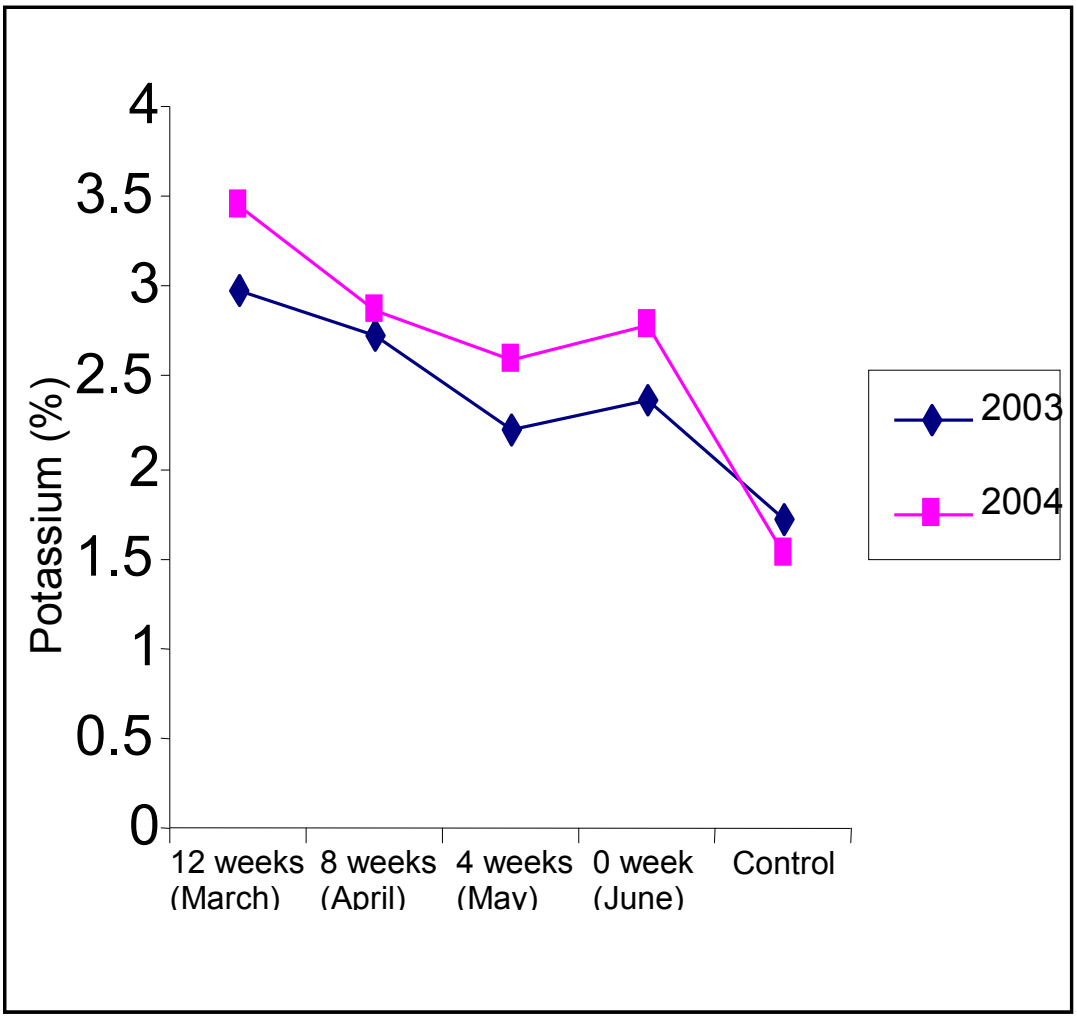


Fig. 4.19: Potassium content of cowdung at termination of one month incubation.

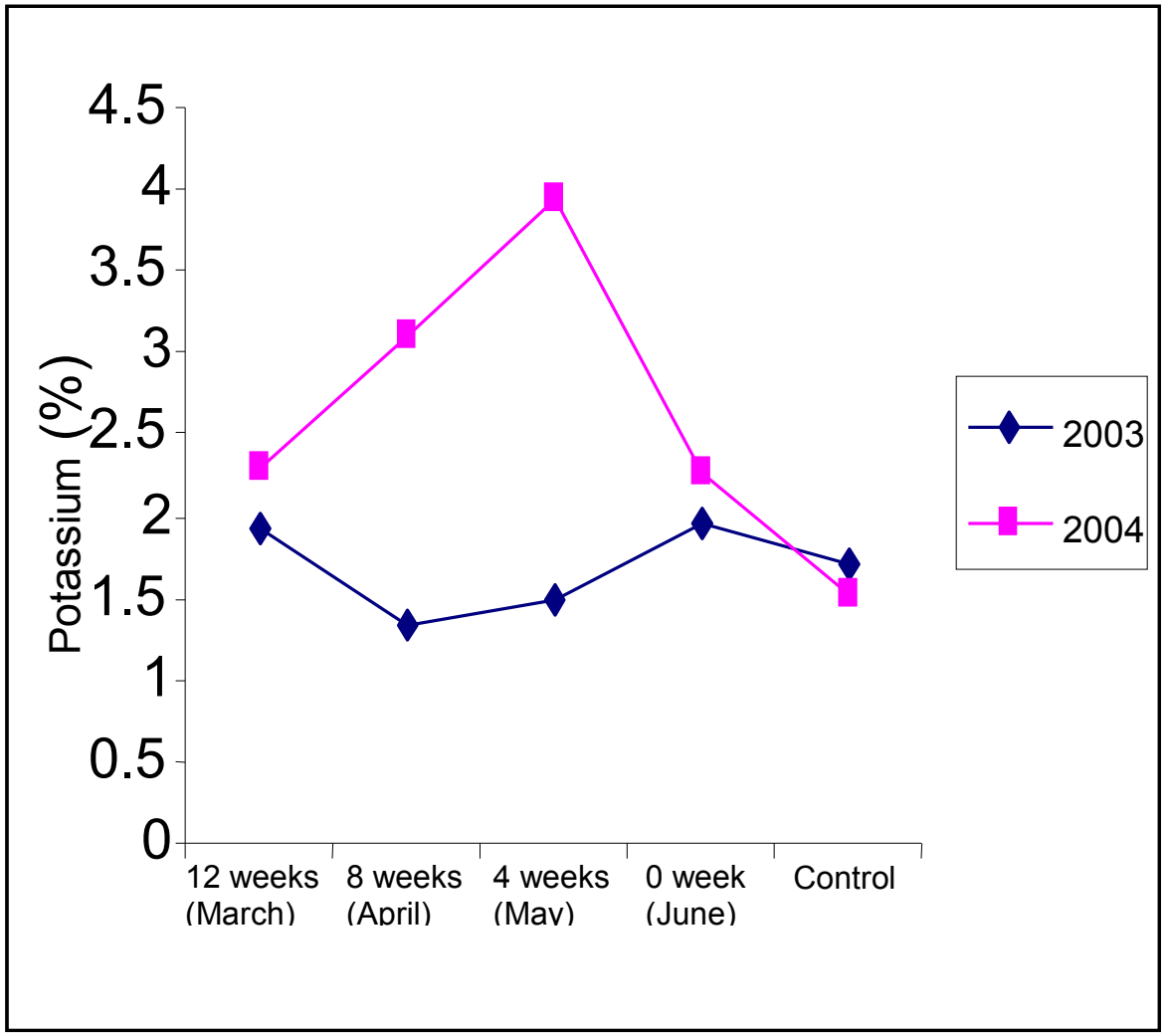


Fig. 4.20: Potassium content of cowdung after storage in the field.

4.3.4 Soil organic carbon

The values of soil organic carbon at termination of one month of incubation are presented in Figure 4.21. The incubation process affected the organic carbon content of the manure differently. In year 2003, the June and control treatments gave higher values, while the lowest value was recorded in April. But in 2004, it was the April treatment that gave the highest value, closely followed by the control treatment, while the lowest value was observed in the March treatment. This result is similar to the work of Egball *et al.* (1997) and Lekasi (2005) who reported that composting manure decreases its organic carbon content.

The organic carbon content generally decreases as the manure was exposed in the field before application to the soil for the two years (Figure 4.22). At the time of field application the control treatments maintains the highest values in the two years, while the lowest values were observed in the April treatment in year 2003, and in March in year 2004.

The results showed that subjecting manure to longer duration of exposure before field application generally decreased the organic carbon content of the manure, this is due to longer duration of mineralization that had already started during the one month incubation. The March treatment in 2003 was a slight exception. Egball *et al.* (1997) and Lekasi (2005) reported a loss of organic carbon during composting of beef cattle manure, because micro organisms oxidized carbon compounds.

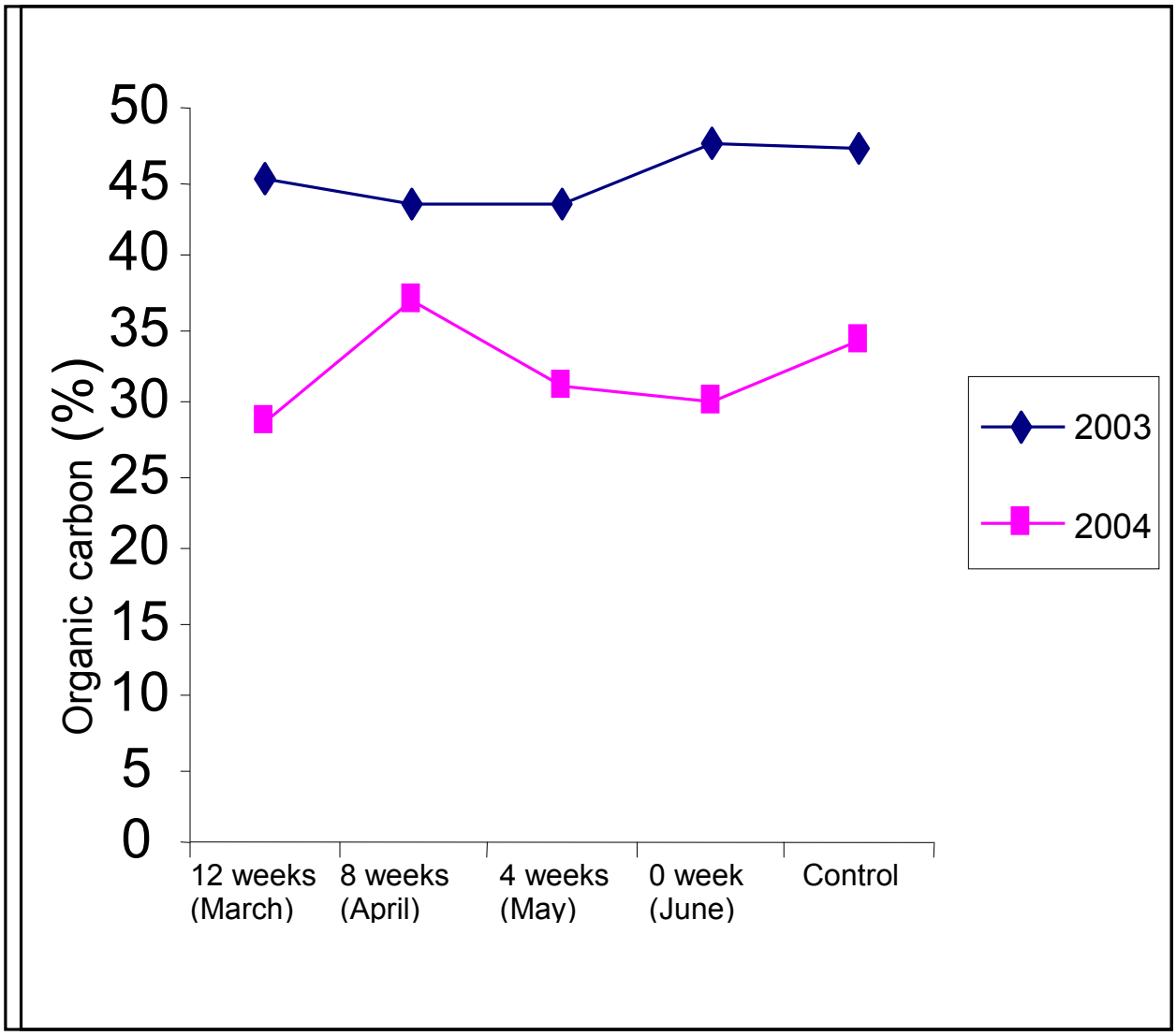


Fig.4.21: Organic Carbon content of cowdung at termination of one month incubation.

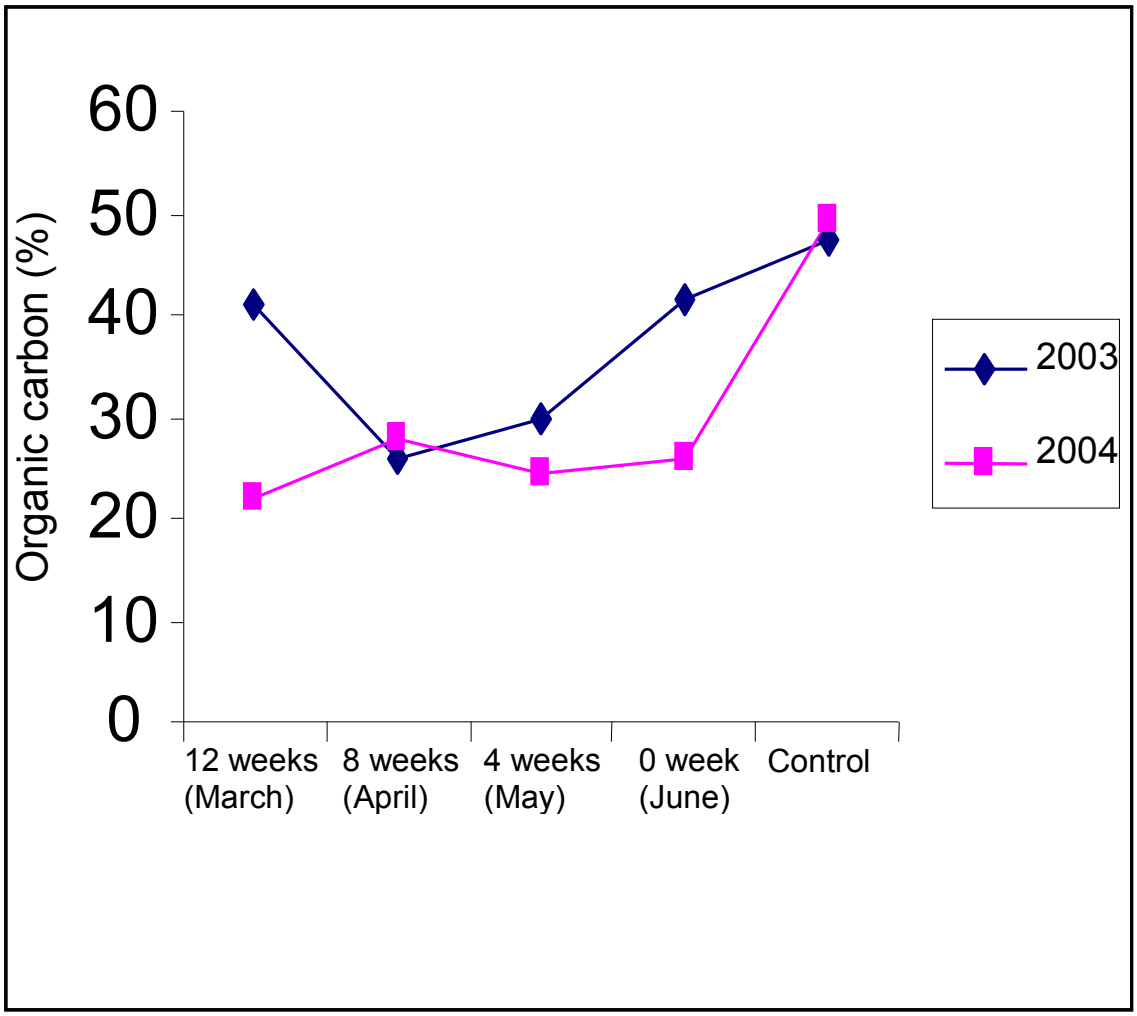


Fig. 4.22: Organic Carbon content of cowdung after storage in the field.

4.3.5 Calcium

The results of manure Ca is shown in Figures 4.23 and 4.24. At the termination of one month of incubation, the May treatment gave the highest values of Ca in the two years, while the March treatments had the lowest values. The results revealed that, incubating the cowdung generally increased the Ca content of the cowdung, since all the values of treated cowdung were higher than that of the control.

At the time of application of the incubated and stored cowdung for the field trial after exposure for different duration, the June treatment gave the highest value, while the lowest value was observed in April. In 2004 the highest value was observed in May while the lowest was observed in June. Also, in 2003 all the treatments were higher than the control, while in 2004 the control was higher than the treatments.

4.3.6 Magnesium

The manure Mg content after one month of incubation is shown in Figure 4.25. The results showed that the May treatment gave the highest values for the two years as was observed for Ca. March treatment gave the highest value in 2003, among the treatments (Figure 4.26). In 2004, among the treatments, April treatment gave the lowest value. Like in Ca, composting the cowdung tended to increase the Mg content of the cowdung.

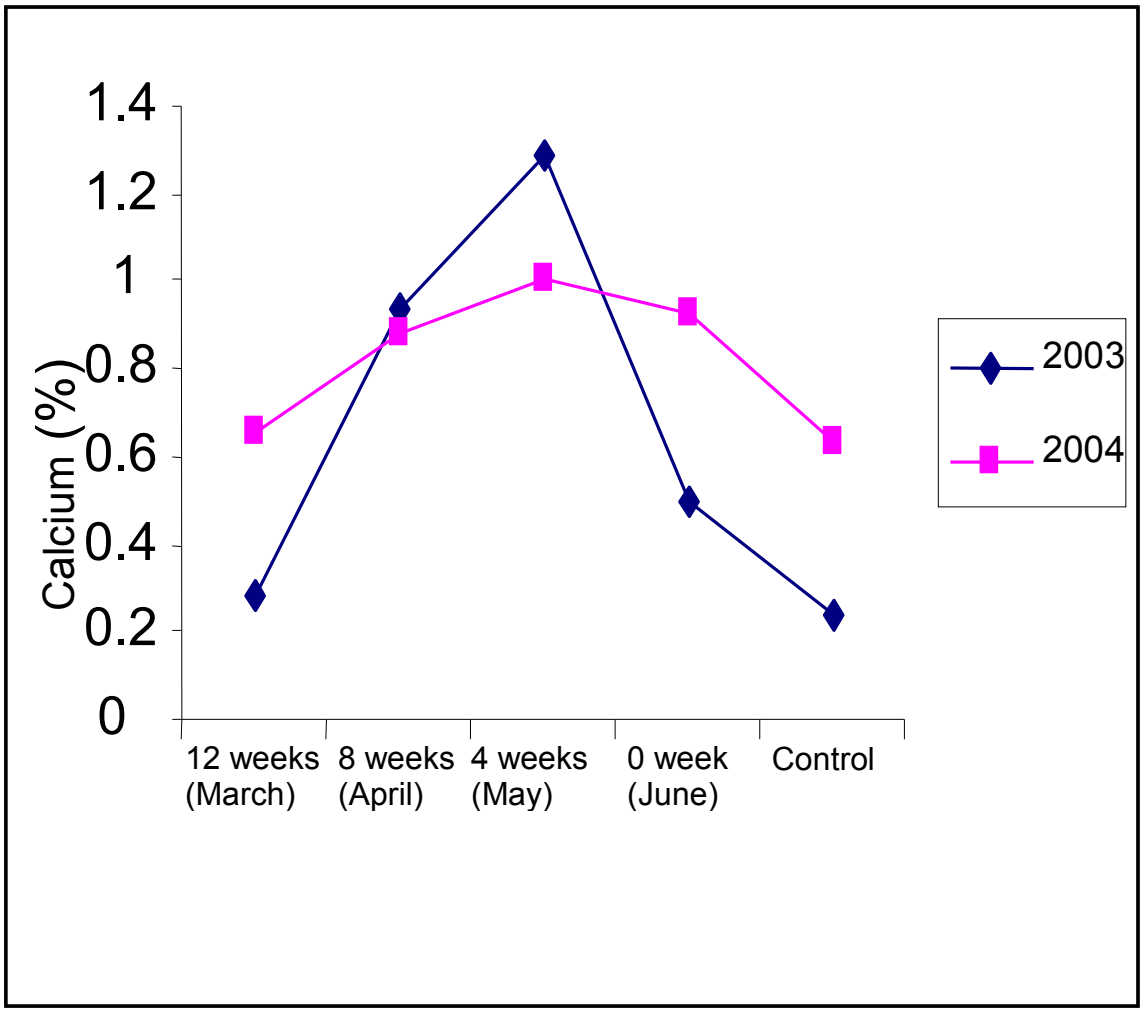


Fig.4.23: Calcium content of cowdung at termination of one month incubation.

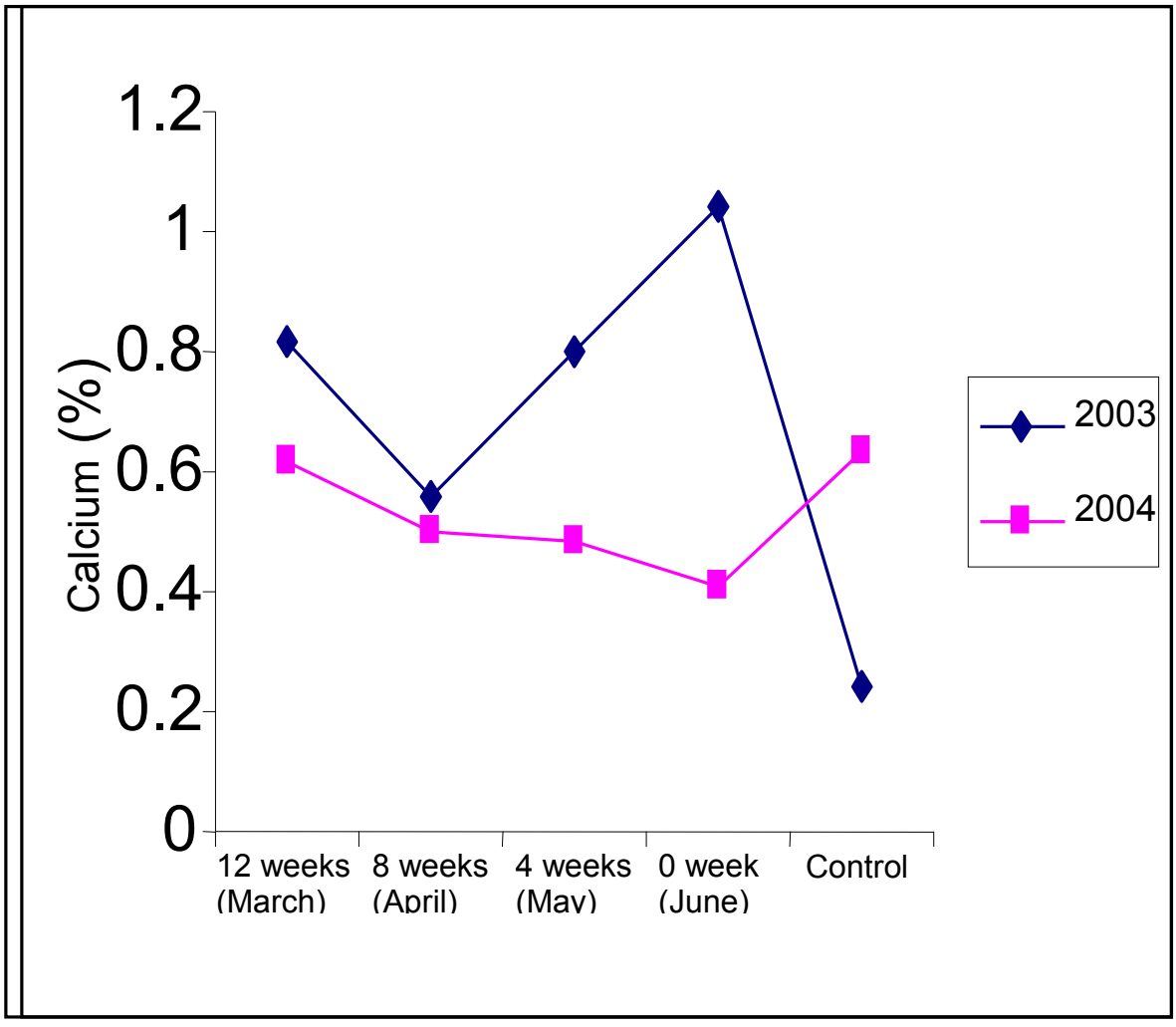


Fig.4.24: Calcium content of cowdung after storage in the field.

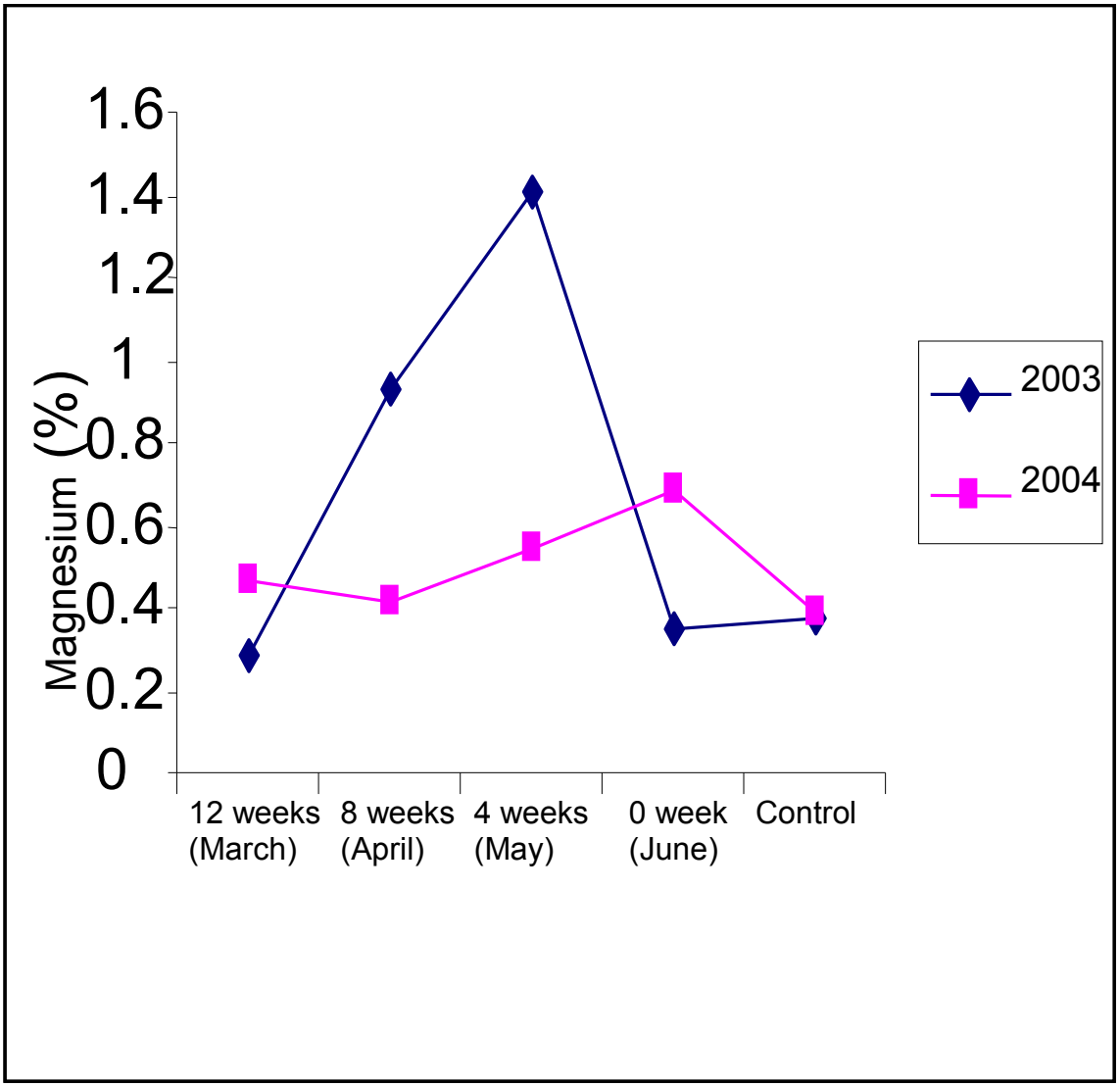


Fig. 4.25: Magnesium content of cowdung at termination of one month incubation.

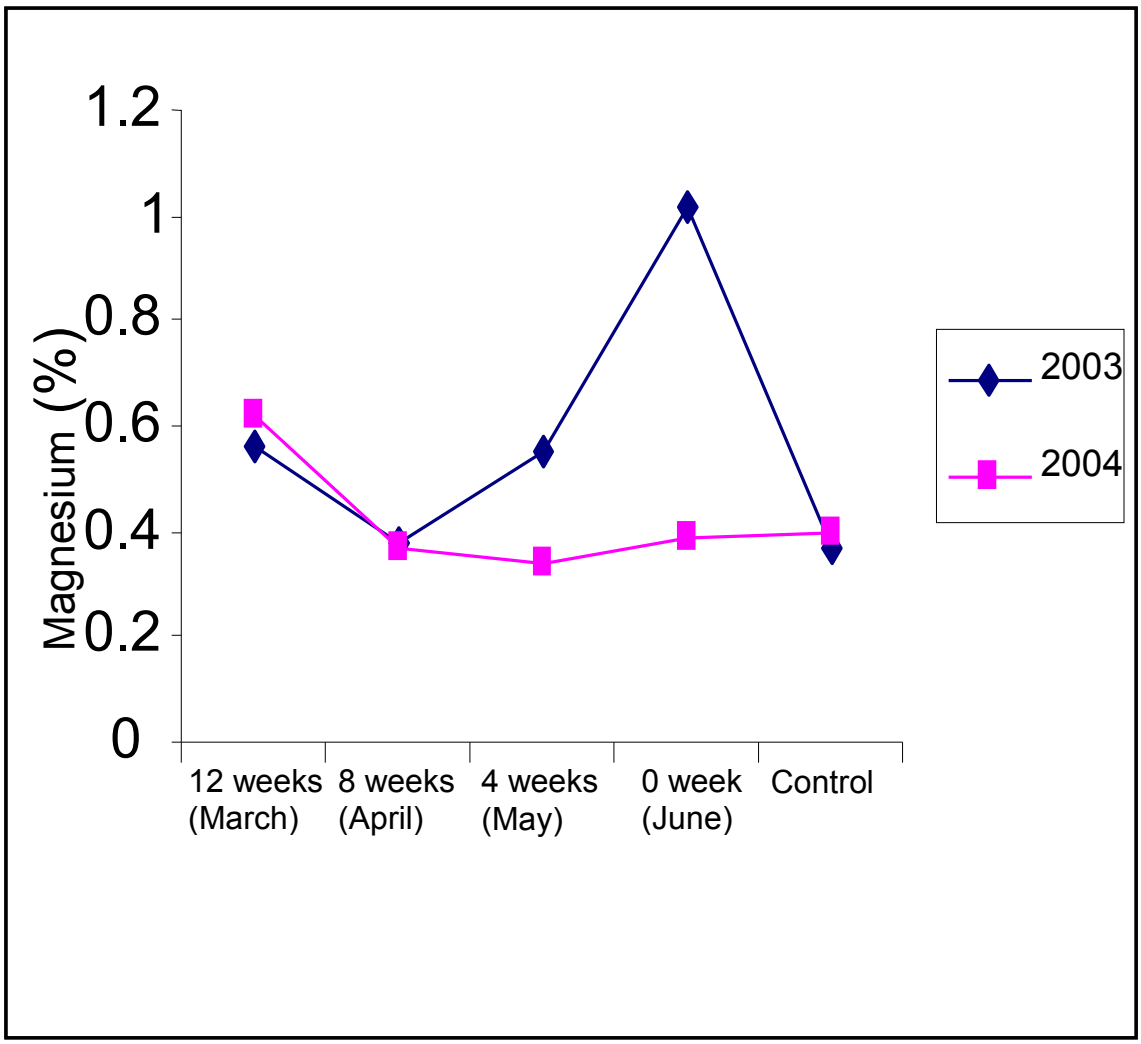


Fig. 4.26: Magnesium content of cowdung after storage in the field

At the time of field application of the cowdung after exposing it to different durations, the June treatment gave the highest Mg content in 2003, while the lowest was observed in April among the treatments. In 2004, it was the March treatment that gave the highest value, while the May treatment gave the lowest value. Some of these results may be due to changes on some of the climatic factors like temperature, rainfall and so on that may influenced their properties before, during and after collection and storage.

4.3.7 Total microbial count

The results of the total microbial count are shown in Figures 4.27 and 4.28. At the termination of one month of incubation in year 2003, the April treatment gave the highest value, while the March treatment was the lowest (Figure 27). In 2004, it was the June treatment that gave the highest value, while the April treatment was the lowest. The control treatment consistently gave lower values in the two years. These result might have been due to variations of the different factors such as duration of storage in the field, temperature, rainfall and so on that affected the nutrient quality of the cowdung. The low values of the control were expected, because it was oven dried (at 40^{o} C for 48 hours) immediately after collection, which must have slowed down the activity of the microbes.

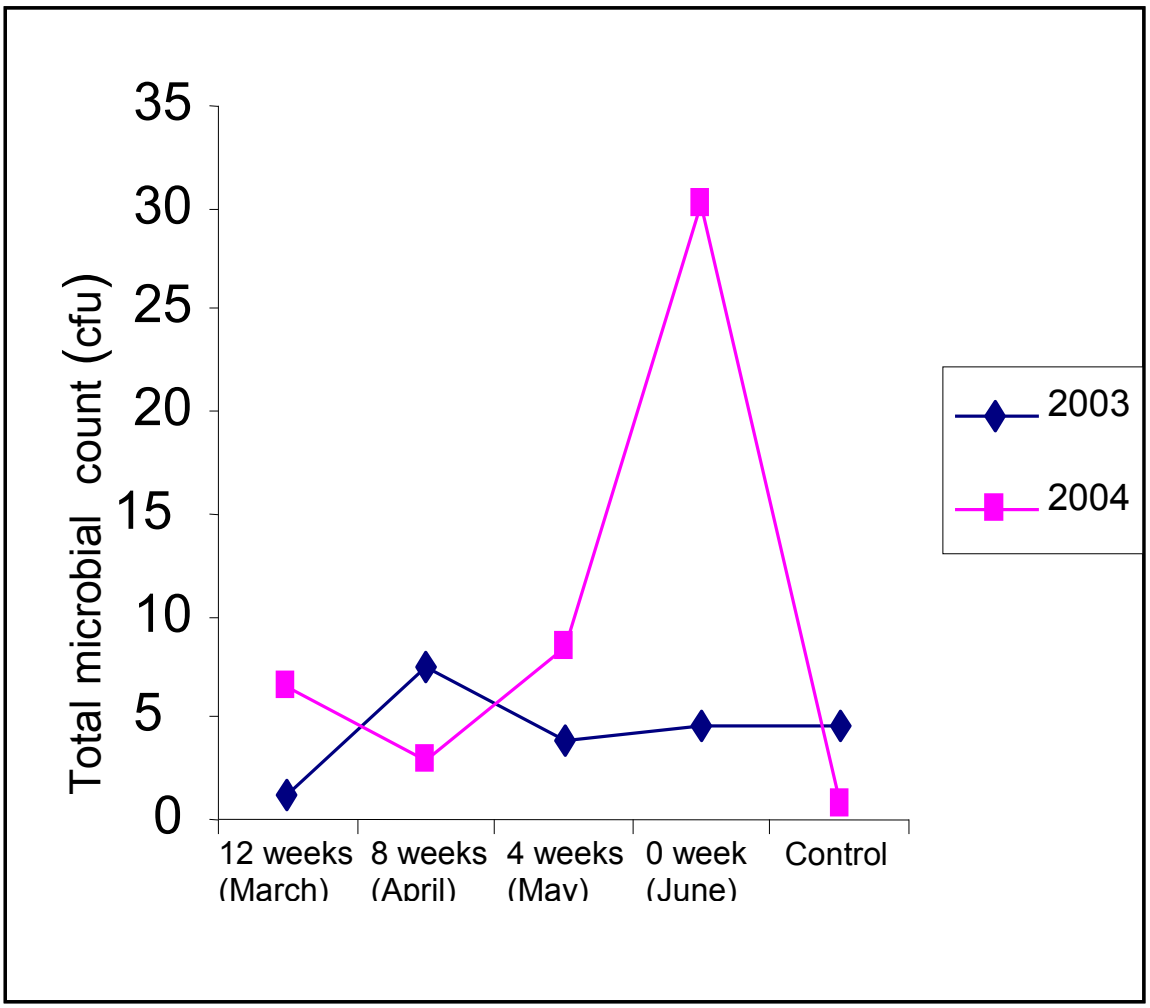


Fig. 4.27: Total microbial count of cowdung at termination of one month incubation

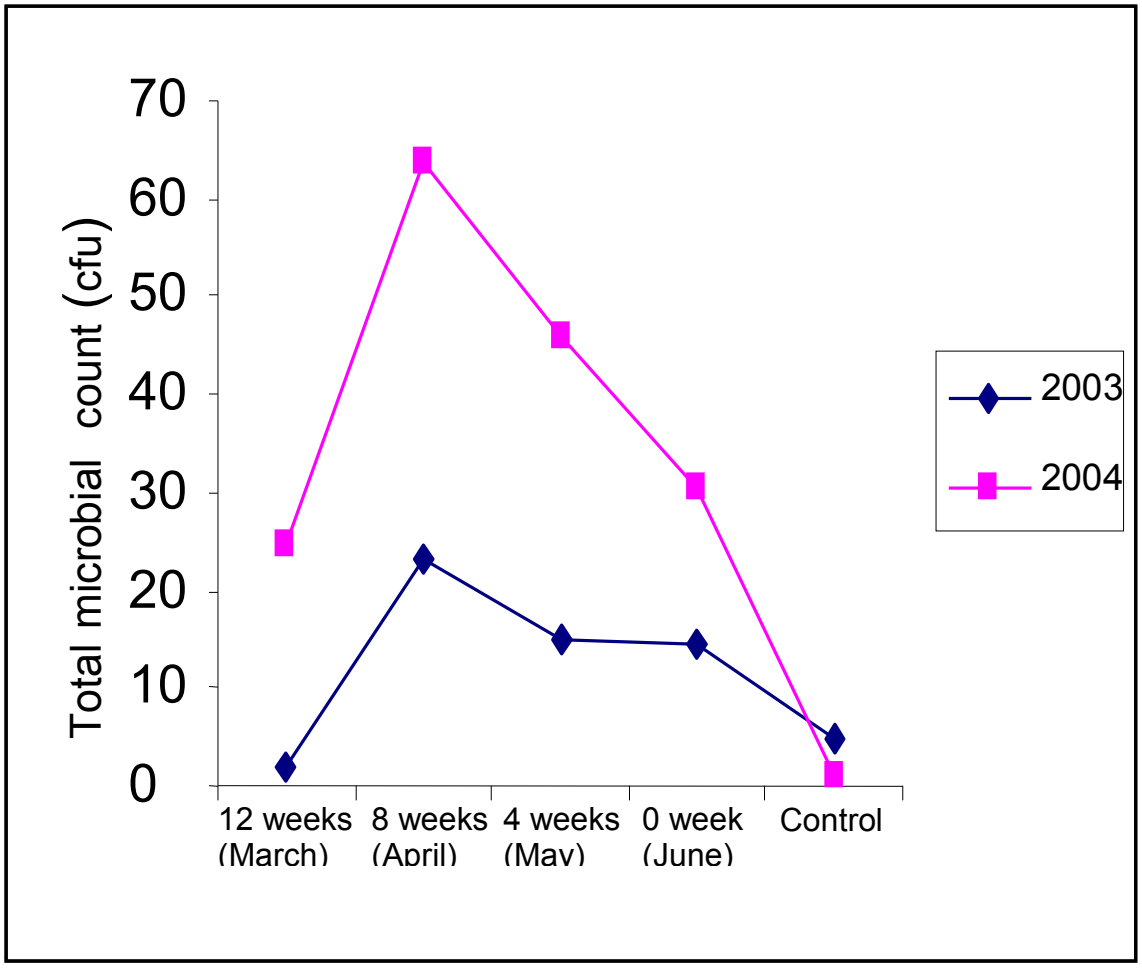


Fig. 4.28: Total microbial count of cowdung after storage in the field.

At the time of application to the field, the April (8 weeks) treatment gave the highest value in the two years and the lowest values were observed in the March (12 weeks) treatments also in the two years (Fig.4. 28). The values at the time of application in the field were generally higher than what was observed at the time of termination of incubation. This is expected, because the activity of the microorganisms is expected to continue even in the field after application.

4.4 Greenhouse study

4.4.1 Effects of treated cowdung and nitrogen levels on maize dry matter yield.

The results of maize dry matter yields are presented on Table 4.4. The results showed that, the NPK treatment gave the highest dry matter yield (22.77 g) per pot, while the control treatment, where manure and nitrogen fertilizers were not added, gave the least values (4.61 g) per pot. The results also showed that the N amended treatments gave values that were generally higher than treatments of direct evaluation, that is, where only the manure was added, without the addition of urea fertilizers.

Among the N amended treatments, the pit covered May (20.04 g) and surface heaped uncovered June (19.29 g) treatments gave the highest values and they were significantly not different from the NPK treatment that gave the highest value. The two treatments in Table 4.2 had 1.75 % total N each, which

Table 4.4 **Effects of cowdung management practices, time of application and nitrogen levels on the dry matter yield and plant height of maize in the greenhouse**

Treatments	DMY (g)		Plant height at 2 WAP (cm)		Plant height at 3 WAP (cm)		Plant height at 4 WAP (cm)		Plant height at 5 WAP (cm)		Plant height at 6 WAP (cm)	
	oN	+N	oN	+N	oN	+N	oN	+N	oN	+N	oN	+N
SHU												
SHUM	7.51hij	11.50fgh	10.00ab	9.00bc	8.80bcd	10.08a-d	14.73a-d	16.08a-d	16.33d-g	18.92b-e	18.72fg	23.08def
SHUA	8.93g-j	15.82c-e	9.00abc	9.67ab	10.47a-d	10.47a-d	15.62a-d	14.87a-d	17.50cde	20.08a-d	19.53efg	25.85bcd
SHUY	9.44ghi	12.79efg	10.00ab	9.33abc	11.10abc	10.78abc	15.23a-d	17.20abc	17.08c-f	22.38ab	19.42efg	29.17ab
SHUJ	7.60hij	19.28abc	10.00ab	9.67ab	10.92abc	10.75abc	13.87b-e	18.17a	16.55def	23.08a	19.20fg	30.42ab
SHC												
SHCM	6.03ij	12.49efg	9.00abc	10.00ab	9.58a-d	12.10a	12.38de	15.75a-d	13.38fgh	21.67ab	17.03gh	29.37ab
SHCA	8.46g-j	17.73bcd	10.00ab	10.00ab	10.92abc	11.95ab	15.07a-d	17.92a	16.80def	22.40ab	19.58efg	29.67ab
SHCY	8.47g-j	16.13b-e	9.33abc	10.00ab	10.85abc	11.58ab	14.15a-d	17.33ab	15.62e-h	22.67ab	16.67gh	28.17bc
SHCJ	7.01ij	12.27efg	9.00abc	8.67bc	9.83a-d	8.78bcd	13.78b-e	13.50b-e	15.02e-h	22.58ab	16.92gh	25.83bcd
PC												
PCM	7.02ij	13.69def	10.33a	10.00ab	9.60a-d	10.90abc	13.78b-e	16.00a-d	15.53e-h	20.75abc	17.58gh	28.01bcd
PCA	5.46ij	13.95def	9.33abc	9.33abc	9.02a-d	9.68a-d	10.03e	16.03a-d	12.48gh	20.92abc	15.92gh	26.28bcd
PCY	5.98ij	20.04ab	9.00abc	10.00ab	9.50a-d	10.83abc	13.32b-e	17.88a	15.17e-h	22.25ab	17.13gh	27.75bcd
PCJ	7.21hij	15.68c-f	9.67ab	9.00abc	11.00abc	7.92cd	14.75a-d	13.16cde	15.92efg	17.12c-f	17.33gh	24.17cde
Control	4.61j		8.00c		7.33d		12.67de		11.83h		12.83h	
NPK	22.77a		10.00ab		11.35ab		18.08a		23.70a		33.50a	
SE±	1.323		0.436		0.933		1.173		1.212		1.521	

Means followed by the same letter(s) within the same group are not significantly different at 5% level of significance using DMRT

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

were next to the highest value. Many workers have already reported an increase in dry matter yield of stover and plant height as N levels increased. Tanimu *et al*. (2007) reported higher doses of N fertilizers increased grain yield and yield related components of maize.

4.4.2 Effects of treated cowdung and nitrogen levels on maize plant height.

The response of maize plant height to manure and N fertilizer application are shown in Table 4.4. The results revealed that, at 2 and 3 WAP, the differences among the treatments were not very consistent. But from 4 WAP, the N amended treatments tended to give higher plant height values. At the 4 WAP the surface heaped uncovered June treatment gave the tallest plants (18.17 cm) which was followed by the NPK treatment (18.08 cm). It can be said that this was when the nutrients released by mineralization of the manure started influencing the growth of the plants.

At 5WAP and 6 WAP, the NPK treatments gave the tallest plants (23.70 cm and 33.50 cm respectively) when compared to other treatments, while the untreated control, where no manure and N fertilizer were applied, gave the least values (11.83 cm and 12.83 cm respectively). Among the N amended treatments, the surface heaped uncovered June treatment consistently maintained the taller plants. These results agreed with what was observed with the dry matter yield in the greenhouse experiment, where the surface heaped

uncovered June treatment gave higher dry matter yield of maize. This may still be attributed to the higher N content of this treatment at the time of field application (Table 4.2) which enhanced high growth rate of the maize as reported by some workers (Tanimu *et. al*., 2007). Good manure should synchronize mineral nitrogen release and plant demand such that the peak mineral nitrogen release coincides with peak plant biomass development and hence peak nitrogen requirements (Myers *et al.,* 1994). Lekasi (2005) also reported that it is advantageous if the organic materials added to the soil mineralize to release nutrients slowly and the rate of nutrient mineralization increases as the plant growth progresses. As the plant matures, it is expected that a good soil would have released adequate nutrients for optimum plant growth.

4.5 Effect of cowdung management practices and nitrogen levels on soil properties.

4.5.1 Soil pH.

The results of some of the soil chemical properties are presented in Table 4.5. The results showed that, the pit covered March treatment gave a significantly higher pH(water) value (6.30). Comparing the ^{o}N and ^{+}N treatment values no particular pattern of relationship was observed for pH (water) soils. However, the pH($CaCl_2$) values were decreased in most cases with N application. It has been reported by Lekasi *et al*., (2005) that metabolic

processes affects the pH of compost. Deamination of proteins rapidly increases the pH of soils due to ammonia. On the average, pH of inputs was acidic, while finished compost was near neutral. The time of manure exposure was after the one month incubation was not particularly different for the soils amended with manure subjected to the various management practices.

4.5.2 Soil total nitrogen

With respect to the total N content of soils, the surface heaped uncovered May treatments gave the highest value in the ^{o}N and ^{+}N treatment (0.54 g kg^{-1} and 0.55 g kg^{-1} respectively) at the time of harvest in the greenhouse (Table 4.5). The surface heaped uncovered June that gave the highest values for dry mater yield and plant height was very low in soil total N. This must have been as a result of high N uptake by the more vigorous, maize plant depleting the soil of N much more than the less responsive treatments. The untreated control gave the least value of total N, this is expected since no N was added to the soil as manure or mineral fertilizer. Regarding N management of applied N as influenced by manure management practices, SHU was superior to other methods for longer duration of storage and pit covered was superior for the shorter storage times. This can be seen where March, April, May and June values and effects were considered.

Table 4.5 Effects of cowdung management practices, time of application and nitrogen levels on some soil chemical properties in the green house

Treatments	pH 1: 2.5 (water)		pH 1: 2.5 ($CaCl_2$)		Total N (g kg^{-1})		Available P(mg kg^{-1})		Org. Carbon (g kg^{-1})	
	oN	+N	oN	+N	oN	+N	oN	+N	oN	+N
SHU										
SHUM	5.03f	5.10ef	4.73a-d	4.57cde	0.18i	0.35c-g	51.57ef	85.63ab	3.87ghi	4.07e-h
SHUA	5.20c-f	5.03f	4.77abc	4.63a-e	0.48abc	0.29e-i	35.52hi	56.60ef	4.13d-h	4.80ab
SHUY	5.07ef	5.97b	4.58b-e	4.43e	0.54ab	0.55a	51.84ef	26.00i	4.70abc	3.97fgh
SHUJ	5.03f	5.20c-f	4.63a-e	4.67a-e	0.18i	0.35c-g	75.46c	56.28ef	2.67hij	4.30c-g
SHC										
SHCM	5.17def	5.03f	4.73a-d	4.50de	0.33d-h	0.35c-g	16.20j	54.07ef	4.17d-g	3.90ghi
SHCA	5.10ef	5.40c	4.63a-e	4.77abc	0.38f-i	0.28f-i	29.15hi	29.22hi	4.57bcd	3.90ghi
SHCY	5.27cde	5.17def	4.57cde	4.50de	0.29e-h	0.39c-f	31.96hi	30.79hi	4.30c-g	4.43b-f
SHCJ	5.03f	5.20c-f	4.60b-e	4.57cde	0.54ab	0.21hi	53.24ef	35.11hi	4.13d-h	3.23j
PC										
PCM	6.30a	5.17def	4.57cde	4.60b-e	0.35c-g	0.46a-d	34.62hi	51.82ef	4.70abc	4.57bcd
PCA	5.10ef	5.17def	4.67a-e	4.83ab	0.24ghi	0.37c-f	59.72de	93.92a	4.80ab	4.90ab
PCY	5.10ef	5.33cd	4.70a-d	4.67a-e	0.37c-f	0.44a-d	58.60e	30.36hi	3.80ghi	4.17d-g
PCJ	5.17def	5.27cde	4.80abc	4.63a-e	0.33d-h	0.24hi	38.51gh	77.00bc	4.47b-e	4.00e-h
Control	5.13def		4.87a		0.17i		47.63gf		3.43ij	
NPK	5.03f		4.63a-e		0.42b-e		68.27cd		5.10a	
SE±	0.058		0.082		0.041		3.238		0.153	

Means followed by the same letter(s) within the same group are not significantly different at 5% level of significance using DMRT

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

4.5.3 Available phosphorus

The results of available P as affected by manure treatments and N amended treatments are presented in Table 4.5. The results showed that, the pit covered April N amended treatment gave the highest available P content (93.92 mg kg $^{-1}$), while the surface heaped covered March treatment gave the least value (16.20 mg kg $^{-1}$). Several interacting factors must have been responsible for the differences in nutrient mineralization in the soils, such that results look erratic. Lekasi, *et al.,* (2001), reported that relatively few of the management practices could as a single factor, be shown to significantly affect nutrient content of the manure. They reported that many factors were responsible for affecting the nutrient content of P in manure.

4.5.4 Organic carbon

The NPK treatment gave the highest organic carbon content in the soil (5.10 g kg^{-1}), while the surface heaped uncovered June treatment gave the lowest value (2.67 g kg^{-1}) (Table 4.5). The application of NPK must have suppressed the oxidation of carbon in that soil, hence the high carbon value was recorded at time of harvest. The low value observed on the surface heaped uncovered June treatment showed that the oxidation of carbon in that soil was very high because of the manure exposure that brought a lot of aeration on that treatment which enhanced the decomposition of organic matter. Sullivan (1999), reported that, excess N applications stimulate increased microbial

activity that speeds organic matter decomposition. It could also be observed that most of the N amended treatments gave carbon values that were greater than the non N amended manure treatments.

4.5.5 Exchangeable Calcium

The results of exchangeable calcium in the soil is presented in Table 4.6. The results showed that, the pit covered April manure, treatment gave a significantly higher exchangeable Ca value (2.77 cmol kg^{-1}) than all other treatments while the pit covered June manure treatment, gave the least value (0.93 cmol kg^{-1}). This showed that, the pit covered treatments must have encouraged the mineralization and released of Ca to the soil, but because of leaching in the month of June, during the rains, much of the Ca must have been leached . Lekasi *et al.,* (2001) had reported that the major sources of loss of nutrients from the soil, are either as a result of leaching, volatilization or erosion by water or air. That, volatilization and leaching are mostly as a result of long time exposure of the cow dung to the agents of weather. The nutrient contents at the time of terminating the greenhouse experiment, have reflected the trend of events during the growing period. Again, some values were low because of the high uptake by the roots of crops which left the soil with virtually low amounts of the nutrients. Agboola *et al.* (1975) had reported an increase in the soil content of exchangeable Ca with manure application.

Table 4.6 Effects of manure management practices, time of application and nitrogen levels on soil exchangeable bases in the greenhouse

Treatments	Exchangeable Ca($cmol^+ kg^{-1}$)		Exchangeable Mg($cmol^+ kg^{-1}$)		Exchangeable K($cmol^+ kg^{-1}$)		Exchangeable Na($cmol^+ kg^{-1}$)	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	1.23def	1.22def	0.75f-i	0.79f-i	0.31c-f	0.08ef	0.14b	0.17b
SHUA	1.37de	1.38de	0.77f-i	0.70ghi	0.22c-f	0.11ef	0.21b	0.15b
SHUY	1.52cd	1.13ef	1.03f-g	0.70ghi	0.15def	0.12ef	0.19b	0.18b
SHUJ	1.30de	1.37de	1.23b-e	1.00c-g	0.48bc	0.09ef	0.17b	0.51a
SHC								
SHCM	1.82b	2.03b	1.17c-f	1.33abc	0.09ef	0.12ef	0.13b	0.16b
SHCA	1.85b	1.38de	1.15c-f	1.00c-g	0.33c-f	0.33c-f	0.15b	0.21b
SHCY	1.37de	1.37de	0.70ghi	0.93c-h	0.19def	0.13ef	0.20b	0.22b
SHCJ	1.07f	1.33de	0.70ghi	0.97c-h	0.37cde	0.16def	0.30b	0.21b
PC								
PCM	1.78bc	1.98b	1.25bcd	0.85d-i	0.16def	0.11ef	0.08b	0.16b
PCA	2.77a	1.17ef	1.67a	0.50i	0.44bcd	0.19def	0.26b	0.20b
PCY	1.30de	1.80bc	0.87d-i	1.13c-f	0.17def	0.05f	0.18b	0.23b
PCJ	0.93f	1.23def	0.57hi	0.83e-i	0.99a	0.67b	0.14b	0.21b
Control	1.23def		1.00c-g		1.08a		0.13b	
NPK	1.90b		1.57ab		0.15def		0.17b	
SE±	0.100		0.115		0.082		0.058	

Means followed by the same letter(s) within the same group are not significantly different at 5% level of significance using DMRT

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

4.5.6 Exchangeable magnesium

The exchangeable magnesium value was significantly higher than most treatments at pit covered April treatment (1.67cmol kg^{-1}) similar to that of exchangeable Ca (Table 4.6). The results revealed that, the pit covered April treatment was higher than all other treatments, while the N amended pit covered April and the pit covered June treatments were among the treatments that gave the lowest values. This may still be associated with leaching as stated earlier and high nutrient uptake by roots of plants from the soil. Lekasi (2005), had reported that organic materials that mineralize too readily subject mineralized nutrients to losses through processes such as leaching and volatilization.

4.5.7 Exchangeable potassium

The result of exchangeable K in the soil as affected by manure management practices, N levels and the months of storage before application are presented in Table 4.6. The results showed that, the control treatment gave the highest value (1.08 cmol kg^{-1}), which was not significantly different from the pit covered June N amended treatment, but both were significantly higher than all other treatments. The least value was observed on the pit covered May N amended treatment (0.05 cmol kg^{-1}). This may still be associated with differential uptake of nutrients by roots of crops cultivated or the nutrient

release pattern of the manure to the soil. Swift *et al*., (1971), Mugwira and Mukurumbira (1986), Murwira and Kirchmann (1993) reported that the overall amount of nutrients released from organic amendments for crop uptake depends on the quality, rate of application, nutrient release pattern and environmental conditions.

4.6 Effects of cowdung and nitrogen levels treated to various management practices on nutrient content of maize tissue.

4.6.1 Nitrogen

The nutrient content of maize tissue from the greenhouse study are presented in Table 4.7. The results revealed that the N content was highest on pit covered April treatment amended with N (27.00 g kg^{-1}), while the least value was on untreated control (7.25 g kg^{-1}). This showed that the pit covered management practice must have made N available for absorption by the maize crop than the other treatments. Gichangi *et al.* (2007) reported that the amount of N lost from manures that were covered was lower than that of uncovered manures. Kirchmann and Lundvall (1998) in their study reported low N losses under anaerobic conditions.

Table 4.7 Effects of manure management practices, time of application and nitrogen levels on nutrient content of maize stover in the greenhouse

Treatments	N (g kg^{-1})		P (g kg^{-1})		K (g kg^{-1})		Ca (g kg^{-1})		Mg (g kg^{-1})	
	oN	+N	oN	+N	oN	+N	oN	+N	oN	+N
SHU										
SHUM	10.05ijk	13.70e-i	7.80a	5.81c-g	26.10bc	31.06a	1.71fg	3.13abc	3.03b-g	3.73abc
SHUA	16.10c-f	13.15f-j	2.86lm	4.18g-l	12.58j	17.73e-h	2.16c-g	2.90a-e	2.39efg	3.39a-e
SHUY	15.30d-h	17.80b-e	3.35j-m	7.38bc	15.65f-j	16.98e-i	2.16c-g	3.09abc	2.56d-g	3.32a-f
SHUJ	12.75f-j	12.80f-j	5.322d-i	6.37b-e	16.33f-j	26.65b	2.42b-g	3.22ab	2.29fg	4.08ab
SHC										
SHCM	16.65c-f	12.25g-i	4.09h-l	4.92e-j	17.57e-f	17.82e-h	1.66fg	2.79a-e	2.91c-g	3.59a-d
SHCA	13.95e-i	13.80e-i	4.86e-j	6.22c-f	18.88d-g	19.30def	2.53b-f	2.96a-e	2.07g	2.56d-g
SHCY	9.05jk	17.15b-f	4.11h-l	6.58bcd	17.73e-h	18.73d-g	1.98efg	2.79a-e	2.53d-g	3.81abc
SHCJ	13.50e-i	18.72bcd	4.19g-l	6.18c-f	16.13f-j	22.43cd	1.98efg	2.16c-g	2.87c-g	3.21b-f
PC										
PCM	10.90h-k	14.30e-i	2.42m	4.60f-k	16.30f-j	16.25f-j	1.48g	2.07efg	2.33efg	2.95c-g
PCA	10.90h-k	27.00a	3.13klm	4.90e-j	14.93h-j	20.88de	2.08d-g	3.57a	2.58d-g	4.33a
PCY	13.85e-i	13.90e-i	4.15g-l	5.89c-f	16.30f-j	18.86d-g	2.09d-g	2.63a-f	2.91c-g	3.20b-f
PCJ	21.05b	18.80bcd	3.65i-m	5.54d-h	14.39hij	20.78de	2.64a-f	3.06a-d	2.88c-g	3.20b-f
Control	7.25k		2.38m		12.93ij		2.45b-g		2.00g	
NPK	19.70bc		9.30b		22.53cd		3.54a		4.07ab	
SE±	1.310		0.497		1.260		0.289		0.311	

Means followed by the same letter(s) within the same group are not significantly different at 5% level of significance using DMRT

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

4.6.2 Phosphorus

The P content of maize dry matter was high with the surface heaped uncovered March cowdung treatment (7.80 g kg^{-1}) (Table 4.7). The lowest value was observed on the untreated control treatment (2.38 g kg^{-1}) as was the case with nitrogen. Normally the lower the nutrient content in the soil the lower the uptake by plants. Because the soil content of available phosphorus was high on the surface heaped uncovered treatment, that must have made the availability of phosphorus high to crops in the soil for uptake. Likewise the lower availability of phosphorus in the soil decreased its uptake to crops in the soil. Agboola *et al.,* (1975) and Charreau, (1975) reported that, the application of manure to the soil promoted root growth and the uptake of phosphorus.

4.6.3 Potassium

The tissues potassium content of maize dry matter was high on surface heaped uncovered March treatment of the N amended soils (31.06 g kg^{-1}) (Table 4.7). The treatment that gave the lowest value was surface heaped uncovered April treatment (12.58 g kg^{-1}). This result did not follow any particular pattern, probably because of the many factors that are involved in influencing nutrient release in the soil. It has been reported that, the overall amount of nutrients release from organic amendments for crop uptake depends on the quality, the rate of application, the nutrient release pattern and the

environmental conditions (Swift *et al.,* 1971, Mugwira and Mukurumbira, 1986; Murwira and Kirchmann, 1993).

4.6.4 Calcium

The results of the Ca content of maize dry matter are presented in Table 4.7. It revealed that, the pit covered April N amended treatment gave the highest maize tissue Ca value (3.57g kg^{-1}) than all other treatments, while the pit covered March direct evaluation treatment gave the lowest value (1.48 g kg^{-1}). This result was similar to what was observed on the N content of maize dry matter, where the pit covered April treatment gave the highest value. This showed that this treatment must have encouraged high nutrient release, which encouraged high nutrient uptake by roots of crops into the crops tissue. Lekasi (2005) reported that closer synchronization of nutrients demand, ensures efficient utilization of organic inputs applied to the soil.

4.6.5 Magnesium

The pattern of maize dry matter nutrient content of Mg is similar to the observation for N (Table 4.7). The results showed that, the pit covered April N amended treatment gave the highest Mg tissues value (4.33 g kg^{-1}), while the lowest was observed on the control treatment where no manure was applied in the soil (2.00 g kg^{-1}). This further confirms that the pit covered April N

amended treatment encouraged high nutrient release for uptake by roots of crops, hence high tissues content of the nutrients on the maize plant. The pit covered April N amended treatments, tended to give higher values of maize tissue nutrient content in the greenhouse.

FIELD STUDY

4.7 Effects of manure treated to various management practices and nitrogen levels on maize yields.

4.7.1 Grain yields

The effects of cowdung management practices, month of storage before application and N levels on maize grain yield for 2003 and 2004 seasons are shown in Table 4.8. Results of treatments were consistent for the two years at direct effects and their residual effects. Where treatments were amended with nitrogen, the surface heaped covered April treatment consistently gave higher maize grain yields for the two years for both the direct and residual effects. But treatments that were not amended with N, the surface heaped uncovered May gave higher grain yields, except for the 2004 residual effect, where surface heaped uncovered April treatment gave a higher value. Also, all the N amended treatments consistently gave higher values than the no N amended soils. The values for the control (where no manure or N was applied) consistently gave lower values compared to the N amended

Table 4.8 Effects of manure management practices, time of application and nitrogen levels on maize grain yield (kg ha^{-1}) in IAR and SCA farms.

Treatments	IAR farm				SCA farm			
	Direct effect(2003)		Residual effect(2004)		Direct effect(2004)		Residual effect(2005)	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	1120.8c-f	1925.0a-e	675.0fg	1462.5ab	241.7i	1308.3c-g	550.0ef	1225.0ab
SHUA	904.2ef	2341.7ab	691.7efg	1433.3abc	500.0hi	2158.3ab	633.3c-f	1066.7a-d
SHUY	1645.8a-e	2195.8abc	962.5b-g	1241.7a-f	800.0e-i	1633.3a-d	416.7f	1058.3a-d
SHUJ	1341.7b-f	1966.7a-e	691.7efg	1550.0a	225.0i	1083.3d-h	583.3ef	1208.3ab
SHC								
SHCM	959.2def	1629.2a-e	633.3g	1470.8ab	243.3i	1316.7c-g	566.7ef	1508.3a
SHCA	1270.8b-f	2545.8a	820.8d-g	1712.5a	691.7f-i	2308.3a	616.7def	1500.0a
SHCY	1312.5b-f	1987.5a-e	875.0c-g	1262.5a-e	441.7hi	1466.7b-e	558.3ef	1166.7ab
SHCJ	1395.8a-e	1875.0a-e	816.7d-g	1550.0a	525.0hi	1050.0d-h	525.0f	1091.7abc
PC								
PCM	1079.2c-f	2090.8a-e	770.8efg	1366.7a-d	508.3hi	1950.0abc	558.3ef	1158.3ab
PCA	1412.5a-e	2112.5a-e	679.2fg	1420.8abc	766.7e-i	1766.7a-d	508.3f	1058.3a-d
PCY	1387.5a-e	2120.8a-d	669.2fg	1358.3a-d	608.3ghi	1416.7c-f	533.3f	1083.3a-d
PCJ	1345.8b-f	1904.2a-e	708.3efg	1445.8abc	208.3i	1108.3d-h	458.3f	1016.7b-e
Control	211.7f		405.0g		275.li		650.0c-f	
SE±	348.65		174.78		230.96		142.69	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

treatments. This result was at variance and contrary to the greenhouse observation on dry matter yield, plant height (Table 4.4) and manure nutrient quality (Table 4.2). Many scientists have advanced reasons why such discrepancies do exist. Myers *et al.,* (1994) reported that good manure should synchronise mineral nitrogen release and plant demand such that the peak mineral nitrogen release coincides with peak plant biomass development and hence peak nitrogen requirements. Also, Lekasi (2005) reported that it is advantageous if the organic materials added to the soil mineralize nutrients slowly and the rate of nutrient mineralization increased as the plant growth progressed. He further explained that, as the plant matures, it is expected that a good soil would have released adequate nutrients for optimum plant growth,

that, closer synchronization of nutrients demand ensures efficient utilization of organic inputs applied to the soil. Organic materials that mineralize too readily, subject mineralized nutrients to losses through processes such as leaching and volatilization on the other hand, organic materials that releases nutrients later in the season will not benefit the plant or crop as it would have matured with inadequate availability of nutrients during the critical growing stages. The overall amounts of nutrients released from organic amendments for crop uptake depends on the quality, the rate of application, the nutrient release pattern and the environmental conditions (Swift *et al.,* 1971, Mugwira and Mukurumbira, 1986, Murwira and Kirchmann, 1993).

All the N amended treatments gave significantly ($P < 0.05$) higher grain yields than the control treatment, while most of the direct evaluation treatments were statistically at par with the control treatment. This agreed with the work of Uyovbisere and Elemo, (2002) who stated that organic matter cannot be used alone, but with some level of inorganic fertilizer. It has been recognized that the combined application of organic matter and inorganic fertilizer is required to increase crop production and arrest soil nutrient depletion in West Africa (FAO, 1999; Giller 2002; Iwuafor *et al*., 2002).

4.7.2 Maize stover yield

Results of the effects of treatments on maize stover yield for direct and residual evaluation for the two seasons are shown in Table 4.9. The direct effect N amended surface heaped covered April gave higher stover yield for the two seasons. But on the residual effect with N amendment, pit covered May treatment gave higher stover yields for the two years. Observing the direct evaluation (non-N amended) treatments, the surface heaped uncovered May treatments gave higher stover yields for the two years, except the residual effect in 2004, that the pit covered May treatment gave a higher value. Some of the discrepancies observed on the treatments could be explained from some of the reasons already stated, that, the rate of mineralization of organic matter depends on many factors, including temperature and rainfall, the quality of the

Table 4.9 Effects of manure management practices, time of application and nitrogen levels on maize Stover yield (kg ha^{-1}) in IAR and SCA farms.

Treatments	IAR farm				SCA farm			
	Direct effect(2003)		Residual effect(2004)		Direct effect(2004)		Residual effect(2005)	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	1354.2gh	2895.8a-e	1058.3ed	2487.5a	583.3i	2666.7b-e	500.0i	1875.0a
SHUA	1558.3fgh	3575.0ab	1154.2cde	2320.8abc	866.7hi	3858.3ab	641.7ghi	1425.0a-d
SHUY	2600.0b-g	3233.3abc	1904.2a-d	1745.8a-e	1825.0d-i	3258.3abc	833.3f-i	1166.7c-f
SHUJ	2091.7c-g	2858.2a-f	1187.5cde	2179.2a-d	558.3i	2258.3c-g	666.7ghi	1125.0c-g
SHC								
SHCM	1512.5gh	2666.7b-g	1175.0cde	2054.2a-d	566.7i	2541.7b-f	1083.3d-h	1525.0a-d
SHCA	2004.2c-g	4008.3a	1483.3a-e	2433.3ab	1466.7e-i	4433.3a	875.0e-i	1750.0ab
SHCY	1887.5d-h	3083.3a-d	1408.3a-e	1900.0a-d	1066.7ghi	2958.3bcd	675.0ghi	1416.7a-d
SHCJ	2112.5c-g	2895.8a-e	1520.8a-e	2533.3a	1266.7f-i	2125.0c-h	833.3f-i	1458.3a-d
PC								
PCM	1704.2e-f	3458.3ab	1137.5cde	2062.5a-d	1033.3ghi	37.8-3ab	608.3hi	1583.3abc
PCA	2079.2c-g	3245.8abc	1237.5b-e	2445.8ab	1700.0d-i	3241.7abc	625.0hi	1333.3b-e
PCY	2070.8c-g	2970.8a-e	1500.0a-e	2558.3a	1058.3ghi	2816.7bcd	1416.7a-d	1833.3a
PCJ	2087.5c-g	2862.5a-f	1341.7a-e	2487.5a	800.0hi	2158.3c-h	750.0f-i	1458.3a-d
Control	650.0h		645.8e		875.0hi		625.0hi	
SE±	392.23		361.15		404.41		148.05	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

soil organic nitrogen, the quality of the organic inputs to the system (Palm *et al.,* 1993). Again, since mineralization is microbially driven, it is influenced by many factors, including temperature, soil moisture, soil properties and manure characteristics (Cassman and Munns, 1980; Eghball, 2000).

The N amended treatments were consistently higher than the non-N amended treatments in all the seasons and at both direct and residual effects. It's been reported that for the poorly buffered soils of the savanna, integrated soil fertility management systems, which combine the use of organic matter and inorganic fertilizer are needed (Sanchez and Salinas, 1981; Kang and Spain, 1986), organic matter from tree foliage cannot be used alone, but with some level of inorganic fertilizer (Uyovbisere and Elemo, 2002).

4.7.3 Cobs yield

The treatments affected the number of cobs plot $^{-1}$, but the effects were not consistent in all cases (Table 4.10). The surface heaped covered April, N amended treatments gave higher values in year 2004 for both the direct and residual effects. But in year 2003, there was no consistency on the direct effect. The surface heaped uncovered June treatment gave the highest value, while on the residual effect, it was the surface heaped uncovered March treatment that gave the highest value. Observing the direct evaluation treatments there was no consistency on how the number of cobs were affected. The reasons for this behaviour may be attributable to the different pattern of

Table 4.10 Effects of manure management practices, time of application and N levels on cobs yield plot $^{-1}$ in IAR and SCA farms.

Treatments	IAR farm				SCA farm			
	Direct effect(2003)		Residual effect(2004)		Direct effect(2003)		Residual effect(2005)	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	45.00cde	55.00a-e	42.67cd	61.67a	18.33de	45.00abc	28.33a-d	32.67a-d
SHUA	42.67e	55.33a-e	42.67d	57.00a-d	34.00b-e	52.67ab	29.00a-d	36.33a-d
SHUY	57.33abc	51.67a-e	44.00cd	47.67a-d	40.00a-d	46.00abc	22.00d	37.33a-d
SHUJ	54.00a-e	61.33a	48.67a-d	55.00a-d	18.00de	42.00abc	24.00cd	30.33a-d
SHC								
SHCM	54.67a-e	50.67a-e	42.00d	46.67a-d	18.33de	44.00abc	32.00a-d	40.33ab
SHCA	51.33a-e	56.33a-d	46.67a-d	60.33ab	35.00b-e	57.67a	24.67bcd	43.00a
SHCY	52.00a-e	52.67a-e	47.33a-d	48.00a-d	29.00cde	44.67abc	29.33a-d	33.33a-d
SHCJ	50.67a-e	59.67ab	53.00a-d	58.33abc	28.33cde	38.67a-e	27.33a-d	31.67a-d
PC								
PCM	47.33b-e	56.33a-d	46.67a-d	54.33a-d	26.00cde	52.33ab	30.67a-d	40.00abc
PCA	43.67de	54.33a-e	43.67cd	57.00a-d	35.67a-e	55.67ab	30.00a-d	33.67a-d
PCY	54.00a-e	55.00a-e	45.00bcd	54.67a-d	33.67b-e	47.33abc	33.33a-d	36.33a-d
PCJ	55.00a-e	58.67ab	46.33a-d	58.00abc	16.33e	45.67abc	29.67a-d	35.33a-d
Control	19.00f		23.67e		18.33de		32.67a-d	
SE±	3.849		4.554		6.577		4.629	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June
oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

nutrient release of the various treatments. Lekasi (2005) said it is advantageous if the organic materials added to the soil mineralize nutrients slowly and the rate of nutrient mineralization increases as the plant growth progresses. He further, explained that as the plant matures, it is expected that a good soil will have released adequate nutrients for optimum plant growth. Closer synchronization of nutrients demand ensures efficient utilization of organic inputs applied to the soil. Organic materials that mineralizes too readily subject mineralized nutrients to loses through processes such as leaching and volatilization. It means that, by the time the cobs are to be produced, there will be no enough nutrients to sustain them. On the other hand, organic materials that release nutrients later in the season will not benefit the plant or crop as it will have matured with inadequate availability of nutrients during the critical growing stages, therefore there will be less number of cobs per plot.

4.8 Effects of cowdung and nitrogen levels treated to various management practices on yield components of maize.

4.8.1 Plant height.

The maize plant height for the two locations and for both the direct and residual effects are presented in Table 4.11. The results showed that, plant height was affected by the various treatments, but there was no consistency in the two locations and the direct and residual effects as observed on some of the yield parameters already discussed. The same reasons already advanced could

Table 4.11 Effects of manure management practices, time of application and nitrogen levels on plant height of maize (cm) in IAR and SCA farms.

Treatments	IAR farm				SCA farm			
	Direct effect(2003)		Residual effect(2004)		Direct effect(2004)		Residual effect(2005)	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	223.33def	229.33cde	183.67gh	183.67gh	99.33i	197.33d-f	118.33gh	175.67ab
SHUA	185.00ij	191.00hij	193.00d-g	198.67de	179.00fg	242.67ab	122.00gh	187.67a
SHUY	231.00b-e	248.33a	178.33hi	216.00b	193.67c-g	267.00a	152.00cd	130.33efg
SHUJ	198.33ghi	216.00ef	165.33j	202.33cd	87.00i	193.67c-g	108.00hi	178.33a
SHC								
SHCM	237.33a-d	206.67fgh	191.33efg	194.00def	169.33fg	195.33c-g	139.00def	144.67de
SHCA	180.00j	235.00a-d	171.67ij	229.67a	185.00d-g	217.00bc	143.33de	184.67a
SHCY	215.00efg	217.67ef	155.67k	184.33fgh	131.33h	261.67a	144.00de	177.33ab
SHCJ	198.33ghi	188.67ij	184.00gh	231.67a	164.33g	208.33cde	115.67ghi	161.67bc
PC								
PCM	214.67efg	242.67abc	177.00hi	197.33de	164.33g	211.00de	100.00i	189.00a
PCA	237.67a-d	222.00def	121.33l	185.00fgh	192.00c-g	218.33bc	126.67fg	180.00a
PCY	192.00hij	247.67ab	169.00ij	183.00gh	177.33efg	209.33cd	152.33cd	187.33a
PCJ	215.00efg	229.00cde	177.00hi	209.33bc	93.67i	192.67c-g	154.67cd	192.67a
Control	151.67k		83.33m		94.67i		123.33fgh	
SE±	5.319		3.088		9.417		5.306	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June
oN = Direct evaluation, +N = 45 kg N ha^{-1}

be responsible for this pattern of behaviour. That is the differences on the rates of mineralization which affected the rates of nutrient release and even lost through either volatilization or leaching (Lekasi, 2005). The N amended surface heaped covered April treatment at the residual effect gave taller plants at the two seasons, these values correlated to what was obtained in the greenhouse, where this same treatment gave taller plants which were not significantly different from the NPK treatment that gave the tallest plants.

However, most of the direct effect plots gave taller plants than the residual effect in the two seasons at each equivalent level of comparison. Also, the N amended plots gave taller plants than the direct evaluation plots. The effects are attributable to nutrient contributions of the materials and rate of nutrient release (Tian *et al.,* 1992a). The control plots also consistently gave shorter plants than the manure and N amended treatments, except at the residual effect of 2004 season.

4.9 Effects of cowdung and nitrogen levels treated to various management practices on soil properties in the field.

4.9.1 Soil pH

In years 2003 and 2004, the highest pH values at direct effect were observed at surface heaped uncovered May treatments of the direct evaluation (6.17 and 6.23 respectively) (Tables 4.12 and 4.13 respectively), while at

Table 4.12 Effects of manure management practices, time of application and N levels on soil pH(water) in IAR farm.

Treatments	Direct effect(2003)				Residual effect(2004)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	6.03abc	5.23e	5.83a-e	5.78a-e	5.62a-d	5.50cd	5.80	5.55
SHUA	5.95a-d	5.88a-d	5.87a-e	5.33e	5.90ab	5.82a-d	5.67	5.58
SHUY	6.17a	5.92a-d	6.00abc	5.32e	5.85abc	5.67a-d	5.67	5.65
SHUJ	6.05abc	5.67bcd	5.93a-d	5.38de	5.95a	5.57bcd	5.73	5.78
SHC								
SHCM	5.48de	5.80a-d	5.65cde	5.70a-e	5.73a-d	5.72a-d	5.70	5.98
SHCA	6.12ab	5.78a-d	5.78a-e	5.68b-e	5.78a-d	5.47d	5.95	5.63
SHCY	5.80a-d	5.95a-d	6.28a	5.85a-e	5.72a-d	5.65a-d	5.85	5.82
SHCJ	6.10ab	5.83a-d	5.82a-e	5.83a-e	5.77a-d	5.68a-d	5.83	5.55
PC								
PCM	5.88a-d	5.73a-d	6.03abc	5.95a-d	5.85abc	5.50cd	6.05	5.55
PCA	5.83a-d	5.58cde	5.97a-d	5.57cde	5.77a-d	5.73a-d	5.75	5.72
PCY	5.62cde	5.65b-e	6.03abc	5.55cde	5.82a-d	5.68a-d	5.80	5.75
PCJ	5.80a-d	5.85a-d	6.03abc	5.83a-e	5.80a-d	5.57bcd	5.75	5.92
Control	5.85a-d		6.27abc		5.85abc		5.80	
SE±	0.136		0.170		0.109		0.155	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

Table 4.13 Effects of manure management practices, time of application and N levels on soil pH(water) in SCA farm.

Treatments	Direct effect(2004)				Residual effect(2005)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	6.23a	4.83f	5.97b-f	5.90b-f	5.47b-e	5.40cde	5.80a-e	5.40b-e
SHUA	5.83abc	5.57b-e	6.03b-f	5.43ef	5.97ab	5.63a-e	5.47b-e	5.13e
SHUY	6.23a	5.53cde	6.00b-f	5.33f	5.80a-d	5.37cde	5.37cde	5.57b-e
SHUJ	6.17ab	5.37c-f	6.13a-e	5.57def	6.13a	5.43b-e	5.67a-e	5.27de
SHC								
SHCM	5.20def	5.63a-e	5.73c-f	6.00b-f	5.70a-d	5.50b-d	5.80a-e	5.77a-e
SHCA	6.17ab	5.70a-d	5.73c-f	5.73c-f	5.63a-e	5.37cde	6.10ab	5.53b-e
SHCY	5.63a-e	5.77a-d	6.73a	5.93b-f	5.67a-e	5.60b-e	6.00abc	5.57b-e
SHCJ	6.17ab	5.77a-d	5.97b-f	6.10a-e	5.77a-d	5.47b-e	5.57b-e	5.23de
PC								
PCM	5.93abc	5.57b-e	6.27a-d	6.40abc	5.97ab	5.23e	6.30a	5.40b-e
PCA	5.77a-d	5.07ef	6.13a-e	5.70c-f	5.73a-e	5.53a-e	5.60b-e	5.40b-e
PCY	5.47cde	5.63a-e	6.50ab	5.60def	5.90abc	5.83abc	5.90a-d	5.70a-e
PCJ	5.80a-d	5.83abc	6.10a-e	5.87b-f	5.80a-d	5.27de	5.77a-e	5.67a-e
Control	5.90abc		6.57ab		5.87abc		5.70a-e	
SE±	0.177		0.205		0.155		0.203	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

harvest it was the surface heaped covered May treatments that gave the highest values at direct evaluation (6.28 and 6.73 respectively).

On the residual effect, at 4 WAP surface heaped uncovered June treatments at direct evaluation gave the highest values (5.95 and 6.13 respectively). Also at harvest the pit covered March treatment of the direct evaluation gave the highest values (6.05 and 6.30 respectively) even though the 2003 values were not statistically significant.

The lowest values for the two years were only consistent on surface heaped uncovered March treatments at N amended at 4 WAP (5.23 and 4.83 respectively). The rest of the lower values were not consistent for the two years.

These results were consistent at the two years and at both direct and residual effects, the direct evaluation (manure amended without nitrogen) treatments increased the pH, while the N amended treatments decreases the pH of the soil.

4.9.2 Soil organic carbon

The results of soil organic carbon are presented in Table 4.14 for year 2003 and Table 4.15 for year 2004. The results showed that, the organic carbon content was significantly affected in the two years, except at 4 WAP at residual effect where there was no significant effect. The manure amended treatments were generally higher than the control treatments in the two years

Table 4.14 Effects of manure management practices, time of application and nitrogen levels on soil organic carbon(g kg $^{-1}$)in IAR farm.

Treatments	Direct effect(2003)				Residual effect(2004)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	44.2ab	49.2a	39.3ab	38.3ab	45.0	41.5	40.8ab	40.2ab
SHUA	46.0ab	48.0a	42.5ab	49.5a	43.2	44.7	43.8ab	36.2ab
SHUY	48.3a	49.3a	45.2ab	47.2a	41.3	51.0	43.8ab	44.0ab
SHUJ	44.0ab	47.0ab	39.3ab	46.7a	41.7	49.5	400.ab	34.2ab
SHC								
SHCM	41.0ab	48.8a	41.7ab	45.2ab	35.5	40.5	33.7ab	36.7ab
SHCA	44.2ab	51.7a	41.5ab	49.0a	34.8	45.5	39.7ab	39.8ab
SHCY	48.3a	47.8a	45.7a	41.7ab	46.7	49.5	41.0ab	41.2ab
SHCJ	46.0ab	47.2a	44.8ab	45.0ab	46.8	41.5	42.2ab	37.8ab
PC								
PCM	42.7ab	45.2ab	45.0ab	43.2ab	49.5	40.8	40.3ab	42.3ab
PCA	51.7a	49.3a	48.2a	44.2ab	48.5	46.8	37.7ab	39.7ab
PCY	54.5a	45.3ab	45.7a	41.5ab	50.7	50.3	43.0ab	41.2ab
PCJ	47.4a	50.3a	41.8ab	45.3a	51.5	46.3	51.0a	41.3ab
Control	30.7b		30.8b		32.0		26.0b	
SE+	4.90		4.77		6.42		5.90	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

Table 4.15 Effects of manure management practices, time of application and nitrogen levels on soil organic carbon(g kg $^{-1}$) in SCA farm.

Treatments	Direct effect(2004)				Residual effect(2005)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	37.0ab	40.7ab	30.7abc	35.7abc	34.0ab	32.0ab	30.0ab	27.3ab
SHUA	42.7a	39.9ab	38.0abc	46.3a	31.0ab	40.0ab	32.7ab	28.3ab
SHUY	36.3ab	39.0ab	32.7abc	37.0abc	32.7ab	36.0ab	37.7a	32.3ab
SHUJ	40.7ab	40.0ab	34.5abc	37.7abc	31.7ab	36.3ab	32.0ab	28.7ab
SHC								
SHCM	38.3ab	39.3ab	33.7abc	36.7abc	29.7ab	30.7ab	27.3ab	26.0ab
SHCA	40.0ab	47.7a	37.0abc	44.7ab	28.7ab	33.0ab	28.0ab	30.3ab
SHCY	40.3ab	46.0a	38.0abc	36.7abc	38.0ab	43.0a	30.0ab	29.0ab
SHCJ	36.3ab	36.7ab	37.0abc	35.0abc	32.3ab	30.3ab	31.0ab	33.0ab
PC								
PCM	37.7ab	35.0ab	45.3ab	33.3abc	39.0ab	35.3ab	29.7ab	35.0ab
PCA	42.0a	45.7a	39.3ab	39.0ab	37.3ab	29.3ab	31.3ab	26.7ab
PCY	49.0a	34.3ab	34.0abc	30.0bc	37.0ab	30.7ab	29.7ab	33.3ab
PCJ	39.0ab	38.7ab	30.7abc	34.7abc	30.0ab	34.7ab	35.7ab	35.0ab
Control	24.7b		23.0c		24.0b		22.0b	
SE±	4.93		4.57		4.92		4.21	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

and at both direct and residual effects. However, the highest organic carbon value for 2003 and 2004 years at direct effects, at 4 WAP were on treatments pit covered May at direct evaluation (5.45 g kg $^{-1}$ and 4.90 g kg $^{-1}$ respectively), while the lowest values were observed on the control treatments (2.07 g kg $^{-1}$ and 2.47 g kg $^{-1}$ respectively). At harvest, the amended surface heaped uncovered April treatments gave the highest values (4.95 g kg $^{-1}$ and 4.63 g kg $^{-1}$ respectively) while the lowest was observed at the control treatments (3.08 g kg $^{-1}$ and 2.30 g kg $^{-1}$ respectively).

Four WAP in 2003 season, the treatments did not affected the organic carbon content of the soil. At harvest, and at direct evaluation, the pit covered June treatment gave the highest value (5.10 g kg $^{-1}$), while the control treatment still gave the lowest value (2.60 g kg $^{-1}$). The treatments affect the organic C content of the residual effect in year 2004. The surface heaped covered May treatment of nitrogen amended at 4 WAP gave the highest value (4.30 g kg $^{-1}$), while the lowest value was observed for the control (2.40 g kg $^{-1}$). At harvest, it was the direct evaluation surface heaped May treatment that gave the highest value (3.77 g kg $^{-1}$), while the control still gave the lowest value.

De Ridder and Van Keulen (1990) reported that, application of organic manure generally aims at two major goals: increased supply of nutrient elements to the crop and increased organic matter content in the soil, resulting in more favourable soil physical and chemical properties. These two goals are

conflicting, as release of nutrient elements requires decomposition of the organic material, which is thus, lost for the formation of soil organic matter.

4.9.3 Total nitrogen

The results of the soil total nitrogen are presented in Tables 4.16 for year 2003 and 4.17 for year 2004. The total N was significantly affected by the various treatments. However, the results did not show any particular trend. For year 2003, the direct effect, at 4 WAP, it was the N amended treatment that gave the highest value (7.0 g kg^{-1}) while the lowest was observed at the pit covered June treatment of direct evaluation (4.3 g kg^{-1}). At harvest, it was the surface heaped uncovered March and control that gave the highest and lowest values 7.0 g kg^{-1} and 4.0 g kg^{-1} respectively.

The residual effect showed a completely different pattern. The surface heaped uncovered June treatment of direct evaluation gave the highest value (0.75 %), while the lowest was recorded at the control treatment (0.40 %). At harvest the highest value was observed on surface heaped covered May treatment (0.70 %), while the lowest was on the control treatment (0.39 %).

In year 2004, the pattern of behavior was completely different from what was observed in 2003. However, the control treatment was consistently gave lowest total N in the two years, except at 4 WAP. Many reasons had been

Table 4.16 Effects of manure management practices, time of application and nitrogen levels on soil total nitrogen (g kg $^{-1}$) in IAR farm.

Treatments	Direct effect(2003)				Residual effect(2004)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	4.9bc	6.8ab	5.6abc	7.9a	4.7ab	4.0c	4.9bc	4.7bc
SHUA	4.4c	5.2abc	4.9bc	6.3abc	4.9bc	6.1abc	5.5abc	6.1ab
SHUY	5.0abc	4.9bc	5.3abc	5.5abc	5.2bc	5.9abc	4.9bc	5.7abc
SHUJ	5.7abc	4.9bc	5.2abc	5.3abc	6.0abc	5.5abc	4.4bc	6.1ab
SHC								
SHCM	6.6ab	5.6abc	4.6bc	5.4abc	5.6abc	5.3bc	5.3abc	5.3abc
SHCA	4.3c	6.2abc	6.5abc	6.4abc	5.9abc	5.4abc	4.6bc	5.8ab
SHCY	5.8abc	6.6ab	6.4abc	7.3ab	5.0bc	6.2abc	7.0a	5.9ab
SHCJ	5.6abc	6.8ab	5.2abc	5.9abc	7.5a	6.1abc	5.9ab	6.1ab
PC								
PCM	5.2abc	5.6abc	6.7abc	4.8bc	5.8abc	6.0abc	5.6abc	6.1ab
PCA	6.1abc	7.0a	6.0abc	6.3abc	6.1abc	6.6ab	5.5abc	4.7bc
PCY	5.2abc	6.1abc	5.7abc	6.2abc	5.6abc	4.9bc	4.7bc	5.4abc
PCJ	4.3c	5.1abc	6.2abc	5.5abc	4.6bc	6.4ab	5.2abc	5.9ab
Control	5.1abc		4.0c		4.2c		3.9c	
SE±	0.61		0.80		0.65		0.53	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

Table 4.17 Effects of manure management practices, time of application and nitrogen levels on soil total nitrogen (g kg $^{-1}$) in SCA farm.

Treatments	Direct effect(2004)				Residual effect(2005)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	3.5de	5.4bc	3.2ef	5.3bc	5.3b	3.4c	5.2b	5.4b
SHUA	3.4de	5.2bc	3.3ef	6.7a	3.3c	5.4b	5.2b	5.4b
SHUY	3.4de	2.4e	5.2bc	3.4ef	5.2b	3.6c	3.4c	3.7c
SHUJ	5.2bc	3.5de	5.3bc	5.4b	5.3b	3.6c	3.5c	5.3b
SHC								
SHCM	6.8a	4.1cd	3.3ef	3.8de	5.3b	5.2b	5.2b	5.4b
SHCA	3.5de	5.5bc	5.3bc	5.3bc	3.3c	3.4c	3.3c	5.2b
SHCY	5.5b	5.3bc	5.2bc	7.4a	3.3c	7.2a	6.7a	3.6c
SHCJ	5.3bc	5.4bc	3.4ef	5.4b	7.2a	5.4b	5.2b	6.8a
PC								
PCM	4.1cd	5.4bc	5.4b	3.8de	5.4b	5.5b	5.2b	5.4b
PCA	5.2bc	5.5bc	3.8de	5.0bc	5.3b	5.3b	5.2b	4.8b
PCY	5.2bc	5.3bc	4.4cd	3.5def	5.4b	3.3c	3.4c	3.4c
PCJ	3.4de	3.4de	5.2bc	3.3ef	3.7c	5.5b	5.2b	5.3b
Control	5.1bc		2.8f		3.2c		2.8d	
SE±	0.41		0.32		0.13		0.17	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

attributed to differences in the release of N from the organic materials to the soil. These include among many other factors: the mineralogy of the soil, chemical and physical characteristics of the manure, environmental conditions (temperature, rainfall etc), the quality of the soil organic N, rate of application, nutrient release pattern, and the quality of the organic inputs to the soil. These results agrees with the work of Beckwith and Parsons (1980), that the amount of nitrogen mineralized from manure and compost depends on soil mineralogy, also the organic material, chemical and physical characteristics (Catellanos and Pratt, 1981; Janssen, 1996) and environmental conditions (Adriano *et al.,* 1974, and Kissel, 1995). The rate of mineralization depends on many factors including temperature and rainfall, the quality of the soil organic nitrogen and the quality of organic inputs to the system (Palm *et al.,* 1997). Again since N mineralization is microbially driven, it is influenced by many factors, including temperature and soil moisture, soil properties and manure characteristics.

4.9.4 Soil phosphorus

The results of the soil available P was affected by the various treatments in the two years (Tables 4.18 and 4.19). In year 2003, all the treatments that did not received manure application gave the lowest available P values at both direct and residual effects. Like in the case of total N, most of the treatments did not give lower or higher values for the two years

Table 4.18 Effects of manure management practices, time of application and nitrogen levels on soil available phosphorus(mg kg $^{-1}$) in IAR farm.

Treatments	Direct effect(2003)				Residual effect(2004)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	16.0abc	12.0c	14.0a-d	13.0cd	11.0b-f	8.0efg	6.0d	6.0d
SHUA	10.0c	11.0c	22.0a	22.0ab	7.0fg	15.0a	8.0bcd	7.0cd
SHUY	10.0c	13.0bc	12.0cd	9.0cd	8.0d-g	13.0a-d	12.0ab	12.0ab
SHUJ	15.0abc	13.0bc	13.0bcd	14.0a-d	8.0d-g	7.0fg	8.0bcd	14.0a
SHC								
SHCM	16.0abc	21.0ab	11.0cd	14.0a-d	7.0fg	8.0d-g	6.0d	6.0d
SHCA	10.0c	13.0bc	11.0cd	10.0cd	8.0fg	9.0c-g	11.0abc	6.0d
SHCY	17.0abc	22.0a	18.0abc	11.0de	8.0d-g	9.0c-g	8.0bcd	9.0bcd
SHCJ	10.0c	11.0c	18.0abc	10.0cd	16.0a	13.0abc	6.0d	8.0bcd
PC								
PCM	9.0c	10.0c	11.0dc	11.0cd	10.0b-f	5.0g	6.0d	10.0bcd
PCA	11.0c	11.0c	12.0cd	15.0a-d	17.0a	12.0a-d	7.0cd	8.0bcd
PCY	11.0c	17.0abc	14.0a-d	9.0cd	14.0ab	10.0c-f	9.0bcd	9.0bcd
PCJ	10.0c	11.0c	15.0a-d	9.0cd	9.0c-f	11.0b-f	8.0bcd	9.0bcd
Control	9.0c		9.0d		7.0fg		6.0d	
SE+	2.57		2.63		1.37		1.22	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

Table 4.19 Effects of manure management practices, time of application and nitrogen levels on soil available phosphorus(mg kg $^{-1}$) in SCA farm.

Treatments	Direct effect(2004)				Residual effect(2005)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	25.0bc	14.0f-j	16.0de	11.0g	11.0def	8.0h-k	8.0g-j	9.0e-h
SHUA	13.0f-j	14.0f-j	35.0a	37..0a	5.0l	15.0c	13.0cd	10.0def
SHUY	13.0hij	12.0hij	17.0d	12.0fg	12.0d-g	13.0d	17.0a	13.0b
SHUJ	21.0d	12.0hij	15.0d-g	22.0c	7.0ijk	8.0h-k	10.0def	17.0a
SHC								
SHCM	25.0bc	32.0a	14.0d-g	13.0efg	8.0ijk	6.0jkl	7.0hij	7.0hij
SHCA	16.0e-h	18.0e	12.0fg	12.0fg	7.0jkl	8.0g-k	11.0de	8.0g-j
SHCY	26.0b	33.0a	28.0b	12.0fg	10.0e-i	10.0d-h	7.0hij	8.0g-j
SHCJ	13.0f-j	10.0j	24.0c	11.0g	22.0a	10.0d-i	7.0hij	9.0fgh
PC								
PCM	11.0j	12.0hij	11.0g	14.0d-g	12.0de	6.0kl	6.0j	13.0bc
PCA	16.0efg	11.0ij	12.0fg	24.0c	22.0a	16.0c	10.0d-g	11.0cde
PCY	17.0ef	23.0cd	14.0d-g	12.fg	19.0b	8.0h-k	12.0bcd	8.0f-j
PCJ	13.0g-j	12.0hij	15.0def	11.0g	7.0ijk	8.0g-k	8.0f-j	8.0f-j
Control	15.0e-i		14.0d-g		9.0f-j		9.0f-j	
SE±	1.02		1.05		0.83		0.63	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha $^{-1}$

consistently, except the surface heaped covered May treatment at N amended and at 4 WAP of the direct effect and the surface heaped covered June treatment at direct evaluation at 4 WAP and surface heaped uncovered June treatment, N amended at harvest of the residual effect.

These results showed that the addition of manure generally increased the soil available P, but because of the various interactions of the factors (temperature, rainfall, microbial population and activity) that are involved on the various treatments there was no consistency on the behaviour of the treatments for the two years. However, it has be reported that a deficit of P or a decrease in its availability on cultivated soils can be counteracted by fertilizing with farm yard manure (Godefroy, 1979; Prasad and Singh, 1980). The reasons why manure brings about an increase in available P are both chemical (higher pH, lower C/P ratio) and biological (heightened biological activity, increased mineralization of P compounds, increased root activity etc).

4.9.5 Soil potassium

The values of exchangeable K in the soil, the unmanured (control) treatments consistently gave lower values than the manured treatments in year 2003 of the direct and residual effects, but in year 2004 it was only the direct effect that gave lower values but the values of residual effect were low (Tables 4.20 and 4.21 respectively). Although the treatments that gave the highest values were not consistent for the two seasons, it was observed that the

Table 4.20 Effects of manure management practices, time of application and nitrogen levels on soil exchangeable potassium($cmol^{+}\ kg^{-1}$) in IAR farm.

Treatments	Direct effect(2003)				Residual effect(2004)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	0.15b	0.13b	0.13c	0.14c	0.12c	0.15c	0.14c	0.14c
SHUA	0.17b	0.17b	0.46ab	0.21bc	1.03a	0.18c	0.15c	1.02a
SHUY	0.15b	0.33b	0.13c	0.15c	0.15c	0.34bc	0.14c	0.16c
SHUJ	0.67a	0.14b	0.19bc	0.09c	0.82a	0.12c	0.15c	0.18c
SHC								
SHCM	0.65a	0.20b	0.57a	0.10c	0.20c	0.15c	0.17c	0.14c
SHCA	0.21b	0.12b	0.12c	0.08c	0.16c	0.18c	0.57b	0.14c
SHCY	0.36b	0.17b	0.20bc	0.21bc	0.24c	0.22c	0.17c	0.18c
SHCJ	0.16b	0.14b	0.11c	0.07c	0.18c	0.21c	0.18c	0.13c
PC								
PCM	0.12b	0.11b	0.09c	0.10c	0.53abc	0.16c	0.22c	0.09c
PCA	0.16b	0.18b	0.12c	0.15c	0.44bc	0.17c	0.11c	0.14c
PCY	0.25b	0.14b	0.12c	0.12c	0.16c	0.36bc	0.15c	0.10c
PCJ	0.20b	0.15b	0.13c	0.09c	0.32bc	0.44bc	0.17c	0.15c
Control	0.11b		0.06c		0.13c		0.12c	
SE±	0.073		0.090		0.17b		0.062	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

Table 4.21 Effects of manure management practices, time of application and nitrogen levels on soil exchangeable potassium($cmol^{+}\ kg^{-1}$) in SCA farm.

Treatments	Direct effect(2004)				Residual effect(2005)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	0.14d	0.11d	0.06hij	0.16c	0.07g-j	0.05ij	0.14d	0.15d
SHUA	0.11d	0.11d	0.27a	0.13cd	0.10ef	0.13bcd	0.17cd	1.18a
SHUY	0.07d	0.44bc	0.14c	0.14c	0.09efg	0.07g-j	0.18cd	0.17cd
SHUJ	1.11a	0.12d	0.08f-j	0.07g-j	0.10ef	0.06hij	0.15d	0.23cd
SHC								
SHCM	1.14a	0.24cd	0.10d-g	0.09e-h	0.16abc	0.08f-i	0.15d	0.11d
SHCA	0.25cd	0.06d	0.11def	0.10d-g	0.14bcd	0.10ef	1.01b	0.14d
SHCY	0.50b	0.18d	0.24ab	0.22b	0.19a	0.16ab	0.16d	0.24cd
SHCJ	0.11d	0.07d	0.06g-j	0.05ij	0.06g-j	0.08f-i	0.16cd	0.12d
PC								
PCM	0.10d	0.08d	0.09f-i	0.09f-i	0.10ef	0.09fgh	0.32c	0.08d
PCA	0.11d	0.17d	0.10d-g	0.22b	0.12de	0.05ij	0.08d	0.14d
PCY	0.28cd	0.09d	0.12cde	0.15c	0.05j	0.07g-j	0.16cd	0.11d
PCJ	0.09d	0.12d	0.15c	0.09e-h	0.06hij	0.10ef	0.18cd	0.16cd
Control	0.09d		0.05j		0.10ef		0.17cd	
SE+	0.071		0.012		0.010		0.048	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

highest values were always found at the direct evaluation treatments, except at the residual effect, at harvest that the surface heaped uncovered April treatment at N amended gave the highest K values.

Fulhage (2000) had reported that manure K is a soluble form and is considered to be immediately and completely available to plants when it is applied and that, it is moderately mobile in the soil. This explains why the manure amended treatments consistently gave higher values of K than the control treatments in the two years. The reasons for the lower values of K on the N amended treatments could probably be due to high K uptake from the soil for high biomass production because of the presence of N, thereby leaving lower K content in the soil, more so that it is immediately and completely available in the soil on application.

4.9.6 Soil calcium

The soil exchangeable Ca was significantly affected by the various treatments in the two years at both direct and residual effects and at the two stages of crop growth (Tables 4.22 and 4.23 respectively). The results showed that in years 2003 and 2004 the direct effect at 4 WAP, the direct evaluation, pit covered May treatments gave the highest values of exchangeable Ca in the soil, but at harvest it was the direct evaluation surface heaped uncovered April treatments that gave higher values for the two years. Observing the residual effect values there was no such consistency at 4 WAP. But at harvest, it was

Table 4.22 Effects of manure management practices, time of application and nitrogen levels on soil exchangeable calcium ($cmol^{+}\ kg^{-1}$) in IAR farm.

Treatments	Direct effect(2003)				Residual effect(2004)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	1.62bcd	2.02abc	1.50f	2.14c-f	3.20a	1.75b	1.47b-f	1.62b-f
SHUA	1.52d	1.65bcd	2.83a	1.59f	2.33ab	1.70b	1.47b-f	1.78bcd
SHUY	1.50d	1.60cd	1.90def	2.05c-f	1.88b	2.05b	1.73b-e	1.63b-f
SHUJ	1.57cd	1.65bcd	1.55f	1.67ef	1.44b	1.27b	1.27def	1.22ef
SHC								
SHCM	1.51d	1.66bcd	1.75ef	1.81def	1.20b	1.57b	1.48b-f	1.95b
SHCA	1.68a-d	2.12a	1.71ef	2.29a-e	2.28ab	1.27b	1.48b-f	1.43b-f
SHCY	1.57cd	1.91a-d	2.13c-f	1.90def	1.88b	1.96b	1.38d-f	2.67a
SHCJ	1.67bcd	1.50d	2.77a	1.73ef	1.17b	1.82b	1.62b-f	1.62b-f
PC								
PCM	1.45d	1.88a-d	2.17b-f	2.10c-f	1.85b	1.72b	1.52b-f	1.52b-f
PCA	2.07ab	1.73a-d	2.78a	2.47a	1.90b	1.40b	1.26def	1.56b-f
PCY	2.12a	1.55d	1.67ef	2.62abc	1.43b	1.39b	1.87bc	1.65b-f
PCJ	1.68a-d	1.59cd	1.86def	1.87def	1.53b	1.78b	1.93b	1.45b-f
Control	1.80a-d		1.53f	1.68ef	1.52b		1.13f	
SE±	0.134		1.198		0.370		0.155	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

Table 4.23 Effects of manure management practices, time of application and nitrogen levels on soil exchangeable calcium ($cmol^{+}\ kg^{-1}$) in SCA farm.

Treatments	Direct effect(2004)				Residual effect(2005)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	1.37k-n	2.10b-e	1.43i-l	2.32cde	1.43g-j	1.70efg	1.57def	1.77de
SHUA	1.50j-m	2.67g-k	3.62a	1.25jkl	1.97cde	1.47ghi	1.37fg	1.57def
SHUY	1.43klm	1.10n	1.43i-l	1.83fgh	2.07bcd	2.23bc	1.73de	1.62def
SHUJ	1.57h-l	1.43klm	1.07l	1.70ghi	1.22h-k	1.30h-k	1.23gh	1.03h
SHC								
SHCM	1.88d-h	1.76f-j	1.40i-l	2.22c-f	1.13jk	1.37h-k	1.63def	2.07bc
SHCA	1.76f-j	2.33bc	1.38i-l	1.31i-l	2.57a	1.20h-k	1.77de	1.45fg
SHCY	1.63g-l	2.18bcd	2.07e-g	1.60h-k	1.73efg	2.35ab	1.40fg	3.63a
SHCJ	1.83e-i	1.20mn	3.11b	1.25jkl	1.67fg	1.17ijk	1.57def	2.10b
PC								
PCM	1.33lmn	2.05c-f	1.93e-h	2.20c-f	1.83def	1.87def	1.83cd	1.43fg
PCA	2.37ab	1.55i-l	2.50c	2.53c	2.10bcd	1.50gh	1.38fg	1.48efg
PCY	2.63a	1.33lmn	1.20kl	2.40cd	1.20h-k	1.12k	2.23b	1.43fg
PCJ	1.33lmn	1.35k-n	1.22kl	1.63hij	1.37h-k	1.73efg	2.30b	1.77de
Control	1.90d-g		1.37i-l		1.50gh		1.37fg	
SE±	0.098		0.124		0.093		0.086	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

the N amended surface heaped covered May treatments that gave the highest values of Ca in the soil for the two years. There was no such consistency on the treatments that gave the lowest soil values of Ca. Most of the control treatments were generally lower than the manure amended treatments, however they did not give the lowest values in most cases.

Comparing the values of direct and residual effect, the residual effects values were generally slightly lower than the direct effects values. Lekasi *et al.* (2000) reported that, although nutrient concentrations are valuable indicators of manure quality, these measurements do not reflect the total amount of nutrients that could be potentially available in the farms. It is quite possible that manures with low nutrient concentration could also have high heap mass, resulting in potentially higher nutrient cycling capacity. The full impact of livestock and manure management practices on nutrient cycling can only be determined if mass balances are recorded. This implies that the inconsistency of the values observed may be as a result of other unknown additions or reactions.

4.9.7 Soil magnesium

The exchangeable Mg in the soil in years 2003 and 2004 are shown in Tables 4.24 and 4.25 respectively. The results showed that, the pit covered May treatment at the direct evaluation, at 4 WAP of the direct effect, gave the

Table 4.24 Effects of manure management practices, time of application and nitrogen levels on soil exchangeable magnesium ($cmol^{+}\ kg^{-1}$) in IAR farm.

Treatments	Direct effect(2003)				Residual effect(2004)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	0.62e	0.85b-e	0.67f	1.22a-d	0.67def	0.72cf	0.73bcd	0.70b-e
SHUA	0.68cde	0.63de	1.53a	0.68f	0.88bcd	0.80b-e	0.72b-e	0.78bc
SHUY	0.85b-e	0.93b-e	1.18a-e	1.03b-f	0.85bcd	0.95abc	0.93b	0.73bcd
SHUJ	0.97bcd	0.77b-e	0.98c-f	0.83def	0.78cde	0.55ef	0.55de	0.42f
SHC								
SHCM	0.63de	0.85b-e	0.77ef	1.17a-e	0.47f	0.87bcd	0.72b-e	0.98b
SHCA	0.83b-e	0.92b-e	0.98c-f	1.00c-f	0.98abc	0.65def	0.78bc	0.58cde
SHCY	0.88b-e	0.93b-e	1.25a-d	1.20a-d	0.83bcd	1.07ab	0.75bc	1.48a
SHCJ	0.83b-e	0.68cde	1.48a	0.97c-f	0.83bcd	0.72c-f	0.80bc	0.82bc
PC								
PCM	0.75b-e	1.00bc	1.15a-e	1.03b-f	1.17a	0.80b-e	0.80bc	0.75bc
PCA	1.08ab	0.73cde	1.48a	1.27abc	0.77cde	0.83bcd	0.73bcd	0.57cde
PCY	1.30a	0.63de	1.18a-e	1.42ab	0.73c-f	0.62def	0.85bc	0.70b-e
PCJ	0.92b-e	0.87b-e	1.12a-e	1.28abc	0.77cde	0.87bcd	0.85bc	0.75bc
Control	0.88b-e		0.83def		0.64def		0.43de	
SE±	0.099		0.124		0.082		0.093	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

Table 4.25 Effects of manure management practices, time of application and nitrogen levels on soil exchangeable magnesium ($cmol^{+}\ kg^{-1}$) in SCA farm.

Treatments	Direct effect(2004)				Residual effect(2005)			
	At 4 WAP		At harvest		At 4 WAP		At harvest	
	oN	+N	oN	+N	oN	+N	oN	+N
SHU								
SHUM	0.57jk	1.03cde	0.57lmn	1.30cd	0.67f	0.70e-j	0.73g-j	0.73g-j
SHUA	0.63ijk	0.80e-j	1.93a	0.53mn	0.90b-f	0.77d-i	0.77f-i	0.67h-k
SHUY	1.03cde	0.77f-j	0.63j-n	0.83ghi	0.93b-e	1.07b	0.93c-f	0.77f-i
SHUJ	0.97c-f	0.80e-j	0.50n	0.77h-k	0.70e-j	0.47jkl	0.57jkl	0.43l
SHC								
SHCM	0.80e-j	0.83e-i	0.60k-n	1.30cd	0.28l	0.80c-h	0.77f-i	1.17b
SHCA	0.77f-j	1.10cd	0.63j-n	0.70i-m	1.03bc	0.53ijk	0.97cde	0.60i-l
SHCY	0.80e-j	1.17bc	1.03ef	0.93fgh	0.73d-i	1.47a	0.87d-g	2.07a
SHCJ	0.93c-g	0.43k	1.53b	0.88g-j	0.77d-i	0.57h-k	0.73g-j	1.10bc
PC								
PCM	0.70g-j	1.17bc	1.03ef	1.13de	1.43a	0.93b-e	1.10bc	0.80e-h
PCA	1.40b	0.90d-h	1.43bc	1.30cd	0.97bcd	0.83b-g	0.67h-k	0.53kl
PCY	1.70a	0.60ijk	0.83ghi	1.27cd	0.53ijk	0.43kl	1.10bc	0.83e-h
PCJ	0.67h-k	0.77f-j	0.97efg	1.08ef	0.56h-k	1.03bc	1.03bcd	0.97cde
Control	1.17bc		0.73i-l		0.65g-k		0.47l	
SE±	0.078		0.061		0.071		0.058	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March, PCM = Pit covered March,
SHUA = Surface heaped uncovered April, SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May PCY = Pit covered May
SHUJ = Surface heaped uncovered June SHCJ = Surface heaped covered June PCJ = Pit covered June

oN = Direct evaluation, +N = 45 kg N ha^{-1}

highest values of Mg in the two years. At harvest, of the direct effect, it was the surface heaped uncovered April treatments of the direct evaluation that gave the highest values for the two years.

Observing the residual effect values at 4 WAP, of the direct evaluation, the pit covered March treatments gave the highest values, while the surface heaped covered March treatments the lowest values. At harvest it was the N amended surface heaped covered May treatments that gave the highest soil values, while the lowest values were observed on N amended surface heaped uncovered June treatments.

The soil Mg values showed some level of consistency in terms of the treatments that gave the highest values in the two years and also at both direct and residual effects. It was observed that, most of the treatments that gave the highest and the lowest values were observed at the direct evaluation treatments, except at harvest of residual effect that they were observed at the N amended treatments in the two years. These could be attributed to low utilization of the nutrients in the direct evaluation treatments, compared to the N amended treatments where there was greater crop performance which could have led to high nutrient utilization by the crops and low levels of nutrients in the soil.

The residual effect values were also generally lower than the direct effect values at each equivalent level of comparison in some instance. This is

expected, because in the year of residual effect there was no addition of manure.

4.10 Correlation Analysis

4.10.1 Greenhouse study

The correlation between plant growth parameters and some soil chemical properties are presented in Table 4.26. Maize dry matter weight was significantly ($P < 0.05$) correlated with total N. Maize has a high and relatively rapid nutrient requirement especially N which makes it to mine the soil nutrients beyond the soil's power to replenish them. Maize response to applied inorganic N in the northern guinea savanna has always been positive (Iwuafor *et al*., 2002).

Plant height was significantly ($P < 0.05$) correlated with total N. Nitrogen is known to increase the maize plant height because of its role in plant growth. Maize dry matter yield was significantly ($P < 0.05$) correlated with organic carbon. This is because organic matter is the major source of total N in the soil, when the organic matter of the soil is high the organic carbon and total N will also be high. This was responsible for the positive correlation between maize dry matter yield and organic carbon.

Exchangeable K was highly significantly ($P < 0.01$) negatively correlated with maize dry matter weight, plant height and total N. Organic carbon and total N significantly ($P < 0.05$) correlated with each other. This

Table 4.26. Correlation matrix between soil chemical properties and maize yields components in the greenhouse.

Parameters	Dry Matter yield	Plant Height	Total N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Org. C
Dry Matter yield								
Plant height	0.82**							
Total N	0.21*	0.22*						
Avail. P	0.11ns	0.09ns	-0.07ns					
Exch. K	-0.34**	-0.37**	-0.29**	0.09ns				
Exch. Ca	0.03ns	0.06ns	0.05ns	-0.06ns	-0.20*			
Exch. Mg	0.04ns	-0.01ns	0.09ns	-0.05ns	-0.06ns	0.74**		
Org. C	0.19*	0.16ns	0.24*	0.10ns	-0.19*	0.27*	-0.01ns	

** = Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant

may be as a result of reasons already stated above on the relationship that exist between organic matter and total N. Dry matter weight and plant height were not related to Ca and Mg.

4.11 Field Study

4.11.1 2003 season direct effect

The correlation between maize performance and soil chemical properties are shown in Table 4.27. The results showed that, grain yield was significantly ($P < 0.05$) correlated with total N. The application of N is known to increase maize grain yield and yield related parameters significantly (Iwuafor *et al*., 2002 and Tanimu *et al*., 2007). Maize grain and stover yield had a highly significant ($P < 0.01$) correlation with organic carbon. This is an indication that, the higher the organic carbon, the higher the total N of the soil; which will in turn increase the maize grain and stover yields.

The soil pH was significantly ($P < 0.05$) negatively correlated with grain yield and plant height. pH is known to control the availability of soil nutrients. As the soil pH decreases the availability of micronutrients generally increases, which may have a negative effect on the grain yield of maize.

Table 4.27. Correlation matrix between maize yields and soil chemical properties for 2003 season direct effect on the field.

Parameters	Grain yield	Plant height	Stover yield	Total N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Org. C	pH
Grain yield										
Plant height	0.436**									
Stover Yield	0.826**	0.348**								
Total N	0.160*	0.083ns	0.152ns							
Avail. P	-0.025ns	-0.141ns	0.017ns	-0.249**						
Exch. K	-0.084ns	0.013	-0.84ns	0.032ns	-0.063ns					
Exch. Ca	0.071ns	0.199*	0.040ns	0.166*	0.058ns	0.054ns				
Exch. Mg	0.114ns	0.103ns	0.108ns	0.207*	-0.012ns	0.018ns	0.779**			
Org. C	0.229**	0.164*	0.215**	0.502**	-0.267**	0.128ns	0.333**	0.295**		
pH	-0.203*	-0.165*	-0.107ns	-0.271**	0.179*	-0.106ns	-0.064ns	0.003ns	-0.256**	

** = Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant,

4.11.2 2003 season residual effect.

Table 4.28 presents the correlation between the maize yields and yield components and soil chemical properties of 2003 season residual effect. Like the direct effect grain yield correlated significantly ($P < 0.05$) with total N. However, the available P that did not correlated at the direct effect but correlated significantly ($P < 0.05$) with grain yield. Organic carbon and pH that correlated positively and negatively respectively were not related at the residual effect. This must have been as a result of the decline in the fertility of the soil, since no cow dung was applied again.

4.11.3 2004 Season direct effect

The correlation between maize yield and soil chemical properties of 2004 season direct effect are shown in Table 4.29. The results showed that, organic carbon highly significantly ($P < 0.01$) correlated with maize grain yield. This is similar to what was observed in 2003 season direct effect. However, contrary to what was observed in that 2003 season direct effect, exchangeable Ca and Mg did not show any relationship, now gave a highly significant ($P < 0.01$) correlation with grain yield, plant height and stover yield. This must have been as a result of the differences in soil properties due to differences in location. Most of the other parameters did not show any relationship.

Table 4.28. Correlation matrix between maize yield and soil chemical properties for 2003 season residual effect on the field.

Parameters	Grain yield	Plant height	Stover yield	Total N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Org. C	pH
Grain yield										
Plant height	0.595**									
Stover yield	0.932**	0.542**								
Total N	0.185*	0.240**	0.155ns							
Avail. P	0.176*	0.131ns	0.132ns	-0.125ns						
Exch. K	0.066ns	0.075ns	0.072ns	-0.115ns	0.045ns					
Exch. Ca	0.106ns	0.180*	0.112ns	-0.111ns	-0.044ns	0.199*				
Exch. Mg	0.035ns	0.120ns	0.033ns	-0.153ns	-0.046ns	0.177*	0.819**			
Org. C	0.017ns	0.093ns	0.015ns	0.306**	-0.236**	-0.094ns	-0.056ns	-0.136ns		
pH	-0.159ns	-0.125ns	0.130ns	0.091ns	-0.242**	-0.041ns	-0.014ns	0.033ns	0.283**	

** = Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant

Table 4.29. Correlation matrix between maize yields and soil chemical properties for 2004 season direct effect on the field.

Parameters	Grain yield	Plant height	Stover yield	Total N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Org. C	pH
Grain yield										
Plant height	0.896**									
Stover yield	0.826**	0.862**								
Total N	0.147ns	0.128ns	0.142ns							
Avail. P	0.077ns	0.003ns	0.139ns	0.121ns						
Exch. K	-0.138ns	-0.164ns	-0.135ns	-0.131ns	-0.124ns					
Exch. Ca	0.283*	0.262*	0.247*	0.259*	-0.040ns	-0.094ns				
Exch. Mg	0.331**	0.300**	0.325**	0.161ns	0.205ns	-0.155ns	0.531**			
Org. C	0.383**	0.263*	0.405**	0.112ns	-0.056ns	0.030ns	0.263*	0.156ns		
pH	-0.151ns	-0.118ns	-0.074ns	-0.042ns	0.162ns	-0.085ns	0.125ns	0.258*	0.000ns	

** = Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant

4.11.4 2004 season residual effect.

The correlation between maize yield and soil chemical properties are presented in Table 4.30. Like the residual effect of the 2003, season grain yield positively correlated with total N and available P. Grain yield was significantly ($P < 0.05$) correlated with total N, while it was highly significantly ($P < 0.01$) correlated with available P. Calcium and organic C were also significantly ($P < 0.05$) correlated with the grain yield . Available P was highly significantly ($P < 0.01$) correlated with plant height and stover yield. Calcium significantly ($P < 0.05$) correlated with plant height and stover yield. There was no relationship with exchangeable K and Mg and pH.

4.11.5 2003 and 2004 seasons combine direct effects.

Table 4.31 presents the combine effects of maize yield and soil chemical properties. The results showed that, total N was highly significantly ($P < 0.01$) correlated with grain yield and plant height, while the relationship was significant ($P < 0.05$) with stover yield. This may be attributable to some of the reasons already stated above. This result agrees with the work reported by Iwuafor *et al*. (2002) and Tanimu *et al*. (2007), that increasing the application of N increases the yield and yield related parameters of maize in the field. Soil pH significantly ($P < 0.05$) affected the grain yield and stover yield of the maize.

Table 4.30. Correlation matrix between maize yields and soil chemical properties for 2004 season residual effect on the field.

Parameters	Grain yield	Plant height	Stover yield	Total N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Org. C	pH
Grain yield										
Plant height	0.896**									
Stover yield	0.826**	0.862**								
Total N	0.239*	0.208ns	0.093ns							
Avail. P	0.336**	0.325**	0.310**	0.395**						
Exch. K	0.057ns	0.059ns	0.102ns	-0.003ns	-0.147ns					
Exch. Ca	0.249*	0.245*	0.278*	0.164ns	-0.130ns	0.466**				
Exch. Mg	0.155ns	0.085ns	0.105ns	0.114ns	-0.313ns	0.404**	0.579**			
Org. C	0.263*	0.185ns	0.378**	0.018ns	0.076ns	0.067ns	0.257*	0.203ns		
pH	0.074ns	0.087ns	0.118ns	0.014ns	0.185ns	0.031ns	0.149ns	-0.027ns	0.036ns	

** = Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant

Table 4.31. Correlation matrix between maize yields and soil chemical properties for 2003 and 2004 seasons combined direct effect on the field.

Parameters	Grain yield	Plant height	Stover yield	Total N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Org. C	pH
Grain yield										
Plant height	0.896**									
Stover yield	0.826**	0.862**								
Total N	0.299**	0.311**	0.280*							
Avail. P	-0.085ns	-0.058ns	-0.039ns	0.131ns						
Exch. K	0.083ns	0.065ns	0.069ns	0.266*	0.445**					
Exch. Ca	-0.071ns	-0.110ns	-0.102ns	-0.324**	0.371**	0.421**				
Exch. Mg	-0.056ns	-0.059ns	-0.063ns	-0.269*	0.241*	0.419**	0.895**			
Org. C	0.203ns	0.069ns	0.141ns	0.276*	0.212ns	0.119ns	0.151ns	0.016ns		
pH	-0.279*	-0.192ns	-0.152*	0.079ns	-0.099ns	0.001ns	0.005ns	0.086ns	-0.050ns	

** = Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant

4.11.6 2003 and 2004 seasons combined residual effect.

The correlation between maize yield and soil chemical properties are presented in Table 4.32. Unlike in the combine direct effect, the total N did not show any relationship between grain, stover yield and plant height. This was also observed with most of the other parameters. This must have been as a result of the decline of the fertility of the soil during the year when residual effect was observed. However, the soil pH was highly significantly ($P < 0.01$) negatively correlated with grain yield and significantly negatively correlated with stover yield. The plant height was highly significantly ($P < 0.01$) correlated with the soil pH. Some of this discrepancies could be attributed to the differences of the two locations combined and as a result of the residual effect.

Table 4.32. Correlation matrix between maize yields and soil chemical properties for 2003 and 2004 seasons combined residual effect on the field.

Parameters	Grain yield	Plant height	Stover yield	Total N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Org. C	pH
Grain yield										
Plant height	0.896**									
Stover yield	0.826**	0.862**								
Total N	0.177ns	0.174ns	0.199ns							
Avail. P	0.149ns	0.183ns	0.187ns	-0.220ns						
Exch. K	0.010ns	0.014ns	-0.010ns	-0.101ns	0.057ns					
Exch. Ca	0.157ns	0.093ns	0.168ns	-0.115ns	-0.252*	0.020ns				
Exch. Mg	0.111ns	0.061ns	0.121ns	-0.073ns	-0.224ns	0.026ns	0.903**			
Org. C	0.131ns	0.027ns	0.071ns	0.040	0.098ns	0.043ns	0.055ns	0.043ns		
pH	-0.329**	0.369**	-0.281*	-0.134	-0.302**	0.002ns	0.051ns	0.141ns	0.236*	

** = Significant at P < 0.01, * = Significant at P < 0.05, ns = not significant

CHAPTER FIVE

SUMMARY AND CONCLUSION

This study looked at different cow dung management practices that could best conserved nutrients and improved manure quality before application to the field, the effect of time of cow dung application in the field on nutrient content and availability to crops in the soil and the combined effects of cow dung and mineral fertilizer on soil fertility and the yield and yield components of maize.

Field and Greenhouse studies were conducted to achieved these objectives. The cow dung was first of all subjected to different management practices in the field and samples were collected at termination of one month incubation for laboratory assessment. The samples were then applied to the field at different times and again samples were collected at the time of field incorporation for all the treatments to assess the effect of duration of exposure of the cow dung on nutrient content and quality. The cow dung was then assessed in the greenhouse and field, using maize as a test crop in two locations IAR and SCA farms were used, and the residual effect for each of the locations were also observed.

The results showed that incubating cow dung in the pit gave higher values of total N than heaped covered and heaped uncovered treatments for the two years, while the control was comparable to the pit treatment. The values of total N were generally lower at the time of incorporation into the soil compared to at

the termination of incubation in the surface heaped covered and the pit covered management practices in year 2003 only. In year 2004, most of the values rather increased, with some few exceptions.

At the termination of incubation of the cow dung to different management practices the heaped covered method gave higher values of total P than the pit covered and heaped uncovered methods. But after exposing the cow dung to the atmosphere at the time of incorporation to the soil, the pit covered method gave lower values of P, when compared to the other two methods. The control treatment consistently gave higher values of total P at the termination of incubation and at the time of incorporation into the soil.

Time of application of cow dung to the soil affected the total N and P content of cow dung. The application of cow dung in June gave higher total N and P content, which was comparable to the control treatment except in year 2004, at the termination of incubation. Also comparing the mean values of available P, at after subjecting it to different management practices and at before incorporation into the soil the values decreased at before incorporation into the soil.

The pit covered method gave higher values of K at the termination of incubation than all other treatments including the control in the two years. But at the time of incorporation into the soil the K values did not give any particular pattern, but the heaped uncovered treatment tended to give higher values which were not too different from the other two treatments. Observing the pit covered

method, at the time of incorporation into the soil the values of K were generally lower compared to at the termination of incubation, while reverse was the case in terms of the heaped covered treatment and heaped uncovered treatment which tended to increase.

The K content of cow dung composted in March was higher than that of other months including the control, at after subjecting it to different management practices. But at the time of incorporation into the soil, the K in the cow dung was higher in the month of May. The K values at the time of incorporation into the soil were generally lower than at termination of incubation.

Subjecting the cow dung to different management practices gave higher values of Ca and Mg, compared to the control treatment. However, among the treatments, the heaped uncovered treatment gave higher values than the other two treatments. At the time of incorporation into the soil the treatments still gave significantly higher values than the untreated control. But among the treatments the values of heaped covered were higher than the other two methods. Also comparing the values at termination of incubation and at time of incorporation into the soil, the after termination of incubation generally gave higher values of Ca and Mg than at the time of incorporation into the soil.

The time of application of cow dung to the field affected the Ca and Mg content of cow dung. At immediately after incubation, the May treatment gave higher Ca values than all other treatments at the two years, but at before incorporation into the soil, the June treatment gave higher Ca values. The May

treatment gave a higher Mg content than all other treatments, when the two years were pooled together at the termination of incubation, but at the time of incorporating the manure into the soil, the June treatment gave the highest values than all other treatments.

The organic carbon content of the untreated control was higher than that of other treatments at the time of incubation and at the time of application of cow dung into the soil. However, among the treatments the mean of the two years showed that, the pit covered treatment gave a higher value than the other two treatments, while at the time of incorporation of cow dung into the soil, the heaped covered treatment gave higher value of organic carbon, than the others.

The organic carbon content of cow dung was not seriously affected at the time of incubation, however, the untreated control tended to give a higher value. But at the time of incorporation into the soil, the control treatment gave higher values than the rest of the treatments. Comparing the other treatments at the termination of incubation and at the time of incorporation into the soil, the at the time of incorporation into the soil gave lower values.

The total microbial count of cow dung at termination of incubation did not show any difference among the treatments, but at the time of incorporation into the soil when the means of the two years were pooled together, the heaped covered treatment gave higher values than the other treatments. The total microbial count of cow dung at the termination of incubation showed that the

June treatment gave the highest value than all other treatments, while at the time of incorporation into the soil, the April treatment gave the highest value.

The NPK treatment in the greenhouse consistently gave higher values of maize dry matter yield and plant height, while the untreated control gave the least values. The N amended treatments (+N) generally gave higher values than the direct evaluation treatments(that is where only the manure was applied, without the addition of mineral nitrogen fertilizers). The pit covered May treatment gave higher values of maize dry matter yield and plant height at four and five weeks after planting, while at six weeks after planting it was the surface heaped uncovered June treatment that gave higher values. The plant height at the second and third week after planting (WAP) was not significantly affected.

The application of cow dung, N at 45 kg N ha^{-1} and NPK fertilizer at the greenhouse significantly affected soil pH. The pit covered March treatment gave the highest pH (water).

The management practices, time of application and N levels significantly affected the N, P and organic carbon content of the soil differently in the greenhouse. There was no treatment that was consistent in all the parameters. However the exchangeable bases were also affected at the direct evaluation. The pit covered April treatment gave higher values of Ca and Mg, while the control treatment was the one that had the highest value of K and on Na it was the nitrogen amended surface heaped uncovered June treatment that gave the highest value.

On the field study the grain yield and plant height showed that the N amended treatments generally gave higher values than the direct evaluation at both direct and residual effects. The surface heaped covered April, N amended and direct effect treatment gave the highest grain yield at both the 2003 and 2004 years, even though the values were not significantly different from most other treatment values. The surface heaped uncovered May, N amended and direct effect treatment also gave taller plants than all other treatments for both the two years.

The soil pH (water), organic carbon, total N, available P, exchangeable K, Ca, Mg and Na were affected differently by the various treatments. The values of these parameters observed in the two years showed some level of consistency, for both the direct and residual effects and at the two stages of sampling (4 WAP and at harvest). The treatments that gave the highest and lowest values for the two years were the same with some few exceptions.

From the results obtained in this study the following conclusions can be drawn.

1. The pit covered method of managing cowdung when the two years were pooled together, conserved more N than the other two methods (surface heaped covered and surface heaped uncovered) by up to 23.56 and 28.03 % respectively at the termination of incubation. The control (untreated cowdung) was comparable to the pit covered method and it was lower by 4.46 %. After field storage of cowdung, the control treatment gave a higher

total N value than the other management practices (surface heaped uncovered, surface heaped covered and pit covered) that ranged from 10.83 to 15.29 % respectively. The values of surface heaped uncovered and surface heaped covered were at par with each other.

2. The pooled values of P at the termination of incubation and after field storage showed that the control treatment gave values that were higher than the management practices that ranged from 9.45 to 18.91 % respectively. However the values of after field storage were generally lower than at termination of incubation.
3. The management practices generally increased the K content of cowdung. The pooled data for the two years at termination of incubation showed that, surface heaped uncovered increased the K content up to 78.48 % and pit covered increased it by 155.06 %. It was only the surface heaped covered that was slightly lower (8.23 %), but comparable to the control. The K content after field storage was still higher for the management practices, which ranged from 11.92 to 62.03 % with surface heaped uncovered having the highest value, followed by surface heaped covered and pit covered with the lowest value.
4. At the termination of incubation and after field storage for the two years pooled, the cowdung subjected to different management practices gave higher values of Ca and Mg compared to the control. At termination of incubation the management practices gave Ca values that were higher than

the control, which ranged from 152.17 to 280.00 %, while after field storage the increase ranged from 100.0 to 240.0 %. For Mg at the termination of incubation , the values increased between 35.14 to 121.62 % and after field storage the values were higher between 18.92 to 118.92 %.

5. Subjecting cowdung to different management practices decreased the organic carbon content of cowdung at both the time of termination of incubation and at after field storage. The values were lower than the control between 9.97 for pit covered to 25.29 % for surface heaped covered which was the highest. After field storage of the cowdung, it gave lower values of organic carbon compared to after incubation.
6. The early application of cowdung in the field reduced the total N content. That is, the 0 week field storage of cowdung in June gave higher values of total N which was comparable to the control. The June treatment was 7.14 % lower than the control, while those of May to March were up to 16.23 to 24.27 %.
7. At the termination of incubation of the cowdung when the two years were pooled together, the May treatments gave higher values of Ca and Mg than all other treatments. But at after field storage the June treatments gave higher values of both Ca and Mg.
8. At after field storage of cowdung, the control treatments gave higher values of organic carbon than the other treatments. Comparing the treatments at

after incubation and after field storage, the later gave lower organic carbon values.

9. Total microbial count of cow dung at after incubation, showed that the June treatments gave the highest values, while after field storage the April treatments gave the highest values.
10. The 45 kg N ha^{-1} treatments gave higher grain and stover yields at both the direct and residual effects, in the two field locations than the 0 kg N ha^{-1} (direct evaluation), while in the greenhouse it increased the dry matter weight and plant height than the 0 kg N ha^{-1}.
11. The application of N at 45 kg N ha^{-1} (+N amended) gave higher soil values for N and P than at 0 kg N ha^{-1} treatment (direct evaluation), while K values were higher at the 0 kg N ha^{-1} treatment than the 45 kg N/ha in the field.
12. The cow dung management practices, duration of cow dung storage and the N levels did not affected soil organic carbon at the residual effects trial.
13. The application of N at 45 kg N ha^{-1} in the field generally decreased the pH of the soil at either the direct or at the residual effects.

It is recommended based on the results of this study that the pit covered method of managing cowdung conserved more N than the other two methods (surface heaped covered and surface heaped uncovered) by up to 23.56 and 28.03 % respectively at the termination of incubation. The 0 week field storage of cowdung in June gave higher values of total N which was comparable to the control. The June treatment was 7.14 % lower than the control, while those of

May to March were up to 16.23 to 24.27 % lower than the control. The application of N at 45 kg N ha^{-1} , surface heaped covered April treatment gave the highest maize grain yield at the two locations (IAR and SCA farms) and at both direct and residual effects.

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APPENDICES

APPENDIX 1: SAMARU METEOROLOGICAL OBSERVATIONS DURING PERIOD OF STUDY IN YEAR 2003.

Month	Rainfall (mm)	Temperature (^{o} C)		Relative Humidity (%)	Sunshine Hours
		Min.	Max.		
January	0.0	15.9	33.0	71.0	8.1
February	0.0	19.4	36.4	72.5	8.1
March	0.0	21.8	36.8	71.3	5.9
April	31.0	24.7	37.8	71.0	7.2
May	78.4	24.0	37.5	72.1	7.4
June	69.2	23.4	32.3	82.3	6.8
July	243.1	22.4	30.6	80.8	5.2
August	427.1	22.2	29.5	83.9	NA
September	219.5	22.3	30.6	78.9	NA
October	67.1	22.3	32.6	70.8	NA
November	0.0	18.4	33.6	25.9	NA
December	0.0	15.6	31.2	18.1	NA

NA = Not available

Source: Meteorological Office, I.A.R., A.B.U., Samaru, Zaria.

APPENDIX 2: SAMARU METEOROLOGICAL OBSERVATIONS DURING PERIOD OF STUDY IN YEAR 2004

Month	Rainfall (mm)	Temperature (^{o}C)		Relative Humidity (%)	Sunshine Hours
		Min.	Max.		
January	0.0	15.7	31.9	14.3	NA
February	0.0	16.7	31.5	13.6	NA
March	13.6	19.6	34.6	16.9	NA
April	7.8	25.8	38.0	54.1	NA
May	162.8	22.2	34.5	66.0	NA
June	190.5	20.4	31.1	77.9	NA
July	245.0	20.2	30.2	76.7	NA
August	308.1	20.4	29.4	83.9	NA
September	126.3	27.2	31.6	76.6	NA
October	20.8	20.6	34.6	58.4	5.9
November	0.0	19.4	34.6	31.4	7.2
December	0.0	16.5	33.5	15.4	8.4

NA = Not available

Source: Meteorological Office, I.A.R., A.B.U., Samaru, Zaria.

APPENDIX 3: SAMARU METEOROLOGICAL OBSERVATIONS DURING PERIOD OF STUDY IN YEAR 2005.

Month	Rainfall (mm)	Temperature (^{o}C)		Relative Humidity (%)	Sunshine Hours
		Min.	Max.		
January	0.0	14.2	29.7	16.7	NA
February	0.0	20.2	36.6	20.9	NA
March	0.0	22.5	38.9	23.0	6.3
April	63.1	23.0	38.3	40.5	7.4
May	113.1	22.4	35.1	68.0	NA
June	160.2	21.0	31.6	78.4	NA
July	152.6	20.9	30.2	83.0	NA
August	235.5	20.1	29.2	85.3	NA
September	122.4	20.3	31.7	74.9	7.3
October	16.8	18.5	33.2	57.1	6.1
November	0.0	14.1	34.4	24.0	NA
December	0.0	13.6	33.2	16.8	NA

NA = Not available

Source: Meteorological Office, I.A.R., A.B.U., Samaru, Zaria.