THE EFFECT OF GREEN MANURE, COWDUNG AND THEIR COMBINATIONS ON GROWTH AND GRAIN YIELD OF MAIZE (Zea mays L.) IN LOW INPUT SYSTEMS

BY
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DECLARATION

I, Shadreck Bwembya, do hereby declare that this dissertation represents my own work and that to the best of my knowledge, it has not been previously submitted for the award of a degree at this or any other university.

Signed: ---------------------

Date: September 15, 1999. --------------------------

APPROVAL

The dissertation of Mr. Shadreck Bwembya is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Agronomy (Crop Science) by the University of Zambia.

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ABSTRACT

As small holder farmers intensify agricultural production, their land becomes more prone to soil degradation due to shorter or absence of fallow period. In order to use these pieces of land continuously, a deliberate soil management strategy which incorporates organic residues may provide multiple benefits of improving soil chemical and physical status. An experiment was carried out using Cassia spectsbilis (cassia) green manure and cowdung as organic soil amendments to improve soil chemical properties and increase maize yields.

Organic manure treatments to supply 1, 2, 3 or 4 tons ha^{-1} of cowdung alone, 2 tons ha^{-1} cassia alone, 2 tons ha^{-1} cassia with 1 ton ha^{-1} cowdung, 2 tons ha^{-1} cassia with 2 tons ha $^{-1}$ cowdung, 2 tons ha $^{-1}$ cassia with 3 tons ha^{-1} cowdung and 2 tons ha^{-1} cassia with 4 tons ha^{-1} cowdung were applied to a Misamfu red soil (Clayey Kaolinitic isohyperthermic Typic Haplustox). A grass fallow was used as a control. The plots were arranged as a randomized complete block design with 4 replications. Maize variety MMV 400 was planted in December and harvested at maturity in July. In the field, plant height, dry matter production, grain yield of maize were determined and nutrient uptake was calculated. Soil samples were collected at the beginning and end of the field study for analysis of the pH, organic C, total N, available P, exchangeable K, Ca, Mg and Na.

There were no significant increases in the chemical properties of the soil among the treatments. The organic C was in the range of 1.2 –1.8 % while the N concentrations ranged from 0.6–0.8 % across all treatments. Generally the C/N ratios decreased from the initial figure of 20 to 18.9 in the plots with 2 tons ha^{-1} cowdung + 2 tons ha^{-1} cassia and 19.5 in the plots with 1 ton ha^{-1} cowdung + 2 tons ha^{-1} cassia. The average concentration of P increased substantially from the initial 1.8 mg kg^{-1} to 6.7 mg kg^{-1} in the control, 6.9 mg kg^{-1} in the cowdung alone, 9.1 mg kg^{-1} in the cassia alone and 7.4 mg kg^{-1} in the cowdung + cassia plots.

The treatments of cassia + cowdung produced significant average plant heights of 317 mm at the 4-6 leaf stage, 1208 mm at the ear-leaf stage and 1705 mm at the maturity stage compared with the control (192 mm, 760 mm and 1513 mm, respectively), the cassia alone (222 mm, 900 mm and 1558 mm, respectively) and the cowdung alone (186 mm, 811 mm and 1481 mm, respectively). The addition of cowdung + cassia gave significant average dry matter yield (2495 kg ha^{-1}) over the control (1409 kg ha^{-1}), the cassia alone (1832 kg ha^{-1}) and the cowdung alone (1437 kg ha^{-1}) treatments. The treatments with cassia + cowdung had an average grain yield of 2226 kg ha^{-1} being 99 %, 41 % and 86 % grain yield increases over the cowdung alone (1120 kg ha^{-1}), the control (1082 kg ha^{-1}) and the cassia (1195 kg ha^{-1}) treatments, respectively. Generally, grain yield increased with increasing levels of manure amendments. The application of the organic matter had no significant effect on plant tissue nutrient concentrations at all stages of growth.

The use of cowdung + cassia, cassia alone, cowdung alone enhanced the uptake of N with the values of 3.06-5.20 kg ha^{-}, 1.51-2.19 kg ha^{-1} and 1.69 kg ha^{-1} respectively as compared to 1.35 kg ha^{-1} in the control plot, at the 4-6 leaf stage. Significant increases occurred in K and Mg uptake at the 4-6 leaf stage especially for the treatments with the cowdung + cassia.

DEDICATION

To the Almighty God with whom everything is possible. To Sola, my beloved wife, continue with your endless love and support for me as you have done before. You have been an inspiration in my life. To my children; beloved sons, Kapembwa, Chengelo, Bwembya and precious daughter Malumbo, I have laid the family foundation for you. Please take it up from here and build on it.

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1.0 INTRODUCTION

The environment in the high rainfall zone of Zambia and the traditional practices of the people provide little support for permanent agriculture. Declining soil fertility arising from natural forces or man's influence through poor farming practices or both is a concern particularly in the Northern Province. The area consists of highly weathered and strongly leached acidic soils which are low in native fertility (Brammer, 1976). Low pH, high aluminium and manganese concentrations are high on the list of major factors of infertility in these soils. In order to overcome the above soil constraints in this region farmers have traditionally practised forms of land husbandry such as *Chitemene* (slash and burn) and *Fundikila* (*Hyparhaenia* grass mound) including the use of cattle manure as coping strategies to replenish soil fertility (Mwakalombe and Mapiki, 1997). However, practices such as *Chitemene* are not sustainable due to increasing pressure on the land resulting from the rising population. The *Fundikila* practice is also of low productivity due to the poor quality of grass biomass used in the mounds and yields decline after a few years of cultivation.

The continuous use of inorganic fertilisers alone has proven unsustainable in small holder agriculture. Not only is the material expensive, it is also many times unavailable for proper timing of application. Dalland *et al.*(1993) and Stocking (1988) further demonstrated that the continuous application of nitrogenous fertilisers may have negative effects on the soil. They showed that as urea application increased, there were significant decreases in soil pH, Mg and K concentrations and increases in Al concentration and warned against the use of chemical fertilisers alone to serve as a panacea for all soil fertility problems.

It is therefore clear that crop production should not be practised with inorganic management alone but should include an organic component. The effect of these inputs should be regarded as complementary rather than substitutes of each other. This is particularly so because Zambia can not achieve the goal of sustaining the level of food production required to feed itself by the use of organic fertilisers alone (Ministry of Agriculture and Ministry of Finance, 1989). There are several useful sources of organic manures in the study area. Among the most widely tested plant sources of organic matter are *Cassia spectabilis*, *Clotalaria zanzibarica*, *Clotalaria juncea*, *Cajanus cajan*, *Tephrosia vogelii* and *Sesbania sesban*. The advantages of most of these plant species are that they are indigenous and well adapted to the environment. Some of them are fast growing leguminous tree species and produce high amounts of quality biomass. The low number of cattle reared is nevertheless, one of the major factors limiting the widespread usage of cowdung among many farmers. However, the study is particularly targeted to the extreme northern part of the country which includes Mbala, Nakonde and Isoka where more cattle are reared. Despite the scarcity of farmyard manure, work related to the use of cowdung and other available sources of organic manure need to commence long before cattle rearing becomes widespread in order to provide recommendations as well as packages on their utilization.

On the basis of the knowledge relating to the incorporation of organic manures in the study area, some plant species have been identified to hold potential for soil amelioration and fertility restoration. At Misamfu Research Centre, SPRP (1993) observed a response of maize to fresh prunings of *Flemingia congesta* and *Cassia spectabilis* incorporated as green manure. It was shown that maize yields (Var. MM 604) were increased with 6 tons ha $^{-1}$ cassia dry matter closer to the yields (6500 kg ha^{-1}) obtained with the application of 50 kg of compound D (10 N, 20 P_2O_5, 10 K_2O) and 50 kg of urea (46% N) per quarter of an hectare.

The Farming Systems Research Team in the Western Province conducted some work on use of manure by kraaling animals on plots for 3, 7 and 10 days from which 4.1, 9.6 and 13.7 tons ha $^{-1}$ of dry matter of cattle manure were respectively obtained (Penninkoff, 1995). Yields of bulrush millet of 1.9 tons, 2.3 tons and 1.8 tons ha $^{-1}$, respectively, were obtained in 1986. Increases in potassium and phosphorus observed were used to explain increases in the yield.

The sustainable management of soil chemical and physical properties in such a fragile ecological zone should be considered as a priority in order to increase and sustain agricultural production. The long term effect of organic manure application would in general be an improvement in the soil physical properties that would facilitate continuous farm land utilization as opposed to shifting cultivation and short fallows.

The following study was undertaken to evaluate the effect on soil properties and yield of maize when using *Cassia spectabilis* and cowdung either singly or in combination as soil amendments and sources of plant nutrients.

2.0 LITERATURE REVIEW

The basis for the use of green manures and cowdung lies in the key role organic matter derived from these materials plays in the improvement of tropical soils. Young (1976) pointed out that the significance of organic mass in tropical soils is greater than any other soil characteristics apart from moisture. Sanchez (1976) also stressed that maintenance of organic matter is fundamental to the productivity of tropical soils.

2.1 Organic matter decomposition and its effect on soil chemical properties

It is important that the nutrient supplying potential of various farmer available resources be evaluated before promoting their utilization. The type of material used and the quality have an effect on the decomposition and nutrient release rates. It has been established that the fast decomposers provide large amounts of nutrients in early stages of crop growth but may not influence soil physical conditions whereas slow decomposers have opposite effects (Tian et al., 1993). Leguminous plant materials used as green manures tend to decompose faster and release nutrients much quickly in the early stages of plant growth thus contributing more to the initial supply of plant nutrients (Ladd et al., 1981). Farmyard manures on the other hand act as slow release fertilisers. This characteristic, is some times desirable as there is a reduction in the leaching loss of N due to the slow decomposition and release of ammonium N and slow conversion to nitrate (Murwira and Kirchman, 1993).

During the process of decomposition, microorganisms are involved in the mineralisation of the added organic matter. The products of organic residue decomposition can cause either a reduction or an increase in the pH of the soil. Morachen et al. (1972) observed that green manuring maize for 3 years with alfalfa residues at 16 tons ha^{-1} reduced the soil pH from 5.3 to 5.1 while Maurya and Ghosh (1972) observed a decrease in soil pH by 0.3 to 0.4 units by green manuring maize with sunhemp for 4 years. It has been reported that green manure decreases soil pH by producing organic acids and CO_2 during decomposition (Motomura, 1962). On the other hand, organic acid reducing substances formed during decomposition are responsible for reducing iron and manganese oxides thereby causing soil pH to rise (Ponnamperuma, 1965). In addition, the soil pH may also increase due to the mineralisation of organic anions to CO_2 and H_20 and the rise in the soil pH also reduces the aluminium toxicity.

With regard to the effect of organic matter on the electrical conductivity (EC) of soils, very few investigations have been made to study the effect of green manure on upland soils. However, under water logged conditions the EC of soil solutions increases with time, reaches a peak and then declines. The rise in the EC is related to the increase in the amounts of mineralised NH_4^+, K^+, Mn^{2+}, Ca^{2+} and Mg^{2+} ions (Ponnamperuma, 1976) and the decomposition of organic matter in soil. The decrease in EC after an initial rise may be due to precipitation of Ca^{2+} and Mg^{2+} and consequent adsorption of other cations on the exchange sites as well as the decrease in P_{CO2} and decomposition of organic acids (Ponnamperuma, 1972). Katyal (1977) reported that application of *Gliricidia* green manure to red, black and alluvial soils caused sharp increases in EC within 14 days of flooding followed by a rapid asymptotic decline up to 28 days.

In addition to supplying P directly, organic matter can reduce P sorption capacity as well as improve the low Ca, Mg and K, conditions characteristic of most acid soils (National Research Council, 1991). Charreau (1975) also pointed out that fertilization with farmyard manure reduces or reverses acidification, increases Ca and Mg, reduces contents of Al and Mn and promotes root growth and uptake of P. The maintenance of surface soil carbon, Mg and K by residue incorporation has been demonstrated in Nigeria by Jones (1971, 1976). When studies on continuous fertilizer and manure experiments were conducted in the tropical conditions of India, Goyal et al. (1992) showed that soil microbial biomass carbon and nitrogen increased with balanced fertilization. The additions of organic amendments increased microbial biomass even when the organic carbon content of the soil did not increase. Grant (1967a) also reported significant but small absolute increase in soil organic C levels from 0.46% to 0.57% due to annual applications of 15 tons ha^{-1} manure in a five year trial at Grassland Research Station at Morondera in Zimbabwe. Exchangeable K, Ca and Mg increased progressively with annual applications of manure and good cropping conditions (Grant, 1970). Annual applications of 7.5 tons ha^{-1} or 15 tons ha^{-1} of manure raised the fertility of the soil by increasing the CEC, the exchangeable bases and soil pH (Grant, 1967b).

2..2 *Effect of organic manure on soil physical properties*

Manure incorporation into the soil results in increases in water holding capacity, hydraulic conductivity, infiltration rates and decrease in bulk density (Grant, 1967a). Lal et al. (1975) have shown that application of organic materials decreases soil temperatures, conserves soil moisture and prevents erosion. High levels of organic matter are important for good soil structure which is an essential determinant of the fertility of the soil. The humic substances as end products of organic matter decomposition play the most important role in the formation of the soil structure (Kellerman, 1957)). Rodel et al. (1980) in a five year trial in Zimbabwe reported that the overall effect of improving physical properties is a marked increase in crop yields. Apart from the control, they treated some plots with 4.5 tons ha $^{-1}$ and 9.0 tons ha $^{-1}$ of farmyard manure and planted maize as a test crop. The findings of this experiment were that the maize yield from plots fertilized with farmyard manure was higher in the dry year (1967-68) receiving 350 mm rainfall than the previous year when 800 mm of rainfall was recorded. It was found that maize yields of 819 and 1890 kg ha^{-1} were obtained from plots treated with 4.5 and 9.0 tons ha^{-1} of manure, respectively, in the wet year of 1966-67. However, maize yields of 2340 and 2980 kg ha^{-1} were obtained for the same treatments in the dry year of 1967-68.

A laboratory study by Rennie et al. (1954) showed that more readily decomposable legumes produced more stable aggregates in the short term, but that non leguminous plant material produced longer lasting effects. Allison (1968) stated that the direct effect of incorporated organic matter on aggregation is small and short lived. The benefit is obtained from the cementing action on soil particles of microbial cells and polysaccharides released during decomposition of the organic matter. In fact, organic matter, be it from leguminous green material or not, has a favourable influence on soil condition by lowering the bulk density and consequently increasing porosity (Dara et al., 1968).

Improvement in water holding capacity of the soil due to green manure was reported by Kang et al. (1985) who discovered that repeated application of *leucaena* prunings increased the moisture retention capacity of a sandy loam soil in Southern Nigeria. Joshi et al. (1990) found that after harvesting rice, drained plots that were treated with *Sesbania sesban* green manure retained 4% more water in the top 30 cm soil than plots receiving inorganic fertilizer. Green manuring effects on improved soil water transmission properties such as hydraulic conductivity, infiltration rate, drainage capacity and porosity have been reported by Jen et al. (1965). They found that green manure increased total porosity of soil from 43.9% in unamended soil to 45.8% in green manure plots and promoted aggregation. Liu (1988) reported that total and non capillary porosity were increased from 36.5% and 8.8% in no-green manure plots to 45.9 and 10.9% in green manure plots respectively. Yaacob and Blair (1981) reported a beneficial effect of incorporating soybean residues on the infiltration rate of soil; the rate (0-5 min) increased from 8.1 mm min^{-1} after one crop to 13.4 mm min^{-1} after six crops.

2.3 Effect of organic manure on soil biology

Addition of organic residues to the soil tends to increase the biological activity. This is because population and activities of micro-organisms and soil fauna responsible for decomposition increase, and added organic materials also stimulate the decomposition of soil organic matter (Alexander, 1961). In fact micro-organisms are present on organic residues even before the materials touch the soil (Burges and Raw , 1967) so that decomposition commences before then. Ghildyal and Gupta (1959) observed that the population of bacteria tend to increase in the early stage of decomposition while fungi and actinomycetes predominate in the later stages or during decomposition of resistant or mature organic materials. Organic amendments have also been associated with a decrease in the population of phytopathogenic nematodes. Sayre (1971) discussed decreases in root knot incidence with organic residue management. A marked decrease in the nematode population in rice soil due to the presence of green manure was reported by Germani et al. (1983) while Reddy et al. (1986) found that the use of selected leguminous green manure in a multiple cropping system reduced soil population of root knot nematodes. It was observed that when eight organic amendments were made to tomato, *Timothy* hay controlled root lesion nematodes while cellulose decreased the population of *Heterodera* and soybean meal reduced the population of *Pratylenchus penetrans*.

Studies conducted by Kute and Mann (1968), Ramaswami and Raj (1973) and Thomas and Shantaram (1984) recorded a considerable increase in the population of *Azotobacter* and other bacteria and microbial biomass in soils amended with green manure. It was reported that the population of *Azotobacter*, other bacteria and microbial activities increased by 49%, 53% and 471% respectively with the addition of green manure. They also concluded that N_2 fixing populations are stimulated by green manure. Bolton et al. (1985) also observed a marked decrease in the *Nitrosomonas* population in soils treated with green manure while population of denitrifying organisms was slightly increased. Generally, green manures provide energy and nutrients which encourage the growth and activity of desirable micro-organisms that play a key role in transforming and liberating plant nutrients in the soil and also discourage some undesirable ones.

2.4 Effect of organic manure on crop growth and yield

A study of the green manure legume effects on soil N and grain yield and N nutrition of wheat was done by Badaruddin and Meyer (1990). Results showed increases in grain yield, grain N and N uptake of unfertilized wheat following the legume treatment and were similar to those following a fallow and wheat fertilized with 15 kg N ha^{-1} . They concluded that green-manure legumes should be considered as an alternative to fallow on set-aside land . Brar and Dhillon (1994) investigating the effect of farmyard manure application on yield and soil fertility in a rice-wheat rotation showed that the grain yield of both rice and wheat increased significantly with graded levels of farmyard manure. However, the yield of 6.7 tons ha^{-1} was obtained with a very high rate of farmyard manure at 40 tons ha^{-1} thus limiting its use among farmers with few numbers of livestock.

Reddy et al. (1986) evaluated several tropical legumes as green manure for maize in the United States. The results showed that the yield of maize in green manure plots ranged from 3.4-5.7 tons ha^{-1} with a mean of 4.2 tons ha^{-1}, compared with 2.7 ton ha^{-1} produced on the fallow plot. Similar work on effect of organic manure on maize yields in Brazil showed that green manuring with legumes in general increased maize yield from 0.7 to 3.7 ton ha^{-1} over the control (Bowen, 1987; Carsky, 1989). Maize yields up to 6.3 tons ha^{-1} were achieved using the legume green manure *mucuna* as the N source.

In the Philippines, Gonzales (1962) reported that *Mung* bean green manure plus 30 kg N ha^{-1} as top dressing fertilizer produced grain yields of dry-season maize comparable with those from 60 kg N ha^{-1} applied on fallow plots. Sharma and Mittra (1990) studied the response of rice to rate and time of application of organic materials and showed that the residual soil fertility estimated by organic C and available N, P and K increased under all the organic materials and favourably influenced growth and yield of two rice crops.

Findings from a three year field experiment at two locations in Northern Zambia showed that the main factor responsible for increased bean yield was the amount of N added per hectare through legume organic matter of *Clotalaria zanzibarica, Clotalaria juncea* and *Sesbania sesban* (Mwambazi et al., 1998). *Clotalaria zanzibarica,* contained 1.91 % N and produced the highest bean yield whereas *Hyperrhenia* species as the control contained 0.4 % N and gave the lowest bean yield. It was found that the relatively faster decomposition rates associated with legume green manures compared to the *Hyperrhenia* indicated the potential of legume green manures in improving crop yields. It was concluded that *Hyperrhenia* with structural fractions of over twice that of *Clotalaria zanzibarica* may not provide as much N in the short term as that of legumes. However, it may be important in maintaining soil physical properties and build up of organic matter. Wade and Sanchez (1983) conducted an experiment on mulch and green manure application to determine the possibility of continuous crop production in Yurimaguas in Peru. The trial in a split plot design had the following treatments: Bare soil residue removed, grass mulch but first crop had rice straw, Kudzu (*Pueraria phaseoloides* mulch), Guinea grass incorporated as green manure and Kudzu incorporated as green manure. The results showed that the incorporation of Kudzu at a rate of 8 tons ha $^{-1}$ fresh material produced yields which were 90 % of the crops receiving complete inorganic fertilizer and liming. The beneficial effect of incorporating *Kudzu* as green manure were associated with amounts of N, P, K, Ca and Mg released from the decomposing material. The uptake of all nutrients except Mg was enhanced for treatments receiving Kudzu. There was also a decrease in Al and Al saturation and enhanced nutrient accumulation due to less moisture stress and lower bulky density.

The effect of chicken manure treatment on yields of rice was determined for six consecutive seasons at the International Rice Research Institute farm in Los Banos, Laguna in the Phillippines (Cayton et al., 1988). It was shown that chicken manure increased available N and was less prone to N losses associated with inorganic fertilisers. The treatment with chicken manure every season maintained total N and increased available P and in addition chicken manure supplied K, Mg, Ca, trace amounts of Fe, Mn, Zn and Cu and organic substances which promote rice growth.

The potential of optimizing cowdung use with maize were also studied by Munguri et al. (1996) in Chinyika area in Zimbabwe. Findings from on farm trials on the effect of cattle manure quantity and application method showed little or no effect on maize grain yield. Station placement of manure gave the highest yield and was superior to broadcasting, even though, results were similar to drilling in the planting furrow. The most positive results from application of farmyard manure were achieved in the Savannah zones with a sub-humid climate where even relatively modest applications of manure of 5-7.5 tons ha^{-1} produced substantial improvement in soil physical properties and the C and N status of the soil (Mokwunye, 1980).

Saka and Haque (1993) conducted some manure studies in the Ethiopian highlands, on the effects of cattle manure on dry matter yields, plant tissue nutrient concentration and plant nutrient uptake of *Medicago sativa*. Findings indicated that manure application significantly increased dry matter yield though plant tissue nutrient concentration data showed no significant effect of the manure application except for P and Mg which were significantly increased. Plant nutrient uptake was generally significantly increased by the addition of manure except N, Ca and Mg. Studies also showed that uptake of nutrient elements significantly increased and that the correlation between dry matter yields and plant tissue nutrient concentrations were generally poor except for K and Mg in the final harvest.

The incorporation of organic manures has long term benefits. Regmi(1994) observed increases in organic matter, total N, available P, total P, CEC, and Mg contents of the soil and a reduction in the soil pH of a calcareous soil in a rice-rice-wheat cropping system in Nepal, after long term application of farmyard manure. He concluded that the application of locally available low cost farmyard manure may be the best alternative when one cannot afford the costly mineral fertilisers. Hatam et al. (1994) evaluated the effect of farmyard manure on productivity of rain fed wheat and chickpea and on soil fertility. The results showed a depression in wheat grain (29%) and biological yield (20%) and tillers (10%). However, significant increase in grain yield

(25%), pods per plant (31%) and substantial increase in dry matter accumulation were noticed. The number of nodules per plant also increased by 84% with 10 tons of farmyard manure ha^{-1} at two locations.

The effect of farmyard manure as a P fertilizer as well as its improved effectiveness of mineral P fertilisers was described by Agboola et al. (1975). This was in an extremely acidic, humid tropical site where a mineral P fertilizer had no effect whatsoever on cowpea. However, when the fertilizer was applied with relatively small amount of farmyard manure of 2.5 tons ha^{-1}, the yield of cowpea was increased. A deficit in P or decrease in its availability can be counteracted by fertilizing with farmyard manure (Prasad and Singh, 1980).

Some studies on plant-animal waste combinations were conducted by Agbim (1981). The experiment was a green house study on maize (*Zea mays, L*) to assess the effect of cassava peels (CP) as a soil amendment when mixed with cowdung (D). The mixtures in different proportions were applied at rates equivalent to 200 metric tons ha^{-1} to 4 kg of potted soil. Nitrogen, P, K and Mg fertilisers (F) were added as variables. The result of this evaluation was that as the rate of CP + D mixture increased and the more the proportion of D in the mixture, the greater was the yield for the first crop. It was also observed that mixtures without F, containing 50 % CP or above and CP with F at and above 100 metric tons ha^{-1} gave higher yields with the second cropping. From this trial it was suggested that pre-plant incubation beyond 3 weeks was desirable to get greater mineralisation in the first cropping. It was deduced that over the two cropping periods increasing rates of CP increased yields from 29 % to 244 % over the control, thus showing the value of CP as a soil amendment. Moreover, CP + F was generally as effective as CP + D and D + F combinations.

A field trial on the potential of cassava peels as a soil amendment was carried out by Agbim (1985). The cassava peels (CP) were applied in different proportions with poultry droppings (PD) for a four year period which included a 1 year fallow to study their effect on the growth of cocoyam (*Colocasia esculenta*, (*L*) Schott). The treatments which included 100 % CP + 0 % PD, 75 % CP + 25 % PD, 50 % CP + 50 % PD, 25 % CP + 75 % PD and 0 % CP + 100 % PD were each applied at the rates of 0, 10, 25 and 50 Mg ha^{-1}. Findings showed that at 10 Mg ha^{-1} the CP-PD mixtures increased yield by 559, 328 and 311 % respectively for the 1979, 1980, and

1982 cropping seasons, thus emphasizing the value of such organic residue amendments. The general conclusion was that while the CP was a good soil amendment, there was need to incorporate the PD with the CP to maximize the yield.

A similar study by Agbim (1988) investigating the effect of plant and animal waste combinations of cassava peels and cattle dung on intercropping yields in a tropical environment produced positive responses. The effect of cassava peels (CP) mixed in different proportions with cowdung (D) on the growth of maize (*Zea mays*), yam (*Dioscorea rotundata*) and yam bean (*Sphenostylis stenocarpa*) intercrops was evaluated on a 0.28 ha plot of a sandy loam soil. The treatments were: 100 % CP + % D; 75 % CP + 25 % D; 50 % CP + 50 % D; 25 % CP + 75 % D and 0 % CP + 100 % D. Each of the treatments was applied at the rate of 0, 25, 50 and 75 Mg ha $^{-1}$, respectively, and after a month of incubation planted to maize and yam with yambean following one month later. The most interesting finding from the experiment was that the respective maize forage and grain yields of 7.04 and 2.25 Mg ha^{-1} obtained at 100 % CP increased correspondingly to 9.22 and 2.99 Mg ha $^{-1}$ with 100 % D. For yam, fresh weight yield increased from 8.83 Mg ha $^{-1}$ for 100 % CP to the highest value of 10.37 Mg ha $^{-1}$ at 50 % CP + 50 % D. Significantly the highest yam-bean yield (5.58 Mg ha $^{-1}$) was obtained with the 50 % CP + 50 % D treatment and on the overall the intercropping yield values increased with increasing proportion of D up to 50 % CP + 50 % D and declined thereafter. He concluded that other than showing the importance of organic matter the study showed that farmers in rural communities can utilise locally available agricultural wastes to improve crop yields.

3.0 MATERIALS AND METHODS

3.1 Location

The trial was conducted at Misamfu Research Centre in Kasama, Zambia. The agro-ecological site is in the high rainfall zone receiving an average of 1200 mm of rainfall per annum. The approximate location is 10^{0} 10` S and $31^{0}$ 10` E at an altitude of 1380 m above sea level. The climate is unimodal with a wet season from November to April and a dry season from May to October. The soil of the site is the Misamfu Red Series classified as a Clayey Kaolinitic Isohyperthermic Typic Haplustox (USDA, 1975). The average bulk density of the soil was 1.5g cm^3 with a $pH_{(CaCl2)}$ of 4.2.

3.2 Field preparation, trial layout and design

Field preparation commenced in November, 1996 when the site was selected. Being under fallow for at least three years, the experimental site had shrubs and tall *Hyperrhaenia* grass species on it. Stumping and clearing of the field was necessary. After clearing, the field was demarcated into plots according to the plan. Ridging was delayed due to the late onset of rains. The experimental layout was a randomized complete block design (RCBD) with 10 treatments and 4 replications. The gross plot dimensions were 6 m x 5 m comprising 6 ridges and a net plot of 4 m x 3 m consisting of 4 rows. The spacing between replicates was 2 m while it was 1 m between plots. The treatments were as follows: Grass fallow (control), 1 ton ha^{-1} of cowdung, 2 tons ha^{-1} of cowdung, 3 tons ha^{-1} of cowdung, 4 tons ha^{-1} of cowdung, 2 tons ha^{-1} *C. spectabilis*, 2 tons ha^{-1} *C. spectabilis* with 1 ton ha^{-1} cowdung, 2 tons ha^{-1} *C. spectabilis* with 2 tons ha^{-1} cowdung, 2 tons ha^{-1} *C. spectabilis* with 3 tons ha^{-1} cowdung and 2 tons ha^{-1} *C. spectabilis* with 4 tons ha^{-1} cowdung.

3.3 *Cassia spectabilis* biomass

Cassia spectabilis was used because of its attributes of high biomass productivity, high N content and ease of establishment as a source of green manure. A single rate of 2 tons ha^{-1} *C. spectabilis* was used as the optimum level to supply the required amount of N. With an N concentration of 3.85 %, 2 tons ha^{-1} cassia was estimated to provide 77.0 kg ha^{-1} of N.
The biomass of cassia (leaves and twigs) was cut from already established trees at Misamfu and imported into the experimental plots. The material was weighed to obtain the fresh weight. Three sub samples from this biomass were collected and oven dried at 105°C for 12 hours when a constant weight was obtained for each of them and re-weighed to obtain the oven dry weight for determination of the dry matter (DM) content (Anderson and Ingram, 1993). The amount of *C. spectabilis* applied to each plot was calculated on a dry weight basis. A constant amount of *C. spectabilis* at 2 tons ha^{-1} of DM was applied to each plot receiving green manure. At this rate and on the basis of a 25.8% DM content of *C. spectabilis*, each 0.003 hectare plot received 23.3 kg fresh biomass.

3.4 *Farmyard manure*

All the cowdung used in this study was obtained in October from one resource farmer in Mbala. The amount of cowdung applied was calculated on a dry weight basis. This was determined by taking the initial weight of three sub samples which were placed in the oven at 105 ° C for 12 hours. The samples were re-weighed to obtain the oven dry weight from which the average dry matter content was calculated. The quantity of dry matter in the cowdung was 89.8% at the time of collection and was applied at four rates of 1, 2, 3 and 4 tons ha^{-1} DM of manure. Treatments with 1, 2, 3 and 4 tons ha^{-1} DM cowdung received 3.34, 6.68, 10.02 and 13.36 kg plot^{-1} fresh cowdung respectively. At 1.12 % N concentration, varying rates of 1,2, 3, and 4 tons ha^{-1} cowdung were estimated to supply 11.2, 22.4, 33.6 and 44.8 kg ha^{-1} of N respectively.

3.5 Manure incorporation and mounding

The preparation of ridges was done on 25th December, 1996. For plots receiving *C. spectabilis* alone, the biomass was placed along the rows as marked and buried to make ridges. Where *C. spectabilis* and cowdung were combined, cowdung was placed on top of the *C. spectabilis* and ridged up. The cowdung alone manure, was placed along the rows and then buried under ridges. The control plots were prepared in the ordinary way as farmers normally do by gathering the vegetative materials in rows and mounding to form ridges.

3.6 Planting

The test crop used was an early maturing and open pollinated maize variety (MMV 400). Seeds were sown to a depth of 3 cm on 27th December, 1996. Planting was delayed due to the late onset of steady rains (Figure 1.). Three seeds were planted per station. The inter and intra-row spacings were 100 cm and 25 cm respectively giving a plant population of 120 plants $plot^{-1}$ or 40000 plants ha^{-1}.

3.7 Fertilization

All treatments in the experiment including the control received half the recommended rates of 100 kg ha^{-1} of compound D (10 N, 20 P_2O_5, 10 K_2O) for basal dressing and 100 kg ha^{-1} of urea (46 % N) for top dressing. Compound D was applied 2 weeks after planting while urea was applied 6 weeks after planting. The mode of fertilization was the spot application where fertilizer was placed in a shallow hole made on the side of each plant and covered with soil.

3.8 Thinning

Seeds emerged within seven days after planting. Seed emergence was excellent as there was at least a seedling per planting station. Two weeks after emergence all plots were thinned to one plant per station.

3.9 Weed control

Two weedings were carried out during the experimental period. Weeding was done by hand and hoe. Early weeds were smothered by re-ridging 4 weeks after planting while intermediate weeds were removed by hand pulling 3 weeks after the first weeding. The most common weeds noticed were: *Rhynchelytrium repens* and *Cyperus esculentus*.

3.10 Pests and diseases

There were no serious pest/disease problems during the growing season except for *Beseoula fusca* which set in when the crop was already mature. Therefore, no control measures were found necessary since it was not economical to do so.

3.11.0 Trial observations and measurements

3.11.1 Plant height

Plant height was the length of the maize from the ground surface up to the tip of the growing point or tip of the tassel if in bloom and where the two terminal leaves form a surface perpendicular to the ground if the tip was missing. Height measurements were determined at three intervals; at the 4–6 leaf stage, at the ear leaf stage and at the maturity stage. Only 10 randomly selected plants were sampled and measured per plot.

3.11.2 Dry matter

Dry matter assessments were conducted only for the above ground biomass and at three intervals. These were; at the 4 - 6 leaf stage , at the ear leaf and maturity stages. Six randomly selected plants were sampled from the border area of each plot. The plants were cut from the crown of the stem at ground level and weighed to obtain the fresh weight at every stage of sampling. Sub-samples were also collected for each treatment, weighed to get the initial weight and then dried in the oven at 105 °C for 12 hours when a constant weight was obtained. The samples were re-weighed to get the oven dry weights. The DM yield per hectare was calculated for 40000 plants.

3.11.3 Soil chemical analysis

Soil samples for chemical analysis were collected twice during the experimental period. The first sampling was done at the beginning of the experiment in November, 1996 and the second *sampling at the end of the experimental season in June, 1997. Soil samples were taken in a* zigzag pattern using a standard auger. The first samples were taken immediately after the field was stumped and cleared from a plough depth of 0-20 cm and composited . The final samples were collected from the ridges for selected plots, within the net plot area. Samples were air dried, sieved through a 2 mm mesh sieve and placed in polythene bags. All analyses were done at Misamfu Research Centre, except for plant and soil N concentrations which were analysed for at the University of Zambia Soil Analysis Laboratory. Total N was determined by the Kjeldalh method (Bradstreet, 1965) while available P was analysed by the Bray 1 method (Schuffelen et al., 1961) and the soil pH in a 1:2 soil to $CaCl_2$ solution ratio. Organic C was determined by the Walkley Black method and K, Ca Mg and Na were extracted in 1 M ammonium acetate (buffered at pH 7.0) and concentrations determined using Atomic absorption spectrophotometry (David, 1961).

3.11.4 Plant tissue analysis and nutrient uptake

Leaf samples were taken from the maize plants at three different stages of growth during the growing season. These were: at the 4-6 leaf stage, at the ear leaf stage and at the maturity stage. During the 4 - 6 leaf stage, six randomly selected plants sampled for the dry matter determination were used to obtain the samples for nutrient analysis. At this stage, the whole plant portion above the ground was sampled and analysed since stems were too rudimentary to be separated from the leaves. The plant samples were immediately transported to the laboratory where they were washed by sponging with a piece of cotton wool in a 0.1% detergent solution (teepoll) and rinsed in pure water and then dried in the oven set at 60 °C for 2 hours. After being adequately dried samples were ground to pass through a 0.15 mm mesh sieve into a powder according to Anderson and Ingram (1993). A sub-sample was weighed and analysed for N, P, K, Ca and Mg using methods described above.

The second sampling was done at the ear leaf stage. The analysis was done for the leaf nutrient concentration only as an indicator of sufficient levels. Six randomly selected plants sampled for the dry matter determination were used to obtain the samples for nutrient analysis. The leaf immediately below the lowest cob was sampled. If no cob/ear had developed, samples were collected from the sixth leaf from the bottom of the plant. Similarly, the samples were processed using the same procedure as at the 4 - 6 leaf stage and analysed for N, P, K, Ca and Mg using methods described above.

In the third sampling, only selected treatments were taken for both leaf and stem samples. Six randomly selected plants were used to obtain the samples for nutrient analysis. The leaf immediately below the lowest cob was sampled. For stem samples, four internodes were taken from the internode immediately below the lowest cob. The plant samples were processed using procedures and methods described above. Plant nutrient uptake was calculated on the basis of the data on plant dry matter and nutrient concentrations (Walsh and Beaton, 1983). The plant uptake at the ear-leaf stage was not calculated because the data on the nutrient concentrations for the whole plant at this stage was not collected.

3.11.5 Organic matter analysis

Leaf and twig samples were taken from cassia plant at the beginning of the trial. They were dried in the oven at 60 ° C and ground to pass through a 0.15 mm. Cowdung samples were also collected from the heap prior to the commencement of the experiment, oven dried at 40 ° C to prevent volatilisation and ground to pass through 0.15 mm mesh. All the samples were packed in polythene bags prior to analysis for organic C, N, P and K. The carbon -nitrogen ratio was also calculated. All analyses were done following procedures described above.

3.12 Statistical analysis

The data was analysed using the analysis of variance (ANOVA), Mean Separation by Duncan's Multiple Range Test and Orthogonal Contrast for the different sources of organic manures.

4.0 RESULTS AND DISCUSSION

4.1 *Soil chemical analysis*

The organic carbon concentration was 1.2 %. The soil was acidic with a pH of 4.2. The concentrations of N, P, K, Ca, Mg and Na were 0.06 %, 1.8 mg kg^{-1}, 0.7, 1.7, 6.5 and 0.2 cmolc kg^{-1} respectively. The cation exchange capacity was 0.93 cmolc kg^{-1} with a C/N ratio of 20 (Table 1). Though it was not possible to observe a lot of changes in soil chemical properties within the short run, apparent changes in the soil nutrient status resulting from treatment effects were observed. In all the selected treatments, pH values were increased above those obtained before the treatments were imposed at the beginning of the experiment (Table 2). This supports the findings of the National Research Council (1991) that adding large amounts of organic materials to the soil can reduce the acidity by raising the pH. The soil pH increased from 4.2 to 4.6 in the control and to an average of 4.4 in the treatments where organic matter was used. There were no significant differences among the individual treatments. It was not well understood why the soil pH, organic carbon, Ca and Mg concentrations were highest in the control plot. However, the control plot had some grass biomass and perhaps there is a possibility to obtain such results.

Table 1 Some chemical characteristics of the Misamfu red soil before trial establishment

pH	C	N	P	C/N	K	Mg	Ca	Na	CEC	Exc.acid	Ex. Al
($CaCl_2$)	(%)		mg kg^{-1}		cmolc kg^{-1}						
4.2	1.2	0.06	1.8	20	0.07	0.17	0.65	0.02	0.93	0.60	0.50

Although there were no significant differences in soil N concentration among treatments, appreciable increases from 0.06-0.08% were noticed. The effect of organic residue addition to the soil on organic carbon was similar to that on the soil pH status. The organic carbon levels increased from the initial 1.2% to 1.8 % in the control and this can not be explained. However. most of the materials contained in the samples were not fully decomposed as sampling was done on the ridges. All the plots treated with either cowdung or cassia were statistically the same, but the increase in organic carbon was less in plots with a combination of cassia and cowdung than in the control and the cowdung alone plots.

Table 2 Some soil chemical properties of six treatments as affected by organic matter treatments at the end of the trial.

Treatment			pH	Org.C	N	P	C/N	K	Ca	Mg	Na	CEC	Ex.acid	Ex.Al
Grass fallow	Cowdung	Cassia	CaCl2	(%)		mg kg $^{-1}$		cmolc kg $^{-1}$						
Control			4.6	1.80	0.08	6.7	23.38	0.12	0.48	0.24	0.01	0.85	0.83	0.27
	1 t/ha		4.3	1.67	0.08	6.5	21.69	0.11	0.30	0.19	0.02	0.62	0.90	0.30
	2 t/ha		4.4	1.70	0.10	7.4	17.53	0.11	0.28	0.16	0.01	0.62	1.13	0.33
		2 t/ha	4.3	1.57	0.08	9.1	20.39	0.10	0.28	0.13	0.03	0.54	1.13	0.33
	1 t/ha	2 t/ha	4.4	1.50	0.08	5.9	19.48	0.14	0.38	0.19	0.04	0.75	0.83	0.27
	2 t/ha	2 t/ha	4.3	1.57	0.08	8.9	18.92	0.10	0.24	0.12	0.04	0.50	1.13	0.30
LSD(0.05)			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)			4.68	12.09	16.18	43.49	26.28	22.30	45.13	49.97	26.00	22.8	31.46	30.43

ns=not significant at $P \leq 0.05$

This could be due to the high levels of undecomposed materials with high C/N ratio (34.7) in the cowdung and the control with a C/N ratio of 23.4 (Table 3). Generally the C/N ratios decreased in the plots with 2 tons ha^{-1} cowdung + 2 tons ha^{-1} cassia (18.9) and 1 ton ha^{-1} cowdung + 2 tons ha^{-1} cassia (19.5). The average concentration of P increased substantially from 1.8 mg kg^{-1} to 6.7 mg kg^{-1} in the control, 6.9 mg kg^{-1} in the cowdung alone, 7.4 mg kg^{-1} in the cowdung + cassia to as high as 9.1 mg kg^{-1} in the cassia alone plot. These findings are similar to results obtained by Penninkoff (1995) in the kraaling trial in which increases in P as a result of kraal manure application were observed and attributed to the increase in the bulrush millet yield. Calcium, magnesium and sodium did not show any significant changes in the concentrations though Ca decreased from the initial 0.65 cmolc kg^{-1} in all the treatments to as low as 0.24 cmolc kg^{-1} in the plot with 2 tons ha^{-1} cassia + 2 tons ha^{-1} cowdung possibly due to some leaching effect. This is contrary to the observations made by Charreau (1975) with farmyard manure which raised Ca and Mg concentrations when it was incorporated into the soil.

4.2 Organic matter analysis

The chemical composition of the organic residues used in the study are presented in Table 3. The *Cassia spectabilis* residue had a higher concentration of organic C, N, and K while P levels in cowdung were slightly higher than those in cassia. The carbon-nitrogen ratio for cassia was 12 compared to that of cowdung at 35. Generally there was a reduction in the C/N ratio for treatments with 1 ton ha^{-1} cowdung + 2 tons ha^{-1} cassia (19.5). and that of 2 tons ha^{-1} cowdung + 2 tons ha^{-1} cassia (18.9)

Table 3 Some chemical characteristics of organic residues used in the study

Source	Org. C	N	P	K	C / N
	(%)				
Cowdung	38.89	1.12	0.40	0.06	34.73
C. spectabilis	47.56	3.85	0.37	0.16	12.35

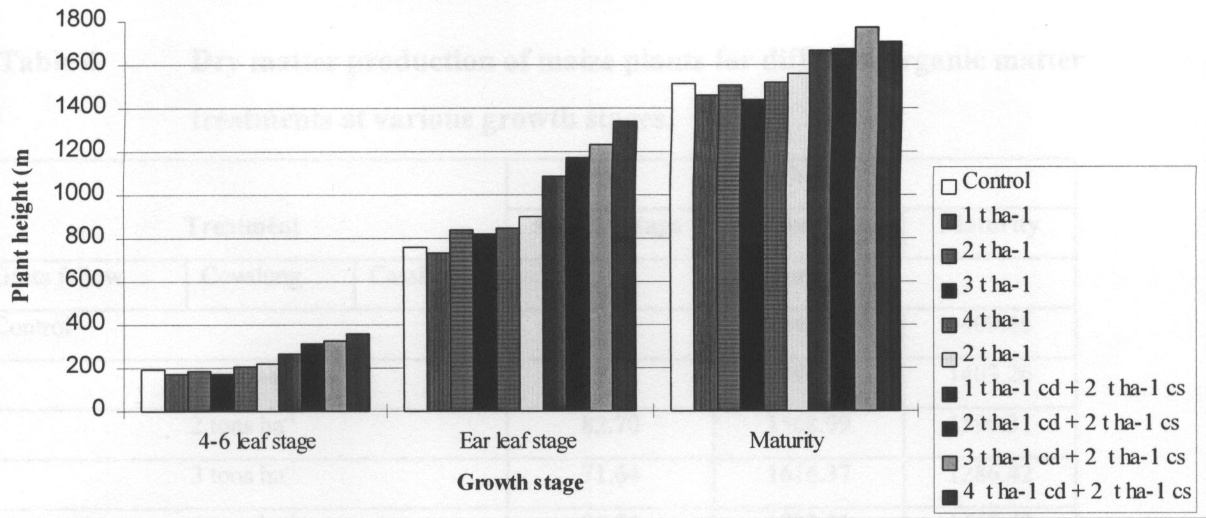
4.3.0 Effect of organic matter treatments on maize plant height

4.3.1 Plant height at the 4-6-leaf stage, ear-leaf and maturity stages

The change in the height of plants resulting from the effects of the organic manure treatments was used as a measure of growth. Plants that establish well and grow fast have high chances of survival as they are able to out grow most of the undergrowth especially weeds. In addition, they are capable of establishing an efficient canopy that allows uniform distribution of incident sunlight energy over the total leaf area (Duncan, 1978). The result of this is increased efficient interception of photosynthetically active radiation leading to increased dry matter build up and subsequent grain yield.

The information in Figure 1 shows the changes in maize plant height at various growth stages as affected by different organic matter amendments. At all the stages, significant height differences ($P \leq 0.05$) among the treatments were observed. The general trend in plant growth at the three stages was that height increased with increasing amounts of organic matter inputs. At the 4-6 leaf stage, plots receiving 1, 2, 3, 4 tons ha^{-1} cowdung alone, produced plant heights of 170, 189, 175 and 208 mm while treatments of 1, 2, 3, 4 tons ha^{-1} cowdung + 2 tons ha^{-1} cassia produced plant heights of 266, 311, 329 and 361 mm respectively. For the same treatments at the ear-leaf stage, the cowdung alone plots produced plant heights of 732, 840, 821 and 848 mm whereas the cowdung + cassia plots gave plant heights of 1084, 1173, 1232 and 1340 mm respectively. Plant heights at the maturity stage for the same treatments were 1460, 1507, 1439 and 1519 mm for cowdung alone and 1664, 1673,1775 and 1708 mm for the cowdung + cassia plots. The plants in plots with cowdung + cassia were significantly ($P \leq 0.05$) taller than those in other plots. Plots treated with cassia had plants which were numerically taller than those treated with cowdung alone and those in the control plot. Generally, there was an added advantage of combining cowdung and cassia over the control, the cowdung alone and cassia alone.

Figure 1. Maize plant height at various growth stages as affected by organic matter treatments



KEY:

t ha-1 = tons per hectare; cd = cowdung; cs = cassia spectabilis

$LSD_{0.05}$ at 4-6 leaf stage =39.93; CV = 11.35%

$LSD_{0.05}$ at ear leaf stage = 160.7; CV = 11.38%

$LSD_{0.05}$ at maturity stage = 176.9; CV = 7.69%

4.4.0 Effect of organic matter treatments on maize dry matter production

4.4.1 Maize dry matter yield at the 4-6 leaf stage

The biomass production was unusually low because of the unexpected drought and poor growth conditions experienced this year. The dry matter produced was least in the control plots with 67 kg ha $^{-1}$ and highest in the plots with a combination of cowdung and cassia (4 tons ha $^{-1}$ cowdung + 2 tons ha $^{-1}$ cassia) with 231 kg ha $^{-1}$ (Table 4). The amount of dry matter increased as organic manure inputs increased. The order of mean dry matter yield was cowdung + cassia (195.2 kg ha^{-1}*)* > cassia(87.6 kg ha^{-1}*)* > the cowdung alone plots (79.9 kg ha^{-1} *)* and least was the control (67.0 kg ha^{-1}*)*. Generally, all plants with combinations of cowdung and cassia green manure significantly ($P \leq 0.05$) accumulated the greatest amounts of dry matter. All plants treated with cowdung alone, the control plots as well as those treated with cassia did not show any significant differences in dry matter yield though numerical differences were observed. The plants treated with cassia alone responded much faster in dry matter build up than those amended with cowdung alone.

Table 4 Dry matter production of maize plants for different organic matter treatments at various growth stages.

Treatment			Plant height		
			4-6 leaf stage	Ear leaf stage	Maturity
Grass fallow	Cowdung	Cassia	(mm)		
Control			67.03	1542.44	1409.46
	1 ton ha^{-1}		69.62	1494.31	1403.26
	2 tons ha^{-1}		82.70	1568.99	1590.31
	3 tons ha^{-1}		71.64	1616.37	1286.42
	4 tons ha^{-1}		95.75	1893.81	1467.40
		2 tons ha^{-1}	87.58	1747.39	1832.40
	1 ton ha^{-1}	2 tons ha^{-1}	151.19	2694.27	2189.25
	2 tons ha^{-1}	2 tons ha^{-1}	196.95	2362.75	2144.13
	3 tons ha^{-1}	2 tons ha^{-1}	201.64	2741.30	2931.21
	4 tons ha^{-1}	2 tons ha^{-1}	231.15	2757.06	2717.31
LSD (0.05)			34.52	489.89	683.00
CV (%)			18.95	16.54	24.82

4.4.2 Maize dry matter yield at the ear-leaf stage

The highest DM yield (2757 kg ha^{-1}) was obtained from the combination of 4 tons ha^{-1} cowdung with 2 tons ha^{-1} cassia green manure whereas the lowest yield (1494 kg ha $^{-1}$) came from the 1 ton ha $^{-1}$ cowdung alone (Table 4). The trend shown at 4-6 leaf stage for the treatments in which cowdung and cassia green manure were combined was also exhibited at the ear-leaf stage. The plants in plots with cowdung + cassia had significant dry matter increases over the rest of the treatments. There was a tendency for the dry matter yield to increase as organic matter inputs increased. The plants amended with cassia alone generally gained more dry matter (1747 kg ha^{-1}) than plants in the control (1542 kg ha^{-1}) and the cowdung alone plots except for the 4 tons ha^{-1} of cowdung (1894 kg ha^{-1}). The results obtained by Reddy et al. (1986) in which green manure treatment increased maize dry matter yield from 2700 to 5700 kg ha^{-1} over the fallow control is in agreement with these findings.

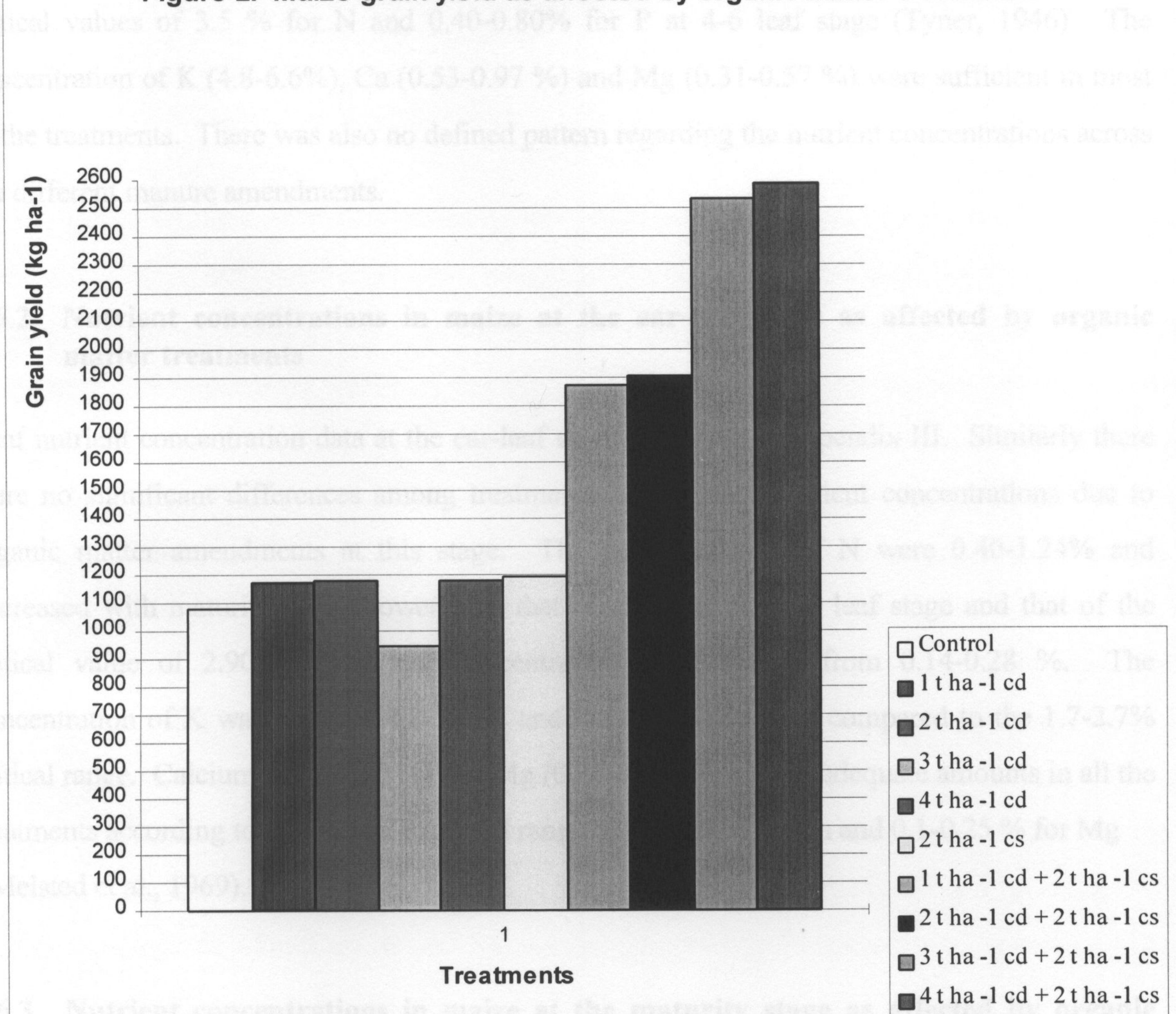
4.4.3 Maize dry matter yield at the maturity stage

There were no significant differences ($P \leq 0.05$) among the following treatments: the control, cowdung alone and the cassia alone treatments. However, the plots with cowdung + cassia had a significantly higher mean value (2495 kg ha^{-1}) of dry matter than the control (1409 kg ha^{-1}), the cassia alone (1832 kg ha^{-1}) and the cowdung alone (1437 kg ha^{-1}) treatments (Table 4). The overall observation was that there were appreciable and in some cases significant dry matter yield increases in all manured plots. Significant dry matter increases obtained by Saka and Haque (1993) when they conducted a study on the effect of cattle manure on DM yield of *Medicago sativa* are in accordance with the increases in maize dry matter noticed in this study.

4.5.0 Maize grain yield as affected by organic matter treatments

The data on the maize grain yield is presented in Figure 2. The average maize grain yields were slightly lower than expected for MMV 400 whose yield under normal agronomic and climatic conditions reaches 3500 kg ha^{-1}. This could be attributed to late planting due to delayed onset of rains and the long drought experienced at the ear leaf stage. The yields ranged from 900-2600 kg ha^{-1}. Generally, the grain yield increased as the amount of organic residues increased and was more pronounced in the cassia + cowdung treatments. The grain yield for the cowdung alone treatments ranged from 945-1182 kg ha^{-1} while that of the cowdung + cassia treatments ranged from 1874-2586 kg ha^{-1}. The lowest yield (945 kg ha^{-1}) was obtained from 3 tons ha^{-1} cowdung. The highest yield (2586 kg ha^{-1}) came from the 4 tons ha^{-1} combined with 2 tons ha^{-1} cassia. The grain yield in the control was 1082 kg ha^{-1} and 1195 kg ha^{-1} in the cassia treatment with 113 kg increase over the control though not significant. This, however, is in accordance with Bowen (1987) and Carsky (1989) who found that green manuring with different legumes especially *Mucuna* increased maize grain yield from 700 to 3700 kg ha^{-1} over the control. The findings on the cowdung treatments having no significant effect on the yield, are supported with the observations made by Munguri et al. (1996) whose results on the effect of cattle manure on quantity and application method for cattle manure showed little or no effect on maize grain yield. It was generally observed that the plants in the cassia + cowdung plots were less affected by the long dry spells experienced at the ear leaf stage and subsequently gave higher maize yields than those in other treatments. The cowdung + cassia (mean yield of 2226 kg ha^{-1}) produced significant yield increases over the control (1082 kg ha^{-1}), cassia alone (1195 kg ha^{-1}) and the cowdung alone treatments (1120 kg ha^{-1}). The cowdung + cassia treatments had 1144, 1031 and 1106 kg ha^{-1} grain yield increases over the control, cassia alone and the cowdung alone treatments respectively. These results are supported by the findings of Agbim (1988) who studied the effect of plant and animal waste combinations of cassava peels and cattle dung on the intercropping yields of yam and bean. He found that the highest yam-bean yield was obtained with the combination of 50 % cassava peels + 50 % cattle dung treatment. These observations suggest that even though cassia or cowdung used separately may be useful as good soil improvers there is need for the combined use of both plant and animal manure sources if available. This is also supported with observations made by Agbim (1985) in a field trial on the potential of cassava peels as a soil amendment applied in different proportions with poultry droppings. In this trial he concluded that while the cassava peel was a good soil amendment, there was need to incorporate the poultry droppings with the cassava peel to maximize the yield. It is observed that the yield results show some possible synergistic effects. The combined effect of ccowdung and cassia seemed to be greater than the sum of their separate effects. For instance, the yield from the combined application of 4 tons cowdung + 2 tons cassia (2586 kg ha^{-1}) was greater than the sum of individual treatments of 4 tons cowdung (1182 kg ha^{-1}) and 2 tons cassia (1180 kg ha^{-1}). It is expected that the release of nutrients from the cassia with a low C/N ratio in the early stages was complemented by the continued release from the cowdung as a slow release fertilizer. Such treatments with a combined effect are more likely to syncronize the nutrient release from the organic residues with plant demand.

Figure 2. Maize grain yield as affected by organic matter treatments



CV (%) = 7.12: Lsd $_{0.05}$ = 161.0

KEY: t ha-1 = tons per hectare; cd = cowdung; cs = Cassia spectabilis

4.6.0 Concentrations of macro nutrients in maize as affected by organic matter

4.6.1 Nutrient concentrations in maize at the 4-6 leaf stage as affected by organic matter treatments

There were no significant effects of the organic matter treatments on the plant tissue concentrations of N, P, K, Ca and Mg (Appendix II). These findings are similar to results obtained by Saka and Haque (1993) in which manure application on *Medicago sativa* did not show any significant effects on plant tissue nutrient concentration. The concentrations of N ranged between 0.78 -1.60% and that of P from 0.12-0.33% and were lower than the established critical values of 3.5 % for N and 0.40-0.80% for P at 4-6 leaf stage (Tyner, 1946). The concentration of K (4.8-6.6%), Ca (0.53-0.97 %) and Mg (0.31-0.57 %) were sufficient in most of the treatments. There was also no defined pattern regarding the nutrient concentrations across the different manure amendments.

4.6.2 Nutrient concentrations in maize at the ear-leaf stage as affected by organic matter treatments

Leaf nutrient concentration data at the ear-leaf stage are given in appendix III. Similarly there were no significant differences among treatments in the plant nutrient concentrations due to organic matter amendments at this stage. The concentrations of N were 0.40-1.24% and decreased with maturity, being lower than that observed at the 4-6 leaf stage and that of the critical value of 2.90 %. The leaf concentration of P ranged from 0.14-0.28 %. The concentration of K was between 4.8-5.3 % and was more adequate compared to the 1.7-2.7% critical range. Calcium (0.90-1.30 %) and Mg (0.24-0.52 %) were in adequate amounts in all the treatments according to the normal expected range of 0.4-1.0 % for Ca and 0.1-0.25 % for Mg (Melsted et al., 1969).

4.6.3 Nutrient concentrations in maize at the maturity stage as affected by organic matter treatments

At the maturity stage, nutrient concentrations were determined in the stem, leaf and grain portions separately (Appendix IV, V, VI). In all the portions, there were no significant effects in nutrient concentrations amongst the treatments. Generally there was a tendency for higher nutrient concentration in leaves than in stems. The N concentrations ranged from 1.63 % for 2 tons ha^{-1} cowdung + 2 tons ha^{-1} cassia to 2.10 % for the for 2 tons ha^{-1} cowdung alone, while the concentrations of P were between 0.1 % and 0.17 % and those of K were 0.06 % in all the treatments except the 1 tons ha^{-1} cowdung + 2 tons ha^{-1} cassia with 0.05 %.

4.7.0 Plant uptake of macro nutrients in maize as affected by organic manure

4.7.1 Plant uptake of macro nutrients in maize at the 4-6 leaf stage as affected by organic matter treatments

The values for plant uptake are generally low. This may be explained by the low biomass yield resulting from poor plant performance caused by the adverse weather conditions during the early stages of growth. The nutrient uptake of maize plants at the 4 - 6 leaf stage are provided in Table 5. The uptake for nitrogen was lowest in the control plot and highest under 2 tons ha^{-1} cassia + 1 ton ha^{-1} cowdung. It was observed that plants treated with either cassia alone, cowdung alone or a combination of cowdung and cassia had higher uptake values than the control. In the cassia alone, cowdung alone or a combination of cassia and cowdung plots the N uptake values were 1.69 kg ha^{-1} ,1.51-2.19 kg ha^{-1} and 3.06-5.20 kg ha^{-1} respectively as compared to 1.35 kg ha^{-1} in the control. This perhaps suggests that organic manure contributed to the increased N uptake in the manured plots rather than the control though there could be other factors. The trend in the uptake of N within the cowdung alone or the cowdung + cassia plots was not clearly shown. Plants treated with cowdung alone and cassia alone had similar N uptake. Similar results supporting these findings were reported by Wade and Sanchez (1983) that the uptake of all nutrients except Mg was enhanced when *Kudzu* was used as green manure.

Table 5 Plant uptake of major nutrients in maize leaves for different organic manure amendments at the 4 - 6 leaf stage

Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	(kg ha $^{-1}$				
Control			1.346	0.497	0.298	0.026	0.008
	1 ton ha^{-1}		2.192	0.320	0.280	0..019	0.005
	2 tons ha^{-1}		1.992	0.338	0.330	0.030	0.009
	3 tons ha^{-1}		1.513	0.330	0.286	0.018	0.005
	4 t tons ha^{-1}		1.963	0.502	0.423	0.036	0.012
		2 tons ha^{-1}	1.687	0.449	0.346	0.025	0.008
	1 ton ha^{-1}	2 tons ha^{-1}	5.196	0.596	0.814	0.064	0.020
	2 tons ha^{-1}	2 tons ha^{-1}	3.060	1.155	0.943	0.072	0.015
	3 tons ha^{-1}	2 tons ha^{-1}	4.140	0.710	0.946	0.059	0.028
	4 tons ha^{-1}	2 tons ha^{-1}	3.545	0.543	1.102	0.061	0.029
LSD (0.05)			2.410	ns	0.334	ns	0.013
CV (%)			62.36	70.06	39.87	69.25	66.41

ns=not significant $P \leq 0.05$

There was no significant pattern in P and Ca uptake observed among all treatments even though uptake figures were generally higher in the treatments with cowdung + Cassia. The average plant uptake for Ca under cowdung + cassia treatments was 0.064 kg ha^{-1}, 0.026 kg ha^{-1} for the cowdung alone, 0.026 kg ha^{-1} for the control and 0.025 kg ha^{-1} for the cassia alone plots. The uptake of P in the cowdung + cassia plots (0.751 kg ha $^{-1}$) was almost twice as much as that in the cowdung alone (0.372 kg ha $^{-1}$). The Ca uptake for the control plot was 0.497 kg ha $^{-1}$ whereas that under the cassia alone treatment was 0.449 kg ha$^{-1.}$ There was a distinct pattern in K uptake for all plots receiving a combination of cassia and cowdung manure (Figure 2). The uptake of K increased with increasing levels of organic manure inputs. The uptake value of the 2 tons ha $^{-1}$ *C* cassia alone plot (0.346 kg ha $^{-1}$) was numerically higher than the cowdung alone treatments except the 4 tons ha -1 plot (0.423 kg ha $^{-1}$). A similar pattern to that of K was observed for Mg. The uptake for the 2 tons ha^{-1} cassia + 4 tons ha^{-1} cowdung (0.029 kg ha $^{-1}$) was significantly higher than the control (0.008 kg ha $^{-1}$), the cowdung alone (0.008 kg ha $^{-1}$) and the cassia alone (0.008 kg ha $^{-1}$) treatments.

The significant increase in K and Mg uptake especially for the plots with cowdung + cassia might explain the plant growth vigour visually observed in these treatments at this stage. Generally, the uptake of N, K and Mg were enhanced in plots of Cassia, cowdung and their combination.

4.7.3 Plant uptake of macro nutrients in maize at the maturity stage as affected by organic matter treatments

There were no significant differences among the treatments in the overall plant nutrient uptake at the end of the growing season (Table 6). It is possible to obtain such results in the first cropping season when organic manures are incorporated until there is a build up effect in the long term. .However plant uptake in treatments of cassia green manure and cowdung + cassia were slightly more than the control for all the nutrients. The data generally indicates that there was some advantage in incorporating cassia alone and also combining cowdung and cassia manures to the soil. The uptake of all nutrients in the cassia green manure was greater than that cowdung alone treatment possibly because the contribution from cassia was more effective, being a relatively fast decomposer, than from the cowdung which is a slow release fertilizer. The contribution from the combination of cowdung and cassia was more effective as a result of the combined effect of the two organic sources.

Generally, uptake of N decreased while that of P, Ca and Mg increased with maturity. The N uptake could be lower probably due to leaching and volatilization losses as a result of long dry spells experienced at the beginning of the season followed by heavy rains received during the mid and towards the end of the season (Appendix I).

Table 6 Plant uptake of major nutrients in maize for different organic manure amendments at the maturity stage

Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	(kg ha^{-1}				
Control			49.85	85.92	57.82	38.60	53.10
	1 ton ha^{-1}		46.72	73.27	52.22	25.78	42.82
	2 tons ha^{-1}		49.51	67.19	61.52	28.99	53.16
		2 tons ha^{-1}	58.04	85.24	72.42	36.05	65.57
	1 ton ha^{-1}	2 tons ha^{-1}	71.35	80.19	86.75	46.66	71.44
	2 tons ha^{-1}	2 tons ha^{-1}	63.64	69.10	70.33	40.91	61.79
LSD ($P \leq 0.05$)			ns	ns	ns	ns	ns
CV (%)			24.96	43.45	34.19	42.27	31.38

ns=not significant $P \leq 0.05$

5.0 CONCLUSION AND RECOMMENDATIONS

The study gave indications of the importance of organic residue in improving soil fertility and crop yields. Appreciable increases in the soil pH, organic C, N, P though not significant were observed. The exchangeable aluminium concentrations were also reduced. An increase in plant uptake of N over the control was noticed in all plots receiving cowdung, cassia and their combination. This suggests that it is beneficial to utilise these organic materials to increase the plant uptake of N, K and Mg.

The results also showed that plant height increased with increasing organic materials at all the growth stages. The plant response to all cowdung alone treatments was slower than that to the cassia green manure treatments particularly in the early stages of growth. However the combination of cassia green manure and cowdung showed a much quicker plant response.
The results also clearly showed that the addition of both cassia and cowdung produced significant DM yield increases over the control, green manure alone and cowdung alone treatments. In addition, the treatments in which both cassia and cowdung were combined had 99%, 86% and 40% grain yield increases over the cowdung alone, the control and the cassia green manure treatments respectively. These observations suggest that in order to increase maize DM yield there is need for the combined use of both plant and animal manures if available. Generally, grain yield increased with increasing levels of manure amendments. The plots with a combination of cassia green manure and cowdung produced significant grain yield increases over the rest of the treatments.

Due to time and financial constraints, the parameters to determine the effect of organic residues on the soil physical and biological properties as major contributors to improved soil fertility and productivity were not done. It is recommended that such important parameters especially for long term studies on organic manures should not be over looked.

Studies to establish the true economic value of the organic materials used in the trial were not done. This therefore leaves room for future investigation to determine the cost/benefit analysis of the various procedures of collecting, processing and distribution/application of organic fertilisers.

Finally, the trial was the first known documentation of its kind in the study area and was conducted in only one season on a single location and therefore no concrete recommendations can be given on the basis of preliminary results alone. The experiment is therefore recommended for further investigations over seasons and across locations in order to obtain multi-locational as well as seasonal variations, as a verification, upon which sound conclusions can be drawn.

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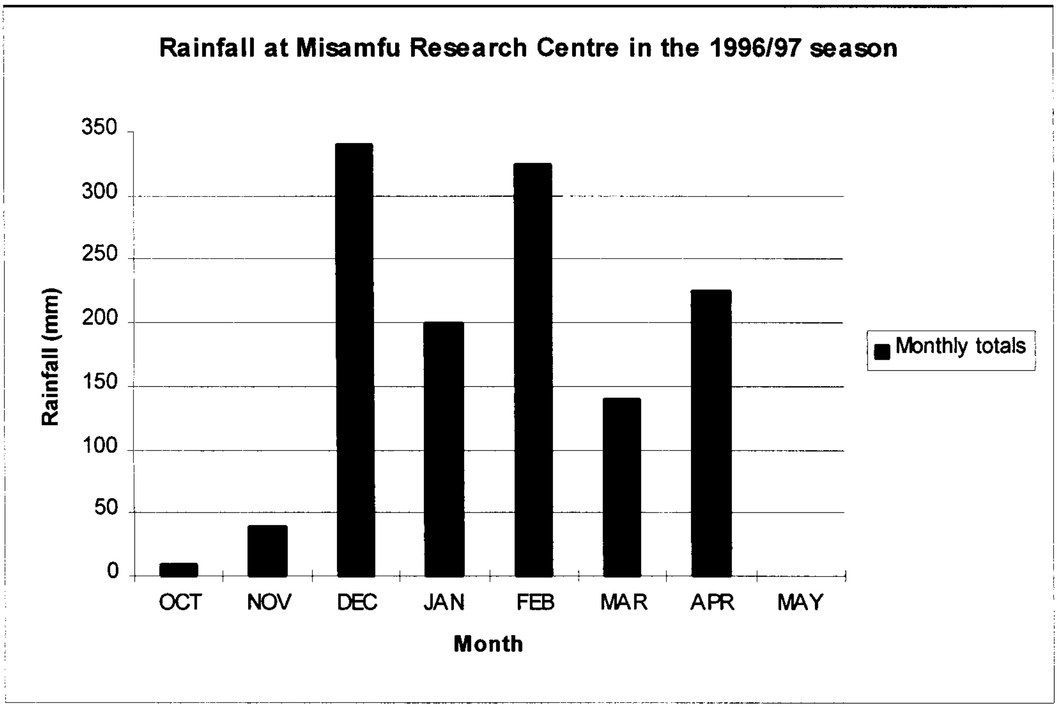
7.O APPENDICES

APPENDIX I: Rainfall at Misamfu during the experimental period



APPENDIX II Nutrient concentrations in maize at the 4-6 leaf stage as affected by organic matter treatments

Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	(%)				
Control			0.98	033	5.61	0.94	0.51
	1 ton ha^{-1}		1.41	0.30	5.53	0.71	0.31
	2 tons ha^{-1}		1.22	0.21	5.15	0.93	0.41
	3 tons ha^{-1}		0.98	0.21	4.81	0.53	0.36
	4 t tons ha^{-1}		0.98	0.22	5.45	0.93	0.57
		2 tons ha^{-1}	0.94	0.24	5.04	0.68	0.36
	1 ton ha^{-1}	2 tons ha^{-1}	1.55	0.18	6.62	0.96	0.52
	2 tons ha^{-1}	2 tons ha^{-1}	0.78	0.28	6.06	0.97	0.31
	3 tons ha^{-1}	2 tons ha^{-1}	1.03	0.17	5.90	0.75	0.56
	4 tons ha^{-1}	2 tons ha^{-1}	0.78	0.12	6.14	0.65	0.51
$LSD_{0.05}$			ns	ns	ns	ns	ns
CV (%)			46.61	62.92	25.79	56.95	51.63

ns = not significant $P \leq 0.05$

APPENDIX III Nutrient concentrations in maize at the ear-leaf stage as affected by organic matter treatments

Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	(%)				
Control			0.96	0.18	5.07	1.15	0.51
	1 tons ha^{-1}		0.94	0.16	4.89	1.14	0.24
	2 tons ha^{-1}		1.24	0.24	4.98	0.94	0.31
	3 tons ha^{-1}		0.62	0.24	5.35	1.02	0.41
	4 tons ha^{-1}		0.69	0.25	4.89	0.90	0.26
		2 tons ha^{-1}	0.42	0.28	5.21	1.29	0.36
	1 ton ha^{-1}	2 tons ha^{-1}	0.61	0.18	4.81	1.07	0.31
	2 t tons ha^{-1}	2 tons ha^{-1}	0.60	0.15	5.07	1.18	0.36
	3 tons ha^{-1}	2 tons ha^{-1}	0.51	0.20	4.81	1.30	0.41
	4 tons ha^{-1}	2 tons ha^{-1}	0.59	0.14	5.03	1.23	0.36
$LSD_{0.05}$			ns	ns	ns	ns	ns
CV (%)			63.68	58.95	13.29	23.01	42.01

ns=not significant $P \leq 0.05$

APPENDIX IV Nutrient concentrations in maize at the maturity stage as affected by organic matter treatments.

Treatment			N		P		K		Ca		Mg	
			stem	leaf	stem	leaf	stem	leaf	stem	leaf	stem	leaf
Grass fallow	Cowdung	Cassia	(%)									
Control			0.70	1.33	2.46	3.10	1.63	1.90	0.47	1.04	1.32	1.72
	1 tons ha^{-1}		0.75	1.12	2.65	1.90	1.66	2.08	0.34	0.79	1.25	1.77
	2 tons ha^{-1}		0.86	1.24	1.57	2.14	1.52	2.03	0.36	0.93	1.25	1.67
		2 tons ha^{-1}	0.75	1.14	1.26	2.94	1.38	2.19	0.31	0.93	1.34	1.74
	1 tons ha^{-1}	2 tons ha^{-1}	0.68	1.10	1.24	1.80	1.61	2.15	0.27	0.90	1.29	1.58
	2 tons ha^{-1}	2 tons ha^{-1}	0.65	0.98	1.24	1.90	1.53	1.93	0.31	0.87	1.14	1.60
$LSD_{0.05}$			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)			25.1	12.5	60.0	29.6	12.3	14.7	34.7	21.5	18.4	10.0

ns=not significant at $P \leq 0.05$

APPENDIX V Total nutrient concentration in maize plants (stem + leaf) at the maturity stage as affected by organic matter treatments

Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	(%)				
Control			2.03	5.56	3.53	1.51	3.04
	1 ton ha^{-1}		1.86	4.55	3.73	1.13	3.01
	2 tons ha^{-1}		2.10	3.71	3.55	1.29	2.92
		2 tons ha^{-1}	1.89	4.20	3.56	1.24	3.08
	1 ton ha^{-1}	2 tons ha^{-1}	1.77	3.04	3.77	1.17	2.87
	2 tons ha^{-1}	2 tons ha^{-1}	1.63	3.14	3.46	1.18	2.75
$LSD_{0.05}$			ns	ns	ns	ns	ns
CV (%)			9.95	33.19	10.12	19.58	5.51

ns=not significant at $P \leq 0.05$

APPENDIX VI Nutrient concentrations in maize grain at the maturity stage as affected by organic matter treatments.

Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	(%)				
Control			1.68	0.11	0.06	0.17	0.08
	1 ton ha^{-1}		1.68	0.17	0.06	0.17	0.1
	2 tons ha^{-1}		1.75	0.14	0.06	0.18	0.1
		2 tons ha^{-1}	1.66	0.10	0.06	0.18	0.1
	1 ton ha^{-1}	2 tons ha^{-1}	1.56	0.10	0.05	1.83	0.08
	2 tons ha^{-1}	2 tons ha^{-1}	1.63	0.10	0.06	0.18	0.1
$LSD_{0.05}$			ns	ns	ns	ns	ns
CV (%)			8.70	46.32	27.42	9.83	15.78

ns=not significant at $P \leq 0.05$

APPENDIX VII Plant uptake of macro nutrients in maize at the maturity stage as affected by organic matter

Treatment			N		P		K		Ca		Mg	
			stem	leaf	stem	leaf	stem	leaf	stem	leaf	stem	leaf
Grass fallow	Cowdung	Cassia	(kg ha $^{-1}$)									
Control			9.145	20.079	28.884	48.549	23.940	28.243	7.502	16.524	19.715	27.000
	1 ton ha^{-1}		11.129	17.252	43.939	27.718	25.199	31.559	5.167	12.039	18.142	26.070
	2 tons ha^{-1}		13.972	20.937	25.165	35.991	25.124	33.563	5.858	15.957	20.968	27.929
		2 tons ha^{-1}	14.307	22.467	24.854	54.491	26.898	41.682	6.176	17.995	25.638	33.316
	1 ton ha^{-1}	2 tons ha^{-1}	13.919	23.855	27.890	41.558	34.216	46.826	5.983	20.000	27.595	35.028
	2 t/ha	2 tons ha^{-1}	12.178	18.223	22.937	35.918	28.609	35.887	5.926	16.102	21.708	29.871
LSD $_{0.05}$			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)			20.84	39.96	64.67	39.99	29.43	33.88	52.43	43.02	32.93	30.82

ns=not significant P≤0.05

APPENDIX VIII Total plant uptake of macro nutrients in maize (leaves + stems) at the maturity stage as affected by organic matter

Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	($kg\ ha^{-1}$)				
Control			29.246	77.505	52.218	24.037	46.740
	1 ton ha^{-1}		23.995	62.915	47.966	14.518	35.872
	2 tons ha^{-1}		34.909	61.156	58.687	21.815	48.897
		2 tons ha^{-1}	36.773	79.344	68.580	24.170	58.953
	1 ton ha^{-1}	2 tons ha^{-1}	37.765	69.449	81.042	25.983	62.622
	2 tons ha^{-1}	2 tons ha^{-1}	30.400	58.855	64.496	22.028	51.580
$LSD_{0.05}$			ns	ns	ns	ns	ns
CV (%)			37.70	49.40	37.33	46.21	36.23

ns=not significant $P \leq 0.05$

APPENDIX IX Plant uptake of macro nutrients in maize grain at the

maturity stage as affected by organic matter treatments Treatment			N	P	K	Ca	Mg
Grass fallow	Cowdung	Cassia	($kg\ ha^{-1}$)				
Control			20.601	8.419	5.599	14.561	6.363
	1 ton ha^{-1}		22.726	10.356	4.266	11.257	6.948
	2 tons ha^{-1}		14.598	6.031	2.832	7.179	4.258
		2 tons ha^{-1}	21.269	5.894	3.840	11.877	6.615
	1 ton ha^{-1}	2 tons ha^{-1}	33.580	10.742	5.708	20.679	8.818
	2 tons ha^{-1}	2 tons ha^{-1}	33.244	10.247	5.838	18.877	10.208
$LSD_{0.05}$			ns	ns	ns	ns	ns
CV (%)			48.07	59.74	77.95	63.48	60.48

ns=not significant $P \leq 0.05$