THE USE OF ORGANIC WASTES IN RESTORING THE PRODUCTIVITY OF DEGRADED SOILS IN NORTHERN NIGERIAN SAVANNA

By

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Being a thesis submitted to the Post Graduate School, Ahmadu Bello University, in partial fulfilment of the requirements for the award of M.Sc. degree in Soil Science ,

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been accepted in any previous application for a higher degree. All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

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CERTIFICATION

This thesis titled "THE USE OF ORGANIC WASTES IN RESTORING THE PRODUCTIVITY OF DEGRADED SOILS IN NORTHERN NIGERIAN SAVANNA" By I.S. Abdulrahman meets the regulations governing the award of degree of Master of Science (Soil Science) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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TO

My Late Father M. B. Abdulrahman

and

My Late Uncle Alh. Ibrahim Lalo

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ABSTRACT

Two greenhouse experiments were conducted. The first experiment was to test the effectiveness of various organic materials in restoring the productivity of degraded sandy soils from Dambatta (Kano State) and Maiaduwa (Katsina State) - The amendments used were cow dung, poultry droppings, rice straw and sawdust.These were used either alone or with fertilizer and in addition to control without amendment were laid out in a randomised complete block design with three replications. The test crop used was maize which was planted after a four week incubation period- Plant height and girth were measured at weekly intervals from 10 days after emergence while dry matter yield of leaves, stems and roots were taken after harvesting- The concentrations of macro and micronutrients in the plant parts were also determined.

A second cropping was immediately carried out after harvesting and remixing of the soil- Parameters observed in the first cropping were also monitored during the second cropping.

In the second experiment, the effectiveness of ash as a nutrient source in improving crop growth was evaluated. A soil collected from a field at the research farm of the Institute for Agricultural Research, Samaru was used in this study. The ash obtained by burning crop

residue in a drum was used at the rate of 0, .1000, 2000, 3000 and 4000 kg/ha. This was applied either alone or with N fertilizer at the rate of 0,120,240ppm or with complete nutrient solution(CNS)- Maize was used as the test crop and the parameters measured included plant height and girth at weekly intervals, dry matter yields of leaves, stem and roots and the nutrient element concentrations in the three plant parts.

Poultry droppings, cow dung and rice straw all improved crop performance as reflected in plant height, girth and dry matter yields while sawdust depressed all three parameters. Fertilizer addition complemented the effects of these amendments. Poultry droppings, cow dung and rice straw increased concentrations of plant nutrients while sawdust decreased these. Poultry droppings proved best in restoring the productivity of these soils followed by cow dung then rice straw. Crop performance was generally better on Maiaduwa than Dambatta soil and also generally better in the second than the first cropplngs. Increasing levels of ash improved the growth of maize crop more so with the addition of N.

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CHAPTER ONE

INTRODUCTION

The soil has been and will continue to be the main medium for the production of food by man. Although it is possible to grow crops in hydroponics or obtain foodstuff such as proteins by single cell cultures, the biotechnology requires a lot of capital and can be justified only in special cases. It is therefore important to manage the soil in such a way as to minimise its exhaustion and/or degradation in order to keep it permanently productive. Shields (1974) regarded soil degradation as being synonymous with soil misuse or mismanagement.

Soil degradation implies a deterioration in productive capacity and has been defined as the decline in soil quality caused through its use by humans. This includes physical, biological and chemical deterioration. Decline in structural condition, adverse changes in salinity, acidity or alkalinity and the effect of toxic chemical pollutants or excessive inundation are all aspects of soil degradation (UNEP,1982).

The nutrient resources and physical properties dictate the fertility status of a soil to a great extent. Compared with soils of the temperate region (Cooke, 1967) and soils from the forest zone of West Africa (Nye and Greenland, 1960), savanna soils are generally low in native fertility.

They are low in essential nutrient elements and are characterised by low organic matter levels. This situation is further aggravated by the common practices of overgrazing and bush burning. Even where nutrient resources abound in the soil, their efficient utilisation depends on the suitability of the soil as a rooting medium. This is determined by the physical properties of the soil. Unfortunately, savanna soils possess poor physical properties. The soils are predominantly sandy in texture, poorly structured, high in bulk density and have low water holding capacity. Reclamation and or conservation measures must therefore be employed to restore and manage the organic matter and physical properties in order to maintain production and guard against soil degradation. A common way of achieving this is through the use of organic materials. Organic matter enhances soil fertility through increased nutrient supplies, greater cation exchange capacity or base capacity and improved physical conditions. Infact it is generally conceded that organic materials must be added to the soil frequently in order to maintain a reasonable level of organic matter and attendant desirable tilth (Marshall, 1962).

Crop residue management is a very important aspect of soil conservation and management. Many farmers use the resulting crop residue as fuel, building materials or animal

feed, therefore, depriving the soil of at least part of what it has given to the crops. Others return a little to the soil through incorporation or burning of the crop residue. Burning of crop residue forms part of seedbed preparation in traditional farming systems. But its effect on soil productivity and crop performance has not been adequately studied (IITA, 1982). For long, crop residue burning has been considered a deleterious practice. Some of the major fears are centered around volatilisation of N during burning and increased vulnerablity of the soil to erosion (Hooker et al., 1982). However, some beneficial effects are also derived by burning. Biederberk et al. (1980) reported that burning facilitates easier straw management and seedbed preparation, rids the land of diseased plants and reduce weed population.

Although most of the C, N and S are volatilised, the exchangeable cations are retained in the ash after crop residue burning. These are water soluble, therefore immediately available. This fact raises the possibility of using ash as a fertilizer for subsequent plant development (Daubenmire, 1968). Aside from its being a reservoir of nutrients, the ash also raises pH of the soil due to the abundance of alkaline earth metals in it. Such pH elevation may alter nutrient availability directly or by changing the microbial activites and mineralisation rates (Raison, 1976) and can be taken advantage of to reduce cost

incurred in the purchase of liming materals. With burning of crop residues being a common practice in this part of the country, and the fact that its effect on crop performance has not been adequately studied, it becomes necessary to evaluate such effects.

The objectives of the studies carried out here are:

1. To determine whether the productivity of a degraded soil could be improved using various organic wastes and chemical fertilizers and to determine the relative effectiveness of the materials, and

2. To determine the effectiveness of ash as a source of nutrients for improving maize dry matter production and its mineral nutrition.

CHAPTER TWO

LITERATURE REVIEW

2.1. Types and causes of soil degradation

Soil degradation could be in the form of physical, biological and chemical deterioration. These include,decline in structural conditions, erosion, adverse changes in salinity or alkalinity and the effects of toxic chemical pollutants or excessive inundation (UNEP,1982). According to Aubert(1974) forms of degradation include decreased structural stability, compaction of topsoil, soil crusting, decreased permeability and porosity, inundation of subsoil and in Feralsols, the development of Fe concretions or ironstones. Leaching of clay from topsoil and a relative coarsening of the texture are still other forms of degradation.

Aubert (1974) reported that modification of certain factors in the ecosystem particularly vegetation can result in changes in soil characteristics which constitute a virtual degradation since productivity of the soil is reduced. Kovda (1974) listed such factors as shifting cultivation, deforestation and nomadic husbandry (i.e. overgrazing) as causes of soil degadation due to the inherent mismanagement of land associated with these practices.

Aubert 1974) also reported tillage as one of the causes of soil degradation. According to Kovda (1974), soil deterioration in cultivated areas arises from oxidation of organic matter. Okigbo (1985) cited continuous use of inorganic fertilizers in soils of poor physical structure and nutrient retention characteristics as another cause of soil degradation through increased acidity which adversely affect crop growth. He also opined that exclusion of certain soil amendments when they are needed may encourage soil degradation. A typical example is excluding liming when the soil should actually be limed. This leads to Al toxicity which constitutes a form of degradation. Waterlogging has also been named as a cause of degradation (Dielman, 1974). Rice production requires flooding and waterlogging during part of the growing season but when it is replaced by another crop, such soils may be considered as degraded.

Whitney et al. (1950) identified land levelling as a cause of soil degradation. Some land levelling operations tend to leave a field devoid of part or all of the soil surface, the result being similar to that produced by erosion. Such exposed subsoils are usually low in fertility and produce poor crops (Gardner, 1941; Whitney et al., 1948). Burnet and Fisher (1956) also found that because of pulverisation and packing, land levelling affects physical properties of the soil because the organic matter and majority of the microorganisms that are present in the

surface horizon are removed thus reducing soil fertlity. Mbagwu (1981) cited topsoil removal as a cause of degradation in the form of increased silt content and decreased clay content, rapid increase in soil bulk density and reduced water holding capacities. According to Kovda (1974), of the 20 million km^2 destroyed and degraded land the world over, soil erosion, desertification, salinisation and urbanisation can be named as the main causes. Gloyne (1974) reported water and wind as elements of most importance in soil degradation through soil erosion. He also named temperature as a factor next in importance. Temperature exerts its effect by way of encouraging faster breakdown of organic matter. Recycling of industrial wastes can also lead to soil degradation. This is mainly through the addition of heavy metals, pesticides, toxic elements, soluble salts and toxic gasses to the soil (Diderichsen,1974).

2.2. The effect of soil degradation on crop yield

Aubert (1974) suggested some criteria for assessing the amount of degradation that has taken place. These include assessing the organic matter content, pH and base saturation, changes in soil profile characteristics, compaction and microbial activity. Organic matter losses modify the physical characteristics of the soil causing compaction, surface crusting and decreased cation exchange capacity and water permeabilty (Aubert, 1974). He also

commented on the loss of fertility which can be a function of denitrification or leaching, increased acidity, chemical fixation of nutrients into forms unavailable to plants. These changes in soil properties are bound to result in poor crop performance and reduced yields. Hamblin and Davies (1977) while studying structural conditions, reported that loss of organic matter associated with intensive cultivation of the soil has led to much weaker structure which may be causing yield decline through a direct influence on root growth.

Greenland (1981) stated that while the more spectacular problems of erosion, desertification and salinisation are making some areas unusable for crop production, the less spectacular problems of structural deterioration and organic matter loss frequently reduce yield to well below the real potential. Nicou and Chopart (1979) have shown how root gowth is restricted by compaction. Compaction of the subsoil is the most common degradation in the aeolian fine sandy and silty soils of the drier tropics such as the West African savanna (Greenland, 1981).

In the temperate regions, reports have indicated that soil degradation through topsoil removal resulted in severe yield reductions (Van Viets et al., 1976; Miller, 1976; Langdale et al., 1979). However, extent of yield reductions depends on the rainfall distribution (Engelstad et al., 1961). In the tropics, Lal (1976)

reported 23% reduction in maize yield following removal of 2.5 cm soil. The decline in yield was attributed to loss of organic matter content of the soil and severe reduction in the available water holding capacity (Lal,1976). Lal (1987) attributed the reduced yields generally associated with erosion to loss of rooting depth, degradation of soil structure and nutrient imbalance. Mbagwu (1981) also reported a decrease in maize grain yield by 81% at Onne, 5% at Ikenne and 32% at Illora due to removal of 5 cm soil. In Cameroon, Rehm (1978) also reported a 50% drop in maize yield with removal of 2.5 cm topsoil while 7.5 cm removal resulted in complete unproductivity of the exposed subsoil. Lal (1981) reported increased compaction and decreased clay fraction and water intake following accelerated erosion. Obi and Asiegbu (1980) also observed lower water retension capacity on severely eroded soils in southern Nigeria. Ritchey and Fox (1974) noted a reduction in available water holding capacity of Puerto Rican subsoil which led to decline in productivity.

2.3. Restoration of degraded soils

Greenland (1977) suggested that there is need to recognise specific problem areas and take remedial measures if the degradation is reversible. If on the other hand, it is not reversible, then the management methods should be changed. Soil degradation by erosion is often non-reversible particularly where a fertile topsoil is replaced by a

compact subsoil as in many areas of the humid tropics (Greenland, 1981).

Charreau and Nicou (1971) summarised some work which showed that deep cultivation is essential to correct degradation through compaction and that with simultaneous incorporation of a green manure, the porosity and transmission pores can be maintained. As an alternative to structural manipulation to improve aeration, Baver and Farnsworth (1940) suggested the use of peroxides which could be added to the soil to release oxygen.

According to Sanchez (1980), the need to raise pH in soils where acidity is the problem is met by lime application. But this solution is only practicable where lime is cheaply available suggesting that elsewhere, other measures have to be employed. Greenland (1975) put forward the use of cultivation in combination with growth of trees to recycle nutrients as one measure. Djokoto and Stephens(1961) reported that the acidification of soils resulting from continuous cultivation was reduced by the application of farmyard manure. Jones and Wild (1975) attributed this to the large base content of manure. Olsen et al. (1970) also reported an increase in soil pH resulting from manure addition. This alteration in pH may be a mechanism by which manure can change the availability of soil nutrients (Barnes et al., 1968).

According to Whitney et al. (1950) one of the major factors limiting the growth of crops in most degraded soils is nutritional in character. They concluded that such soils would be rapidly brought back to near normal production levels with either manure and or chemical fertilizers. Organic matter in addition to supplying nutrients also brings about increased water holding capacity. Fertilizer supplies nutrients to the soil which encourages greater crop growth thereby ensuring greater turnover of organic material to the soil. Due to its favourable effect on such soil properties as aggregation and aggregate stability, (Mazurak et al., 1965) suggested that manure combined with N P K fertilization may be a satisfactory reclamation measure for exposed subsoil. Aina and Egolum (1980) also made similar suggestion. Mbagwu(1981) showed that depending on the inherent fertility status of the soil and the extent of soil removal, N & P fertilizer combined in the correct proportion can effectively restore the productivity of desurfaced soil. According to Lal (1987), the adverse effects of erosion on crop yields can be mostly compensated for by additional inputs of macronutrients and micronutrients depending on the degree of degradation. But Batchelder and Jones (1972) reported that although applied fertilizer might improve the productivity of exposed subsoil, application of plant nutrients alone does not adequately compensate for the low productivity of many degraded soils. Djokoto and Stephens

(1961) also suggested that from the point of view of general improvement of soil productivity, mineral fertilizer could not substitute manures completely because of the effect of manures on soil physical properties. This observation has been reported by many other investigators (Biswas and Khosla, 1971).

There appears to be a general favourable effect of manure on soil properties. Wallingford et al. (1975) commented on the positive effect of manure on soil permeability, water holding capacity, aeration and micronutrient content. According to Tiarks et al. (1974), organic carbon content of the soil increased markedly after two years of manure application with the increase being linear with increasing amount of manure. Olsen et al. (1970) reported an increase in organic N, available P and exchangeable K, Ca and Mg contents on addition of organic manure especially at high rates. Terman et al. (1948) also indicated that manure addition doubled the K concentration in the soil solution. Iron, Zn and Mn concentrations were also increased after manure additions (Hensler et al., 1970; Wallingford et al., 1975). Jones and Wild (1975) stated that manure is an important source of cations while Bache and Heathcote (1969) reported increased levels of exchangeable cations from use of manure on savanna soil. Lombin and Abdullahi (1977) provided evidence that manure can be used to maintain the

productivity of savanna soils under continuous cropping.

2.4 Formation and nutrient content of ash

Raison (1979) referred to ash as the material that is deposited following burning of vegetation or its residue. Ash is also got from homes where firewood is used as domestic fuel. This type is often applied to the backyard gardens. Variable amounts of ash are deposited on the soil after burning. This depends on the weight and of the fuel and its degree of combustion (Raison and McGarity, 1980).

The nutrient content of ash depends on the composition of the material and the condition under which the material was burnt. A lot of studies have been carried out on the composition of plant ash (Christensen, 1973; Cromer, 1967; Grier, 1975; Miller et al. 1958). Unfortunately however, some of the ashes analysed were obtained by ashing in a muffle furnace (Jordan, 1965; Lloyd, 1975). This is likely to result in an ash with higher mineral elements than would be obtained during field burns (Raison, 1979). High amounts of P, Mg, K and Ca are released by burning forest and shrub vegetation (Nye, 1959; Nye and Greenland, 1964). When ash is added to the soil, it supplies from 46 to 595 kg K/ha and 37 to 1128 kg Ca/ha (Boyle, 1973) reported contribution from ash of 1500 to 3000kg Ca/ha, 180 as a result of ash addition. Nye and Greenland (1964) also

kg Mg/ha and from 600 to 800 kg K/ha. Ash residues are usually dominated by carbonates of alkaline and alkali earth metals (Daubenmire, 1968; Hatch, 1960; Petersen, 1970). They also contain variable amounts of silica, heavy metals sesquioxides and phosphate (Viro,1974); and small amounts of organic and inorganic N (Christensen, 1973; Petersen, 1970). Mineral N content of ash is generally low (Allen, 1964; Wehrman and Johannes, 1965). Therefore, return of available N to the soil is very little (Raison, 1979).

Suebert (1975) analysed some ash samples and found that they contain 70, 14, and 45 kg of N, P_2O_5 and K_2O/ha respectively, 240 kg/ha of dolomitic lime and substantial amounts of Mn, Fe, Cu and Zn. This indicates that not all N is lost in the process of burning (Sanchez, 1976).

2.5 Effect of ash on some soil properties

Increases in soil pH and available nutrients are common after burning. These are attributed to the deposition of ash (Ahlgren, 1960; Miller et al., 1955; Nye and Greenland, 1964; Smith, 1970). Ash initially affects the properties of upper soil layers and soil/ash interface but by leaching of soluble components or with incorporation, the lower depths also become affected (Grier, 1975). The composition of ash and the buffering capacity of the soil largely determine the increases in soil pH and available nutrients (Tryon, 1948).

Nye and Greenland (1964) reported that the pH of top 5

cm layer increased from 5.2 to 8.1 right after burning but decreased to 7.0 two years later. Seurbert (1975) also found a pH increase of from 4.0 to 4.5 in the top soil of an Alfisol. In forest situations, the pH rise may be up to 3 units or more (Uggla, 1957). Such pH increases can affect the availability of soil nutrients to plants (Moore and Adetunji, 1966; Laura and Idnani, 1974). It may also lead to an increase in effective CEC. For example, Sanchez (1976) reported that the effective CEC of a Peruvian Ultisol increased from 2.9 to 3.4 meq/100g soil during the first few months after burning. This was attributed to pH increase due to burning. Additions of partly ashed residues increased levels of total C and N in the soil (Christensen, 1973 Nye and Greenland, 1964). The amount of nutrients released by burning forest is by far greater than that released from savanna grasslands (Nye, 1959). In surface soils, such high levels of available nutrients may persist for a time after additions of ash (Allen et al., 1969; Moore and Adetunji, 1966).

Raison (1979) attributed some of the benefits derived by plants to the stimulatory effect of ash on activities of microorganisms. Such effects may be in the form of increased rates of nutrient cycling (Broadfoot and Pierce, 1939; Kucera and Ehrenriech, 1962) or increased N fixation (Jorgensen and Wells, 1973). Although many workers (Firsora, 1965; Fowels and Stephensen, 1934) claim increased

nitrification by ash, only small increases in nitrification have been recorded after additions of ash to soils (Griffith, 1946; Verona and Ciriotti,1935). Jorgensen (1973) opined that ash may change soil microbial activities by altering pH, adding organic microbial substrates or by improving availability of nutrients.

Although alkaline solutions tend to affect solubilisation of soil organic matter, no increase in availability of soil organic matter due to microorganisms has been reported (Dormaar, 1971; De Serra and Schitzer, 1972). When highly acid tropical soils were treated with ash, a temporary increase in microbial numbers was observed (Dommergues, 1952; Corbett, 1934). This was attributed to a temporary increase in soil pH and availability of nutrients (Laudelout and Dubois, 1951). However, in another study, Duggeli (1938) did not obtain any increase in bacterial number after addition of ash to the soil.

2.6 Effect of ash on plant growth and yield

Earlier workers (Hilgard, 1914; Young and College, 1948) speculated on increase in plant growth due to addition of ash. Addition of ash was found to increase the growth of eucalyptus seedlings by 25 - 31 percent (Loneragan and Loneragan, 1964; Pryor, 1960). Pre-heating the soil to 150 C has been found to give a positive response to ash in some cases (Loneragan and Loneragan, 1964). However, no such

response was observed in other cases (Pryor, 1960). Other workers (Cromer, 1970; Griffith, 1941) also reported increased plant growth due to addition of ash but the effect was not universal (Llyod, 1973; Sampson, 1944).

Different workers have reported varying results of the effect of burning on yield. Leuds (1962) reported that crop residue burning had no effect on average wheat yield. Shipley and Riegier (1977) also reported that burning did not affect yield. Wagner (1976) therefore concluded that burning of crop residues probably did not affect yields. Dormaar et al. (1979) on the other hand, concluded that long term wheat yields tended to be greater when straw was not burnt. They therefore suggested that burning of crop residues on a long term basis should be discouraged. On the other hand, Rains (1963) at Shika, showed that yields of subsequent sorghum were greatly increased when green manure was burnt instead of ploughing in. Vine (1953) obtained similar results at Ibadan. Heathcoate (1970) also obtained significantly higher yields of sorghum, cotton and maize after burning than incorporating residue. Wheat yields increased by residue burning but greatly decreased thereafter (Massee et al., 1966). In all cases, increased yield due to burning of crop residue was attributed to greater availability of plant nutrients and probably more favourable soil pH.

CHAPTER THREE

MATERIALS AND METHODS

Two greenhouse experiments were carried out at the Institute for Agricultural Research Ahmadu Bello University, Zaria (Latitude 11° 11' N and Longitude 7° 38' E)

3.2 Location

The soil samples used for the experiments were collected from three locations namely Dambatta in Kano State, Maiaduwa in Katsina State and Samaru in Kaduna State. The soil samples from the first two locations were used for the first experiment while the sample from Samaru was used for the second experiment.

3.2.1 Dambatta

Dambatta is located in the Sudan Savanna vegetation zone and falls on latitude 12° 17' N and longitude 8° 31' E (Keay, 1959). It has a mean annual rainfall of about 625-750mm confined within June to September with an average of 110-120 rainy days (Kowal and Knabe, 1972). According to D'Hoore (1964) the soils are classified as brown and reddish brown soils or lithosols and are formed from precambrian basement complex (Klinkenberg and Higgins, 1968).

As far back as 1983, it was observed that some part of the land at the Dambatta farm centre had not been able to support even weed growth let alone a successful crop for so many years. Since there was no comprehensive history of the land with regard to agro-chemicals used, it was assumed that this problem was due to exhaustion. The problem was to such an extent that mere addition of mineral fertilizers (N,P &K) alone was not effective. This prompted the setting up of experiments using cow dung and mineral fertilizers as soil amendments. These have shown promising results.

3.2.2 Maiaduwa

Maiaduwa is also located in the Sudan Savanna vegetation zone falling on latitude 13° 12' N and longitude 8° 13' E (Keay, 1959). The mean annual rainfall is about 500-625 mm confined within June to September with an average of 90-100 rainy days (Kowal and Knabe, 1972). The soils are classified as brown and reddish brown or lithosol (D'Hoore, 1964) and are formed from lower cretaceous parent material (Klinkenberg and Higgins,1968).

Some farms under the then Kaduna State Agricultural Development project including that at Maiaduwa were approaching a similar situation to that at the Dambatta farm centre. This was also attributed to soil exhaustion. Field trials using cow dung and fertilizers were also set up here with encouraging results.

3.2.3 Samaru

Samaru is located in the northern Guinea Savanna vegetation zone. The area has a mean annual rainfall of about 1050mm confined to a single 5-month rainy season from May to September (Kowal and Knabe,1972). According to D'Hoore (1964), the soils are classified as leached ferrugenous and are formed on drift material overlying basement complex (Klinkenberg and Higgins ,1968).

3.3 Soil sampling and preparation

From each of the three locations, surface (0-15cm) samples were collected. The samples were air dried by spreading them on trays in the greenhouse. After drying, the clods, especially in the Samaru soil samples, were broken using pestle and mortar and then sieved using 2mm sieve. Subsamples from each location were removed and stored in polythene bags for routine chemical and physical analyses. The rest were used for the experiments.

3.4 Experiment 1.

3.4.1 Amendments used and their preparation

Four organic materials were used as amendments. These were

1. Cow dung(CD)
2. Poultry droppings(PD)

3. Rice straw(RS)

4. Sawdust(SD)

Each of the materials was separately air dried on trays, ground using pestle and mortar and sieved through 9.75mm sieve.The materials were stored for use after taking subsamples for chemical analysis.

3.4.2 Sources and amounts of nutrients applied

1. 200ppm N as NH_4NO_3
2. 100ppm P as $KH_2PO_4.2H_2O$
3. 100ppm K as $KH_2PO_4.2H_2O$
4. 50ppm Mg as $MgSO_4.7H_2O$
5. 5ppm Zn as $ZnSO_4.7H_2O$
6. 5ppm Cu as $CuSO_4.5H_2O$
7. 5ppm Fe as $FeSO_4.7H_2O$
8. 0.25ppm B as H_3BO_3
9. 0.05ppm Mo as $(NH_4)_6Mo_7O_{24}.4H_2O$

3.4.3 Treatments and treatment combinations

Treatments in this experiment included two soils Maiaduwa(M) and Dambatta(D), two fertilizer treatments, no fertilizer (Fo) and with fertilizer (F1) and four organic materials, CD, PD, RS and SD plus a control without amendment (C). These gave twenty treatment combinations thus:-

1.	MCDF0	11.	DCDF0
2.	MPDF0	12.	DPDF0
3.	MRSF0	13.	DRSF0
4.	MSDF0	14.	DSDF0
5.	MCF0	15.	DCF0
6.	MPDF1	16.	DPDF1
7.	MCDF1	17.	DCDF1
8.	MRSF1	18.	DRSF1
9.	MSDF1	19.	DSDF1
10.	MCF1	20.	DCF1

The twenty treatment combinations were allocated randomly within a block and were replicated three times. The design of the experiment was therefore a randomised complete block design.

3.4.3 Application of amendments and fertilizer

Five kilograms of soil was weighed into each pot. Three hundred grams each of prepared amendment was weighed out and applied to the appropriate pots. This amount represented a rate of 6%. The amendment was thoroughly mixed with the soils. Fertilizers were applied in solution into appropriate pots. All pots were incubated at field capacity for four weeks to allow for decomposition.

3.4.4 Planting

At the end of the four-week incubation period, eight

seeds of maize (Var.TZPB)were planted per pot. These were thinned to 5 stands per pot five days after emergence. All pots were kept at field capacity throughout the period of experiment by wetting with deionised water.

3.4.5 Observations taken during experiment

Beginning from ten days after emergence , weekly observations were taken on :-

1. Plant height
2. Plant girth.

Plant height was measured from the soil surface to the whorl using a ruler. Plant girth was measured at the middle of the stalk of the plants by encircling the stalk with a thread and then transfering the thread on to a ruler to find the value in centimetres.

3.4.6 Harvesting

After 7 weeks of growth in the greenhouse, the plants were harvested. Each pot was harvested by cutting the plants just above the soil surface. Each plant was separated into leaves, stems and roots. The harvests were washed thoroughly in distilled water and put into labelled envelopes and dried for 2 days in an electric oven set at $65\ ^{o}C$. The dry weights were taken at the end of the two days. The roots were harvested by emptying the contents of

each pot on a polythene sheet and carefully removing the roots. The harvested roots were also treated in the same manner as the stems and leaves. The dried samples were then ground in a stainless steel Thomas Willy mill in readiness for chemical analysis. After harvesting the first crop, the soil was remixed, wetted to field capacity and cropped a second time just like the first cropping. Plant height was similarly measured while girth was measured only at 38 days after emergence. At the end of the second cropping, harvesting was carried out as was done with the first cropping.

3.5 Experiment 2.

3.5.1. Preparation of ash

Dried crop residues of rice were collected and burnt in a steel drum. The resulting ash was collected and carefully stored for use in the experiment. Subsamples were taken for chemical analyses.

3.5.2. Treatments and treatment combinations

The treatments included four nutrient levels 0ppm(No), 120ppm(N1), 240ppm(N2) and one complete nutrient solution (CNS) and five ash levels, 0(A0), 1000(A1), 2000(A2), 3000(A3), and 4000(A4) kg/ha. The CNS has the same sources and amounts of nutrients as given in 3.4.2 for experiment one but for N which was applied at 120ppm. Nitrogen was supplied as NH_4NO_3.

From these, twenty treatment combinations were obtained thus:-

1. N0A0	11. N2A0
2. N0A1	12 N2A1
3. N0A2	13 N2A2
4. N0A3	14. N2A3
5. N0A4	15. N2A4
6. N1A0	16. CNSA0
7. N1A1	17. CNSA1
8. N1A2	18. CNSA2
9. N1A3	19. CNSA3
10. N1A4	20. CNSA4

The twenty treatment combinations were randomly allocated within a block in a randomised complete block design (RBD) and replicated three times giving 60 experimental units.

3.5.3. Application of ash and fertilizer

Five Kg of soil was weighed into each pot. Ash at 1000, 2000, 3000 and 4000kg/ha was separately weighed into appropriate pots and thoroughly mixed with the soil. The fertilizers were applied in solution to appropriate pots. All pots were then watered to field capacity with deionized water.

3.5.4. Planting

Each pot was planted to 8 seeds of maize

(Var.TZPB). Five days after emergence, the plants were thinned down to five stands per pot. All pots were wetted with deionized water to keep moisture at field capacity throughout the period of the experiment.

3.5.5 Observations taken during experiment

Starting from ten days after emergence, weekly observations on plant height and girth were taken as carried out in experiment 1.

3.5.6 Harvesting

After seven weeks of growth in the greenhouse, the plants were harvested. The procedure for harvesting followed the same pattern as in experiment 1.

3.5.7 Soil analysis

The soil samples were analysed for:-

(1) pH in water (1:2 soil: water) using a Beckmann zeromatic pH meter.
(2) Available P by the Bray No.1 method
(3) Exchangeable cations extracted with neutral 1N NH_4OAC solution.
(4) Particle size distribution by the Boyoucous hydrometer method
(5) Organic carbon by Walkley and Black method and
(6) Cation exchange capacity by ammonium saturation method.

Details of the analytical procedure are as described by Juo (1979).

3.5.8. Plant, ash and amendments analyses

The leaves and stems from the first experiment were combined and analysed as tops while the roots were analysed separately. In the case of the second experiment, the three plant parts- stems, leaves and roots were analysed separately. These samples along with the ash and the organic residues used as amendments were analysed for N, P, K, Ca, Mg, Zn, Cu, Fe and Mn using procedures described by Juo (1979).

Calcium, Mg, Fe, Mn, Zn and Cu from both the soil and the plant samples were determined with the atomic absorbtion spectrophotometer while K was determined by flame photometry. Phosphoreus was determined with a spectrophotometer set at 880um. Nitrogen was determined using micro Kjeldahl's steam distillation method.

3.6 Statistical analyses

All the data collected were subjected to analysis of variance (ANOVA) using the GENSTAT PACKAGE for statistical analysis on the Institute for Agricultural Research computer.

CHAPTER FOUR

RESULTS

4.1. Physico-chemical properties of the soils used

Some of the physical and chemical properties of the soils used for the studies are shown in Table 1. The results show that these soils are dominated by sand sized particles. Clay contents are low, with Dambatta, Maiaduwa and Samaru soils having 5.0, 6.8 and 14.5% respectively. Although the Samaru soil portrayed a clay content rather too high for a typical savanna soil, Maiaduwa and Dambatta soils had values within the range for savanna soils which, according to Jones and Wild (1975) is between 6 to 8%. The soils have near neutral pH and low organic carbon, total N and available P contents.

Cation exchange capacities were low, being 0.85, 1.5 and 4.1 meq/100g for Dambatta, Maiaduwa and Samaru soils respectively. Jones and Wild(1975) reported that savanna soils have CEC less than 5 meq/100g soil. These low levels of CEC are not surprising considering the low organic matter contents of the soils. A number of workers (Fauck, 1963; Nye, 1963; and Martins, 1970) have pointed out the importance of organic matter to the exchange capacity of savanna soils. Fauck et al. (1969) reported a drop from 6.6 to 3.75 meq/100g during six years of cultivation which was attributed to rapid decline in organic matter.

Table 1. Some physico-chemical properties of the soils used

Property	Location		
	Dambatta	Maiaduwa	Samaru
Sand, (%)	89	83	79
Silt, (%)	6	10.2	6.5
Clay, (%)	5	6.8	14.5
pH,1:2,H_2O	6.0	6.1	5.7
Organic C,(%)	0.15	0.50	1.08
Total N,(%)	0.01	0.01	0.02
Available P (ppm)	0.94	1.05	2.6
CEC,(meq/100g)	0.85	1.5	4.1
Exchangeable Cations			
(Meq/100g soil)			
Ca	0.37	0.52	2.51
Mg	0.11	0.22	1.10
Na	0.08	0.07	0.04
K	0.10	0.13	0.26
Micronutrients (ppm)			
Fe	55	70	124
Mn	11	18	34
Cu	0.5	0.8	1.6
Zn	0.56	0.73	2.75

Typical of savanna region soils, the three soils exhibited low exchangeable cations and micronutrient contents. With such low fertility, addition of either chemical and/ or organic fertilizer is expected to increase fertility and enhance greater crop performance.

In Table 2 are shown the nutrient contents of the amendments used. A perusal of the same will reveal that poultry droppings (PD) has the highest content of N, P, K, Ca Mg, Ma, Fe, Mn, Zn, and Cu, followed by cow dung (CD) then rice straw (RS) and lastly sawdust (SD). Organic carbon contents showed a reverse trend thereby giving PD the lowest C:N and C:P ratios (2.02 and 0.59 respectvely) and SD the highest (129.67 and 207.5 respectively).

The nutrient contents of the ash used for the second experiment are also shown in Table 2. The ash had C and N contents of 1.07 and 0.06% respectively, P content of 11000ppm and Ca, K, Mg, Na, Fe, Mn Cu and Zn contents of 34000, 800, 3400, 1400, 272, 28, 125, and 65 ppm respectively. The C:N ratio was 17.83 while the C:P ratio was 0.97.

4.2. Effect of organic amendments and fertilizer on maize performance

4.2.1. Plant height

The effects of organic amendments with and without fertilizer on plant height during the first and second

Table 2: Nutrient contents of amendments used

Nutrient	Amendments				
	Cow dung (CD)	Rice straw (RS)	Poultry droppings (PD)	Sawdust (SD)	Ash (A)
Total N, (%)	0.34	0.31	0.59	0.06	0.06
Available P, (ppm)	4375	3256	20250	375	11000
Organic C, (%)	1.39	5.98	1.19	7.78	1.07
C:N Ratio	4.09	19.29	2.02	127.67	17.83
C:P Ratio	3.17	18.40	0.59	207.67	0.97
Ca (ppm)	12500	8500	53000	3450	34000
Mg (ppm)	3550	2600	6250	1350	3400
K (ppm)	15800	17400	6600	2400	3800
Na (ppm)	1800	1200	4300	160	1400
Fe (ppm)	550	369	775	245	272
Mn (ppm)	800	76	310	5	28
Cu (ppm)	25	10	30	10	125
Zn (ppm)	127	55	150	50	65

croppings are shown in Tables 3 and 4 and Figures 1 and 2. For both soils and at both cropping periods, plant height was not significantly affected by either amendments or fertilizer at 10 and 17 days after emergence (DAE). Slight differences were however observed. The mean analysis (Table 5) also showed similar results. Values were however generally higher for amended soil compared to the controls. At 24, 31 and 38 DAE, plant heights were significantly affected by the treatments during both croppings. Similar results were obtained after the mean data analysis.

All amendments significantly increased plant height with the exception of SD which significantly depressed it. Addition of fertilizer also significantly increased plant height. Amendments X fertilizer X soil and amendments X fertilizer interactions were also significant.

During the first cropping, soils amended with PD with or without fertilizer proved best giving significantly taller plants than the rest of the treatments. This was closely followed by CD then RS. Sawdust either alone or with fertilizer gave significantly shorter plants than the controls. During the second cropping however, the RS gave the tallest plant followed by CD and then PD. Sawdust without fertilizer as in the first cropping depressed plant height significantly but with fertilizer addition, plant height was significantly increased. The mean data analysis (Table 5) showed that the amendments improved plant

Table 3: Effect of organic amendments with and without fertilizer on plant height (1st cropping)

Treatment	Plant Height(cm) DAE			
	10	17	24	31
Maiaduwa				
No Fertilizer				
C	6.07	8.47	13.30	16.30
PD	8.56	12.70	20.17	23.10
CD	7.90	11.26	18.13	21.17
RS	7.37	9.83	17.53	20.57
SD	7.07	9.10	11.53	13.57
Fertilizer added				
C	7.23	10.33	16.37	19.60
PD	9.07	13.67	22.93	26.07
CD	8.60	12.70	21.27	24.23
RS	7.67	11.53	19.63	22.63
SD	7.40	11.03	13.07	15.13
Dambatta				
No Fertilizer				
C	5.37	7.0	12.26	15.20
PD	7.77	10.63	19.03	22.07
CD	7.13	10.10	17.33	20.37
RS	6.60	9.27	16.33	19.13
SD	6.47	8.56	10.13	12.10
Fertilizer added				
C	6.67	9.70	15.73	18.77
PD	8.60	12.70	22.10	25.07
CD	7.77	11.67	20.70	23.23
RS	6.93	11.27	18.57	21.67
SD	6.67	9.67	12.27	14.57
LSD 0.05	n.s.	n.s	0.16	0.16

Table 4: Effect of organic amendments with and without fertilizer on plant height (2nd cropping)

Treatment	Plant Height(cm) DAE			
	10	17	24	31
Maiaduwa				
No Fertilizer				
C	10.17	15.23	19.93	21.87
PD	13.10	22.10	24.33	30.97
CD	13.50	21.63	23.67	29.43
RS	13.73	21.60	25.93	31.73
SD	9.33	9.50	10.73	11.77
Fertilizer added				
C	12.67	17.16	23.50	30.83
PD	13.57	19.93	22.60	30.37
CD	16.67	25.43	27.27	32.03
RS	16.00	25.90	27.33	34.93
SD	17.77	26.23	28.17	36.40
Dambatta				
No Fertilizer				
C	10.07	15.10	19.10	20.97
PD	12.90	18.67	22.57	24.87
CD	15.90	22.60	23.33	24.93
RS	10.43	17.37	24.93	36.07
SD	8.97	9.20	10.80	11.83
Fertilizer added				
C	13.73	16.17	22.73	25.43
PD	12.27	16.43	19.50	23.17
CD	17.97	23.17	26.37	28.77
RS	16.23	23.23	27.00	38.23
SD	15.27	23.40	27.43	38.20
LSD 0.05	n.s	n.s	1.37	1.64

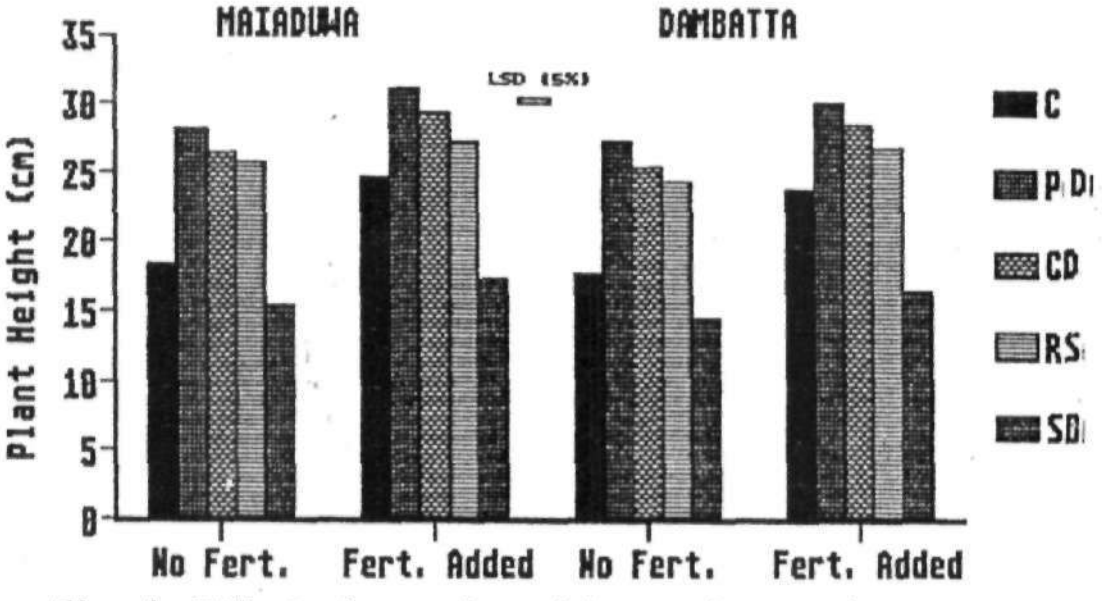


Fig. 1: Effect of organic and inorganic ammendments on plant height 38 days after emergence (Cropping I)

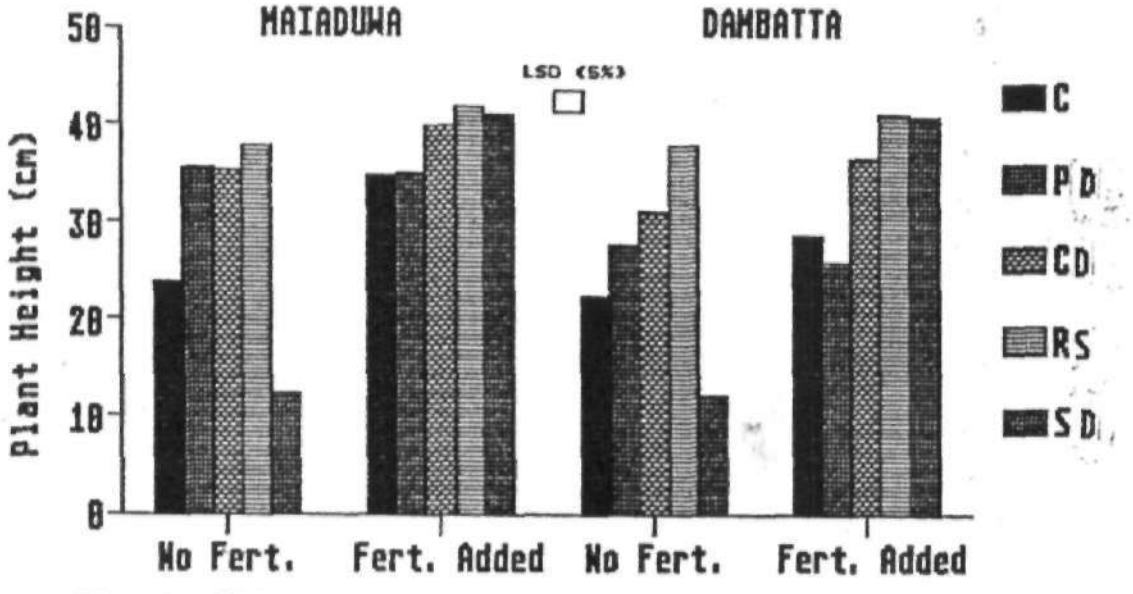


Fig. 2: Effect of organic and inorganic amendments on plant height 38 days after emergence (Cropping II)

Table 5: Effect of organic amendments with and without fertilizer on plant height and girth (mean)

Treatment	Plant Height (cm) DAE 10	17	24	31	38	Girth (cm) 38DAE*
Maiaduwa						
No Fertilizer						
C	8.12	11.85	16.16	18.63	20.68	1.92
PD	10.83	17.40	22.25	28.03	31.80	2.90
CD	10.70	16.45	20.90	25.80	32.18	2.57
RS	10.55	15.72	21.90	26.15	32.82	2.41
SD	8.02	9.30	11.13	12.79	13.86	1.39
Fertilizer added						
C	10.20	13.25	19.89	24.80	29.20	2.39
PD	10.32	16.80	22.77	29.22	33.03	3.26
CD	12.62	19.07	24.27	28.13	34.55	3.22
RS	11.83	18.72	23.48	28.79	34.72	2.96
SD	12.58	18.62	19.63	23.79	29.10	2.37
Dambatta						
No Fertilizer						
C	7.72	11.05	15.70	18.53	19.23	1.57
PD	10.33	14.65	20.80	23.17	27.30	2.64
CD	11.52	16.35	20.33	22.65	28.20	2.53
RS	8.52	13.32	20.63	27.60	31.08	2.32
SD	7.72	8.88	10.49	11.92	13.12	1.33
Fertilizer added						
C	9.95	13.45	19.73	23.52	27.57	2.06
PD	10.13	14.57	20.88	24.43	27.93	3.03
CD	12.87	16.42	23.22	26.10	33.62	2.98
RS	11.58	17.25	23.79	29.95	34.23	2.80
SD	10.99	16.53	19.23	22.38	25.58	2.04
LSD 0.05	NS	N.S	0.69	0.82	1.45	0.10

* Second Cropping.

height in the decreasing order RS > CD > PD with SD depressing plant height whether applied alone or combined with fertilizer. At both croppings and with all amendments, with and without fertilizers, plants were generally taller on Maiaduwa than on Dambatta soils. Amendments and fertilizers therefore appear to be more effective on the former than on the latter soil. This may be as a result of the differences in the initial fertility levels of the soils (Table 1). Plant heights at comparable days after emergence for corresponding treatments were significantly higher in the second cropping compared to the first cropping.

The results of the plant heights taken at 38 DAE for the two croppings appear in Figures 1 and 2. As earlier mentioned, all amendments improved plant height relative to the control with the exception of SD which depressed it. During the first cropping, on Maiaduwa soil, PD CD and RS without fertilizer increased plant height relative to the control by 54, 44 and 40% respectively, while SD depressed plant height by 35% in relation to the control. With addition of fertilizer to the amendments, the increases in height were by 26, 19 and 11% for PD, CD and RS respectively in relation to the control with fertilizer.

During the second cropping on Maiaduwa soil, plant height increased by 49, 48 and 59% respectively with PD, CD and RS additions. The decrease in height with addition of SD alone was by as much as 46%. In this cropping, where

fertilizer was added to the amendments, CD, RS, and SD increased plant height compared to the control with fertilizer by 14, 20 and 18% respectively. Similar results were observed with Dambatta soil at both cropping but percentage increases or decreases were generally greater on Maiaduwa than on Dambatta soils.

4.2.2. Plant girth

The effects of organic amendments with and without fertilizer on plant girth during the two croppings are shown in Table 6. Plant girth during the second cropping was taken only once at 38 DAE (Table 6). As with plant height results, plant girth was not significantly affected by the amendments or fertilizer at 10 and 17 DAE, but slight increases in girth due to addition of amendments and or fertilizer were evident. At 24 and 31 DAE during the first cropping, treatments resulted in significant increases in girth compared to the control. Fertilizer also significantly affected plant girth. The interaction between amendment and fertilizer and also that of amendment x fertilizer x soil were significant. The mean data analysis (Table 5) also exhibited similar results.

While all other amendments with or without fertilizer increased plant girth significantly, sawdust alone reduced girth compared to the control. These observations were true for both croppings and for the mean data

Table 6: Effect of organic amendments with and without fertilizer on plant girth (1st and 2nd croppings)

Treatment	Plant Girth(cm) DAE		First Cropping			Second Cropping
	10	17	24	31	38	38 DAE
Maiaduwa						
No Fertilizer						
C	0.85	1.29	1.45	1.51	1.54	2.23
PD	1.18	1.38	1.74	1.89	2.56	3.23
CD	1.03	1.34	1.66	1.79	2.20	3.10
RS	1.01	1.26	1.63	1.64	1.88	2.93
SD	1.00	1.19	1.30	1.41	1.47	1.30
Fertilizer added						
C	0.94	1.35	1.50	1.68	1.70	2.93
PD	1.28	1.50	1.77	2.20	3.40	3.73
CD	1.12	1.48	1.73	1.92	2.81	3.60
RS	1.06	1.27	1.71	1.77	2.18	3.10
SD	1.06	1.24	1.45	1.52	1.61	2.53
Dambatta						
No Fertilizer						
C	0.90	1.14	1.30	1.49	1.51	1.60
PD	1.14	1.30	1.73	1.86	2.46	3.14
CD	1.02	1.43	1.60	1.75	2.03	3.03
RS	0.99	1.35	1.57	1.67	1.80	2.83
SD	0.91	1.25	1.30	1.42	1.45	1.20
Fertilizer added						
C	0.96	1.27	1.50	1.68	1.72	2.40
PD	1.25	1.37	1.80	2.13	3.09	3.41
CD	1.20	1.30	1.70	1.87	2.75	3.20
RS	1.11	1.24	1.65	1.75	2.20	2.95
SD	0.95	1.28	1.46	1.51	1.52	2.12
LSD 0.05	NS	NS	0.05	0.04	0.06	0.19

analysis (Table 5). Whether used alone or with fertilizer during both croppings, amendments improved plant girth in the order PD > CD > RS. Similar order was observed with the mean data. This indicates that irrespective of cropping period, PD was the best in terms of plant girth improvement followed by CD then RS with SD having a depressive effect on plant girth. Corresponding treatments showed greater girths on Maiaduwa soil than Dambatta. Plant girths were also observed to be significantly greater for corresponding treatments during the second cropping as compared to the first.

4.2.3. Dry matter yield

The effect of organic amendments and fertilizer on the dry matter yields of leaves, stems and roots at both cropping periods are shown in Tables 7 and 8. Significant differences were shown with addition of amendments and /or fertilizer. Interactions of amendment x fertilizer x soil were significant for leaves and stem only in the first cropping and for roots only during the second cropping. Mean data analysis (Table 9) showed that dry matter yields of the three plant parts were significantly affected by the amendments with or without fertilizer. The interaction effect of amendment x fertilizer x soil was also significant (Table 9).

Table:7 Effect of amendments with and without fertilizer on dry matter yield (1st cropping)

Treatment	Dry Matter Yield (DMY) (g/pot)		
	Leaves	Stem	Roots
Maiaduwa			
No Fertilizer			
C	1.52	0.44	0.64
PD	6.13	1.81	1.14
CD	4.20	1.49	0.82
RS	2.16	1.33	0.59
SD	1.42	0.39	0.45
Fertilizer added			
C	3.13	0.99	0.97
PD	8.74	2.41	1.78
CD	6.07	1.89	1.59
RS	3.57	1.55	0.76
SD	1.75	0.60	0.53
Dambatta			
No Fertilizer			
C	1.20	0.37	0.60
PD	5.45	1.37	0.96
CD	3.67	1.15	0.76
RS	1.73	1.07	0.51
SD	1.12	0.30	0.36
Fertilizer added			
C	2.35	0.92	0.93
PD	7.29	2.18	1.56
CD	5.45	1.52	1.36
RS	3.07	1.26	0.70
SD	1.47	0.49	0.43
LSD 0.05	0.20	0.10	n.s.

Table:8 Effect of amendments with and without fertilizer on dry matter yield (2nd cropping)

Treatment	Dry Matter Yield (DMY) (g/pot)		
	Leaves	Stem	Roots
Maiaduwa			
No Fertilizer			
C	6.24	2.34	2.32
PD	12.62	5.25	5.79
CD	11.35	4.71	5.50
RS	10.45	4.36	5.08
SD	1.76	0.42	1.94
Fertilizer added			
C	9.78	4.31	4.67
PD	16.14	7.05	8.68
CD	15.59	6.67	8.07
RS	14.36	6.45	6.76
SD	9.30	3.30	4.07
Dambatta			
No Fertilizer			
C	2.22	0.94	2.15
PD	12.19	4.83	5.75
CD	10.40	4.30	4.32
RS	10.37	3.65	3.37
SD	0.96	0.33	1.76
Fertilizer added			
C	8.49	4.19	4.07
PD	16.01	6.33	6.03
CD	14.55	5.77	5.92
RS	14.49	4.40	5.42
SD	6.90	2.21	3.69
LSD 0.05	n.s	n.s.	0.87

Table 9. Effect of organic amendments with and without fertilizer on dry matter yield (mean)

Treatment	Dry Matter Yield (DMY) (g/pot)		
	Leaves	Stem	Root
Maiaduwa			
No Fertilizer			
C	3.88	1.39	1.48
PD	9.38	3.53	3.47
CD	7.78	3.10	3.16
RS	6.31	2.85	2.84
SD	1.59	0.41	1.20
Fertilizer added			
C	6.46	2.65	2.82
PD	12.44	4.73	5.28
CD	10.83	4.28	4.83
RS	8.97	4.00	3.76
SD	5.53	1.95	2.25
Dambatta			
No Fertilizer			
C	1.71	0.66	1.38
PD	8.82	3.10	3.36
CD	7.04	2.73	2.54
RS	6.05	2.36	1.94
SD	1.04	0.32	1.06
Fertilizer added			
C	5.42	2.55	2.50
PD	11.65	4.60	3.83
CD	10.00	3.65	3.65
RS	8.78	2.83	3.16
SD	4.19	1.35	2.11
LSD 0.05	0.57	0.43	0.44

Results of dry matter yields followed the same trend as those of plant height and girth. At both croppng periods, all the three plant parts were significantly higher in amended soils than the control except those amended with SD which showed sgnificantly lower yields than the control. Fertilizer addition resulted in significant increases in dry matter yields and also significantly complemented the effect of amendments as evidenced by the increased yields where fertilizer was added to the amendment.

Generally, soils amended with PD with or without fertilizer gave the highest dry matter yields. This was followed by CD and then RS. This was true at both croppings and for both soils. Although similar results were obtained for both soils, DMY on Maiaduwa soil was consistently higher than on Dambatta. Generally, significantly higher yields were observed in the second cropping for corresponding treatments.

4.3. Effect of organic amendments with and without fertilizer on nutrient element concentration of maize

4.3.1. Maize tops

The nutrient concentrations of the maize tops (leaves + stems) as influenced by the organic amendments with and without fertilizer at both cropping periods are shown in Tables 10 and 11. The results generally reflect the nutrient status of the organic materials. For both soils

Table 10 : Effect of organic amendments with and without fertilizer on nutrient element Concentration of Shoot (1st cropping)

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
Maiaduwa									
No Fertilizer									
C	1.12	0.07	1.56	0.10	0.16	172	57	66	7
PD	3.23	0.32	2.81	0.21	0.42	625	155	125	15
CD	2.83	0.26	2.34	0.19	0.32	505	117	102	13
RS	2.28	0.24	1.86	0.16	0.20	447	92	99	12
SD	0.72	0.06	1.39	0.07	0.09	127	53	63	6
Fertilizer added									
C	2.17	0.28	2.80	0.21	0.33	502	110	123	17
PD	3.61	0.42	3.22	0.35	0.52	753	175	145	23
CD	3.26	0.31	2.92	0.29	0.41	645	133	125	22
RS	2.45	0.29	2.21	0.22	0.32	501	102	121	20
SD	1.35	0.13	1.65	0.12	0.33	167	73	72	8
Dambatta									
No Fertilizer									
C	0.76	0.05	1.15	0.11	0.12	100	41	47	4
PD	2.98	0.29	2.61	0.25	0.30	552	116	120	10
CD	2.51	0.22	2.00	0.23	0.20	428	75	116	9
RS	1.99	0.20	1.53	0.21	0.13	367	61	80	7
SD	0.58	0.03	1.20	0.08	0.08	60	41	49	3
Fertilizer added									
C	1.96	0.26	2.55	0.29	0.23	431	98	102	12
PD	3.39	0.38	2.96	0.42	0.43	688	132	124	17
CD	2.91	0.26	2.79	0.39	0.30	571	97	103	18
RS	2.33	0.24	1.92	0.30	0.21	422	77	101	15
SD	1.87	0.09	1.52	0.14	0.10	94	61	56	5
LSD 0.05	0.07	ns	0.03	ns	0.01	6.65	3.59	21.76	1.06

Table 11: Effect of organic amendments with and without fertilizer on nutrient element concentration of shoot (2nd cropping)

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
Maiaduwa									
No Fertilizer									
C	1.74	0.15	1.25	0.17	0.21	164	70	78	13
PD	3.53	0.30	3.59	0.46	0.51	591	178	138	26
CD	3.43	0.26	3.51	0.44	0.47	583	174	133	24
RS	3.41	0.21	3.50	0.44	0.46	582	172	131	23
SD	0.72	0.08	1.41	0.10	0.09	133	55	66	7
Fertilizer added									
C	3.32	0.21	2.81	0.39	0.42	577	170	127	22
PD	4.19	0.47	3.74	0.49	0.54	616	187	149	30
CD	4.05	0.36	3.71	0.45	0.50	611	187	147	29
RS	3.97	0.36	3.68	0.45	0.52	599	181	140	28
SD	3.31	0.21	2.35	0.37	0.37	562	155	123	18
Dambatta									
No Fertilizer									
C	1.50	0.11	1.55	0.15	0.18	178	59	67	9
PD	3.22	0.32	3.18	0.38	0.40	581	153	126	21
CD	3.17	0.23	3.16	0.33	0.35	573	152	123	21
RS	3.16	0.22	3.12	0.31	0.32	571	150	121	18
SD	0.60	0.06	1.10	0.07	0.07	126	43	56	5
Fertilizer added									
C	3.21	0.19	2.81	0.34	0.39	571	154	123	21
PD	3.70	0.40	3.34	0.39	0.43	601	163	138	27
CD	3.64	0.38	3.32	0.38	0.42	591	161	135	26
RS	3.61	0.37	3.28	0.36	0.42	572	159	130	23
SD	3.05	0.16	2.54	0.28	0.31	566	151	116	17
LSD 0.05	0.10	0.04	0.03	0.01	0.01	2.26	2.25	2.19	1.15

and at both the first and second croppings, the concentration of nutrient elements were significantly higher with addition of PD, CD and RS than the control with or without fertilizer. Addition of SD to these soils significantly reduced the concentration of all the nutrient elements in the tops in relation to the control especially where no fertilizer was applied. Similar results were observed with the mean data analysis (Table 12). Generally, the addition of fertilizer significantly complemented the effect of the organic materials in both soils. Nutrient concentration in maize tops after the second cropping were generally higher than the values obtained after the first (Tables 10 and 11). This is a as a result of more nutrients made available by further mineralisation during the second cropping.

4.3.2 Maize Roots

Tables 13 and 14 show the nutrient concentrations of maize roots as influenced by amendments with or without fertilizer during the first and second croppings. The amendments significantly affected concentrations of all nutrients at both cropping periods. Fertilizer additions also brought about significant differences in nutrient concentrations. During both croppings, interaction of amendment X fertilizer and also that of amendment X fertilizer X soil were all

Table12: Effect of organic amendments with and without fertilizer on nutrient element concentration of shoot (mean)

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	-----%-----					-----ppm-----			
Maiaduwa									
No Fertilizer									
C	1.31	0.09	1.56	0.17	0.17	190	58	66	8
PD	3.32	0.29	3.16	0.41	0.45	603	164	129	19
CD	3.13	0.27	2.93	0.39	0.39	544	145	118	18
RS	2.90	0.26	2.72	0.36	0.35	520	135	115	17
SD	0.72	0.06	1.40	0.10	0.09	132	54	63	7
Fertilizer added									
C	2.66	0.22	2.81	0.38	0.35	530	127	114	17
PD	3.65	0.37	3.66	0.50	0.47	665	172	136	23
CD	3.47	0.37	3.32	0.46	0.45	630	160	130	20
RS	3.32	0.32	2.94	0.45	0.43	555	145	126	18
SD	2.55	0.25	2.70	0.33	0.30	353	121	106	16
Dambatta									
No Fertilizer									
C	1.26	0.10	1.20	0.20	0.12	174	56	63	7
PD	3.07	0.27	2.86	0.29	0.33	562	133	112	15
CD	2.85	0.25	2.58	0.28	0.26	500	114	102	14
RS	2.61	0.22	2.36	0.28	0.25	474	107	100	12
SD	0.59	0.05	1.15	0.08	0.07	129	42	53	5
Fertilizer added									
C	2.64	0.25	2.45	0.32	0.30	480	126	113	15
PD	3.32	0.28	3.02	0.38	0.37	627	142	121	21
CD	3.28	0.31	2.75	0.35	0.36	587	129	120	19
RS	2.97	0.31	2.60	0.35	0.32	507	120	118	17
SD	2.38	0.23	2.43	0.26	0.23	335	108	93	13
LSD 0.05	0.04	0.01	0.02	0.01	0.01	3.5	2.12	1.93	0.78

Table 13 : Effect of organic amendments with and without fertilizer on nutrient element concentration of root (1st cropping)

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
Maiaduwa									
No Fertilizer									
C	1.39	0.05	0.81	0.20	0.08	77	52	36	7
PD	3.10	0.30	1.15	0.42	0.31	425	131	95	17
CD	2.60	0.25	1.07	0.39	0.20	305	105	71	15
RS	2.30	0.23	0.91	0.33	0.11	247	82	68	14
SD	1.48	0.04	0.70	0.15	0.05	56	41	33	8
Fertilizer added									
C	2.60	0.26	1.50	0.41	0.17	301	96	93	19
PD	3.66	0.38	1.87	0.69	0.40	487	157	115	25
CD	3.20	0.29	1.68	0.58	0.32	445	123	95	24
RS	2.56	0.26	1.30	0.44	0.21	301	102	92	21
SD	1.89	0.10	0.81	0.25	0.09	77	71	4i	10
Dambatta									
No Fertilizer									
C	1.32	0.03	0.65	0.14	0.07	57	47	29	4
PD	2.90	0.26	0.96	0.30	0.20	361	103	76	12
CD	2.16	0.19	0.90	0.27	0.12	232	83	53	10
RS	1.93	0.18	0.71	0.21	0.07	174	66	47	9
SD	1.22	0.02	0.59	0.09	0.04	35	36	28	3
Fertilizer Added									
C	2.10	0.33	1.34	0.35	0.14	241	78	79	16
PD	3.19	0.33	1.89	0.52	0.31	483	127	93	20
CD	2.76	0.24	1.43	0.42	0.23	372	112	76	19
RS	2.32	0.22	1.15	0.36	0.12	235	97	74	17
SD	1.86	0.07	0.70	0.21	0.07	55	61	31	6
LSD 0.05	0.07	NS	0.03	NS	0.01	21	3.12	2.99	1.12

Table 14: Effect of organic amendments with and without fertilizer on nutrient element concentration of root (2nd cropping)

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
Maiaduwa									
No Fertilizer									
C	1.51	0.26	0.71	0.36	0.16	95	51	43	15
PD	3.02	0.36	1.23	0.66	0.31	393	147	108	29
CD	2.91	0.33	1.22	0.46	0.27	387	142	103	27
RS	2.87	0.31	1.20	0.62	0.26	382	141	102	26
SD	0.68	0.12	0.52	0.17	0.07	62	36	36	10
Fertilizer added									
C	2.81	0.28	0.88	0.59	0.23	378	140	97	25
PD	3.70	0.50	1.29	0.69	0.34	415	157	119	33
CD	3.54	0.49	1.24	0.67	0.33	409	157	117	32
RS	3.48	0.42	0.96	0.65	0.31	398	151	101	31
SD	2.80	0.24	0.42	0.39	0.22	370	124	93	23
Dambatta									
No Fertilizer									
C	1.34	0.18	1.00	0.21	0.12	82	40	37	12
PD	3.22	0.33	1.03	0.48	0.40	372	135	94	29
CD	2.71	0.29	1.02	0.48	0.22	371	134	93	23
RS	2.64	0.28	1.01	0.45	0.20	362	130	91	22
SD	0.50	0.09	0.54	0.12	0.06	51	28	27	7
Ferilizer added									
C	2.73	0.38	0.88	0.45	0.20	371	131	91	24
PD	3.41	0.47	1.10	0.56	0.28	390	148	103	29
CD	3.32	0.46	1.02	0.53	0.27	385	147	100	28
RS	3.30	0.41	1.01	0.50	0.25	375	142	93	27
SD	2.44	0.22	0.79	0.39	0.18	359	123	85	20
LDS 0.05	0.02	0.01	0.01	0.01	0.01	2.55	1.66	1.62	1.04

significant for all nutrients but the second order interaction was not significant in the case of P and Ca during the first cropping (Table 13). The mean data showed that amendments, fertilizer and their interaction effect significantly increased the concentration of all nutrient elements.

For both soils and at both cropping periods, addition of PD, CD and RS either alone or with fertilizer significantly increased nutrient concentrations of all nutrients compared to the control. However, concentration of nutrient elements in the roots were significantly higher for Maiaduwa than Dambatta soils. Addition of fertilizer generally significantly complemented the effects of the added organic materials. Nutrient concentrations in the roots were generally higher after the second cropping compared to the first (Tables 13 and 14).

Nutrient element concentrations were generally higher in the shoot than in the root with the exception of Ca and Cu whose concentrations were higher in the root.

4.4. Effect of ash with and without fertilizer on maize performance

4.4.1. Plant height

The influence of ash with and without fertilizer on plant height at various days after emergence are shown in Table 16 and Figure 3. At 10 and 17DAE, Plant height was

Table 15: Effect of organic amendments with and without fertilizer on nutrient element concentration of root (mean)

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
Maiaduwa									
No Fertilizer									
C	1.45	0.12	0.67	0.21	0.10	79	46	36	10
PD	3.06	0.32	1.18	0.53	0.29	406	136	99	22
CD	2.73	0.28	1.14	0.51	0.23	343	123	87	21
RS	2.66	0.29	1.07	0.49	0.21	320	115	80	20
SD	1.08	0.08	0.61	0.16	0.06	50	41	34	8
Fertilizer added									
C	2.61	0.33	1.20	0.45	0.21	325	111	88	21
PD	3.37	0.39	1.49	0.65	0.33	433	149	106	28
CD	3.23	0.38	1.42	0.63	0.31	429	139	100	26
RS	3.13	0.26	1.27	0.57	0.28	355	130	98	24
SD	2.60	0.25	1.01	0.38	0.18	236	105	71	19
Dambatta									
No Fertilizer									
C	1.41	0.13	0.54	0.25	0.11	70	43	36	9
PD	2.77	0.27	0.99	0.39	0.20	366	120	85	19
CD	2.43	0.24	0.95	0.36	0.16	297	110	72	18
RS	2.56	0.25	0.86	0.34	0.15	273	101	70	17
SD	0.84	0.05	0.50	0.11	0.05	46	32	28	6
Fertilizer added									
C	2.58	0.27	1.02	0.37	0.18	301	110	76	19
PD	3.04	0.35	1.27	0.46	0.25	421	129	89	24
CD	2.87	0.33	1.27	0.45	0.23	381	125	83	22
RS	2.81	0.28	1.23	0.44	0.20	310	121	80	20
SD	2.45	0.25	0.86	0.33	0.16	215	101	61	16
LSD 0.05	0.04	0.01	0.02	0.01	0.01	10.6	1.53	1.70	0.76

Table 16. Mean plant height of maize as affected by ash with and without fertilizer

Treatment	Plant Height (cm)			
	DAE			
	10	17	24	31
N0				
Control A0	9.01	10.99	14.27	15.14
A1	10.55	13.88	16.54	18.39
A2	12.55	14.28	17.72	19.27
A3	13.27	15.28	20.88	21.05
A4	13.87	17.50	21.44	23.72
N1				
A0	9.45	13.61	14.89	16.17
A1	13.61	16.72	21.05	24.22
A2	12.44	18.22	25.05	25.47
A3	12.72	19.27	26.67	31.10
A4	13.87	22.11	28.66	33.11
N2				
A0	9.72	12.78	13.27	13.83
A1	10.55	15.11	18.44	24.83
A2	12.05	16.38	21.39	26.51
A3	12.33	17.27	23.05	32.11
A4	13.79	18.05	24.50	34.73
CNS				
A0	13.11	16.33	25.11	31.55
A1	13.62	17.55	25.39	33.05
A2	14.39	17.92	25.61	33.83
A3	13.89	18.39	26.82	35.05
A4	15.27	19.33	26.06	34.39
LSD 0.05	NS	NS	2.30	2.89

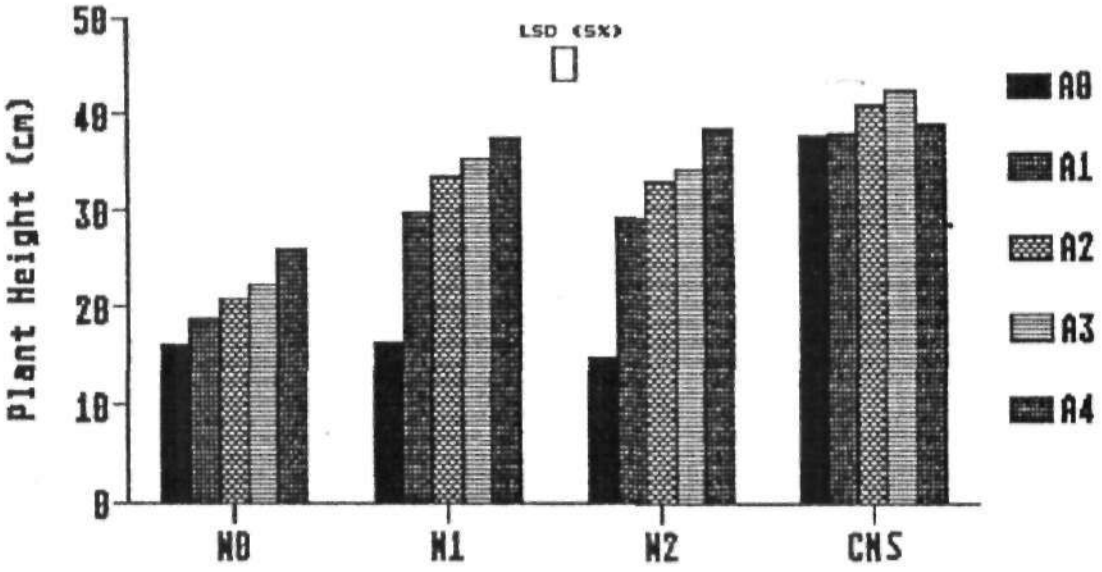


Fig. 3: Effect of ash and fertilizer on plant height 38 days after emergence

not significantly affected by the addition of ash or fertilizer. Interactions of the two were also not significant. At 24, 31 and 38 DAE, significant increases were obtained when ash was added. Fertilizer also increased plant height significantly and the interaction of ash X fertilizer was significant.

At 38 DAE, where no fertilizer was added (No), ash additions at 1000, 2000, 3000 and 4000 kg/ha increased plant height relative to the control by 17, 29, 39 and 61% respectively. At 120 ppm N (N1) and at the four levels of ash, increases in plant height in relation to the control were by 81, 104, 115 and 130% respectively. While at 240 ppm N (N2) the increases were by 95, 121, 129 and 157% for the four ash levels respectively. When complete nutrient solution (CNS) was added, increases as regards the four ash levels in relation to the control were by 1, 9, 13 and 11% respectively.

No significant differences in plant height were observed between 0, 120 and 240ppm N fertilizer additions where no ash (A0) was applied,but complete nutrient solution addition alone significantly increased plant height. Although ash alone gave significant increases in plant height compared to the control, the increase was more pronounced when ash was supplemented with fertilizer N. Plant height significantly increased with increasing rates of ash. At comparable levels of ash, complete nutrient

solution (CNS) gave the tallest plants followed by 240 ppm (N2), then 120 ppm (N1). Plant heights were lowest where no N was applied.

4.4.2. Plant girth

Table 17 shows the effect of ash with and without fertilizer on plant girth. At 10 DAE, ash or fertilizer alone did not result in significant differences in plant girth. The interaction of ash X fertilizer was also not significant. At 17, 24,31 and 38 DAE, addition of ash or fertilizer and their interactions gave significant increases in plant girth compared to the controls.

Without the addition of ash (A0), application of N alone did not produce significant changes in the plant girth. However, addition of complete nutrient solution (CNS) alone resulted in significant increase in plant girth over controls without ash. Increasing levels of ash significantly increased girth. At comparable ash levels, plant girths were greater with additions of CNS followed by those receiving N2 then N1.

4.4.3. Dry matter yield

The effect of ash and fertilizer application on dry matter yield of leaves, stems and roots are shown in Figures 4, 5 and 6 respectively. At all fertilizer levels, addition of ash significantly increased the dry matter yield of all the three plant parts. Without the addition of ash, dry

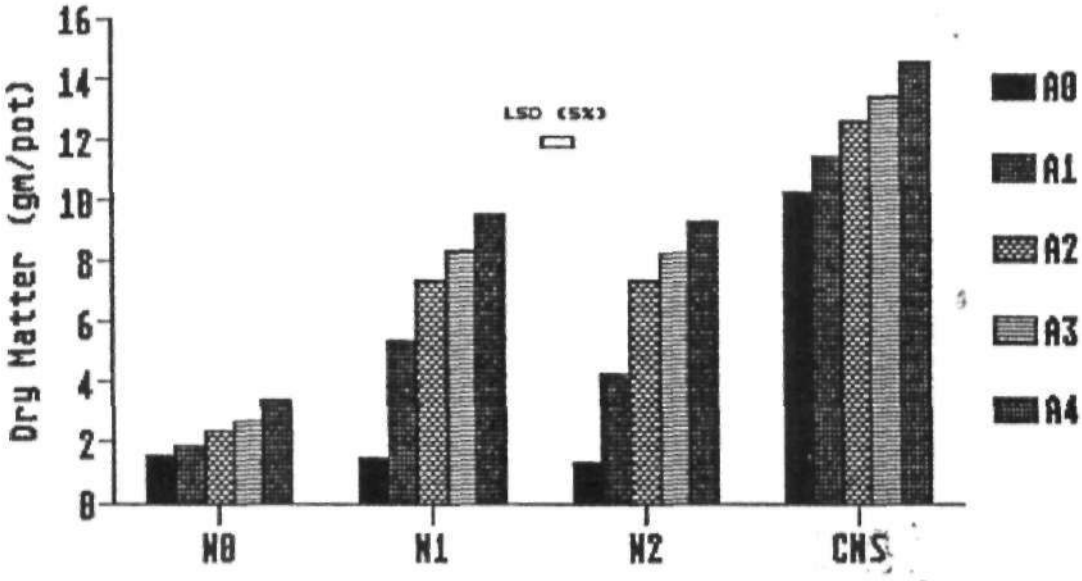


Fig. 4: Effect of ash and fertilizer on dry matter yield of leaves

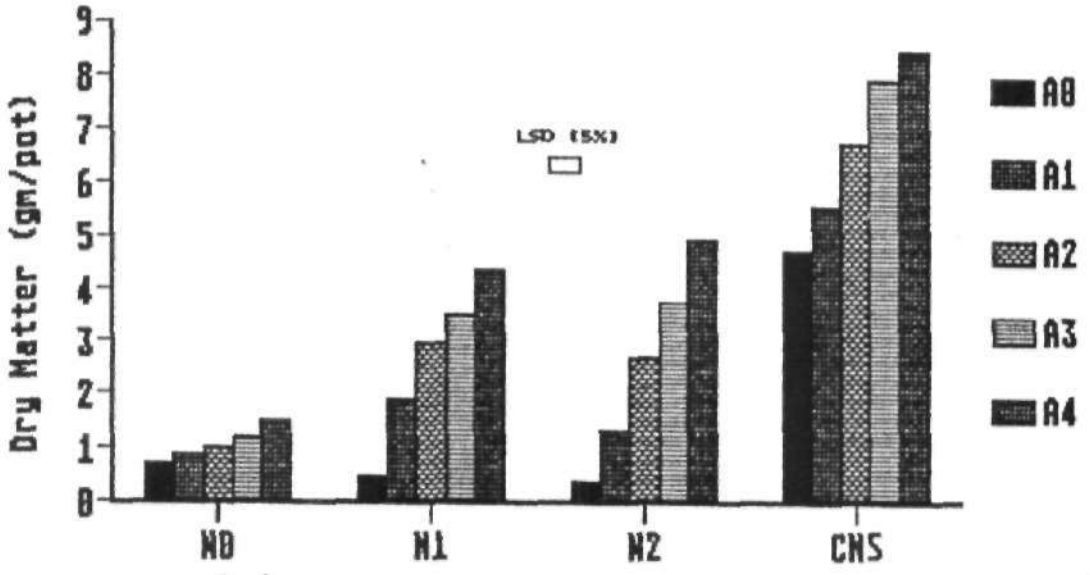


Fig. 5: Effect of ash and fertilizer on the dry matter yield of stems

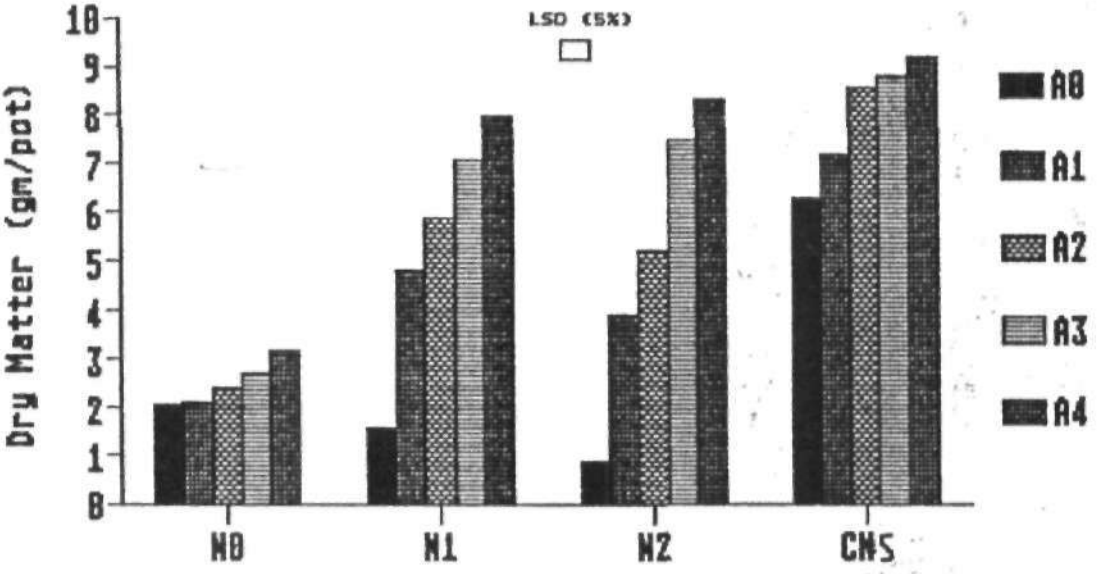


Fig. 6: Effect ofash and fertilizer on the dry matter yield of roots

Table 17: Mean girth as affected by ash with or without fertilizer

Treatment		Plant girth (cm) DAE				
		10	17	24	31	38
N0						
Control	A0	1.31	1.35	1.37	1.47	1.53
	A1	1.37	1.41	1.43	1.57	1.86
	A2	1.43	1.53	1.59	1.66	1.91
	A3	1.55	1.73	1.74	1.88	2.06
	A4	1.62	1.84	1.88	2.05	2.20
N1						
	A0	1.26	1.30	1.32	1.59	1.72
	A1	1.43	1.49	1.50	2.24	2.74
	A2	1.47	1.73	1.89	2.56	2.76
	A3	1.60	1.83	2.44	2.60	2.81
	A4	1.65	1.89	2.19	2.85	2.94
N2						
	A0	1.32	1.35	1.38	1.56	1.67
	A1	1.34	1.50	1.56	2.33	2.47
	A2	1.45	1.61	1.70	2.73	2.86
	A3	1.50	1.81	2.21	2.80	3.17
	A4	1.65	1.91	2.20	3.06	3.50
CNS						
	A0	1.39	1.80	2.03	3.17	3.22
	A1	1.44	1.82	2.20	3.34	3.46
	A2	1.51	1.81	2.31	3.42	3.51
	A3	1.58	1.85	2.36	3.44	3.55
	A4	1.62	1.95	2.44	3.55	3.56
LSD		NS	0.13	0.15	0.30	0.21

matter yields of the parts decreased with increasing levels of N fertilisation but increased significantly where complete nutrient solution (CNS) was applied. Addition of fertilizer alone increased dry matter yields significantly. Ash X fertilizer interaction was also significant. Increasing levels of ash also gave significantly higher dry matter yields of the plant parts. At comparable ash levels, dry matter yields of all the three parts were lowest where no fertilizer (No) was applied and were highest with addition of complete nutrient solution (CNS).

4.5. The effect of ash with and without fertilizer on nutrient element concentration of maize

The effect of ash with and without fertilizer on nutrient concentrations of leaves, stems and roots are shown in Tables 18, 19 and 20 respectively. Similar trends were shown by the three plant parts. At all levels of fertilizer, addition of ash significantly increased the concentrations of N, P, K, and Ca. Concentratons of these elements increased significantly with increasing levels of ash. These nutrient concentrations were similarly significantly increased with increasing levels of N fertilizer. Treatments that received CNS had the highest concentration of nutrients in all the three plant parts while those that did not receive N fertilizer (No) had the least. Magnesium concentration was significantly reduced by the ash and fertilizer treatment. This was

Table 18: Nutrient element concentration of leaves as affected by ash with and without fertilizer

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
N0									
Control	0.85	0.19	1.83	0.10	0.34	210	280	150	40
A1	0.90	0.25	2.50	0.24	0.30	215	285	156	43
A2	1.10	0.34	2.98	0.32	0.28	218	287	160	45
A3	1.20	0.38	3.27	0.41	0.26	220	293	163	47
A4	1.28	0.42	3.63	0.50	0.25	221	295	165	50
N1									
A0	0.83	0.18	1.90	0.11	0.34	160	290	155	43
A1	1.60	0.28	2.50	0.28	0.31	165	293	160	46
A2	1.79	0.40	2.96	0.37	0.29	168	296	163	47
A3	2.00	0.43	3.17	0.44	0.27	172	300	165	50
A4	2.27	0.47	3.53	0.54	0.25	176	305	170	52
N2									
A0	0.81	0.18	2.57	0.10	0.36	165	295	152	42
A1	1.72	0.30	3.07	0.35	0.33	168	297	158	47
A2	2.09	0.42	3.50	0.41	0.29	170	298	162	48
A3	2.37	0.44	3.62	0.54	0.26	175	304	163	51
A4	2.77	0.47	3.84	0.62	0.21	181	310	169	52
CNS									
A0	2.66	0.46	3.31	0.30	0.39	179	306	161	44
A1	2.78	0.56	3.54	0.34	0.34	177	310	162	45
A2	3.10	0.64	3.75	0.48	0.31	179	315	165	48
A3	3.43	0.76	3.95	0.56	0.28	180	317	167	50
A4	3.89	0.91	4.21	0.74	0.25	183	320	170	53
LSD 0.05	0.05	0.05	0.02	0.12	0.02	0.01	ns	ns	ns	ns

Table 19: Nutrient element concentration of stems as affected by ash with and without fertilizer

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
N0									
Control	0.76	0.24	1.40	0.10	0.26	70	100	75	25
A1	0.85	0.50	1.50	0.20	0.22	75	105	78	27
A2	0.96	0.28	1.70	0.26	0.20	76	107	79	29
A3	1.13	0.30	1.81	0.36	0.17	78	108	79	31
A4	1.18	0.30	1.90	0.45	0.14	80	112	83	33
N1									
A0	0.80	0.18	1.60	0.10	0.27	72	103	73	23
A1	1.39	0.30	2.07	0.23	0.24	75	106	79	26
A2	1.51	0.32	2.20	0.32	0.24	76	106	81	28
A3	1.67	0.38	2.60	0.39	0.22	79	107	83	32
A4	1.90	0.41	2.91	0.49	0.20	82	115	85	35
N2									
A0	0.69	0.11	2.30	0.10	0.30	71	105	70	21
A1	1.50	0.31	2.81	0.30	0.27	75	107	75	36
A2	1.69	0.36	3.10	0.36	0.25	77	108	79	28
A3	2.13	0.40	3.38	0.49	0.23	78	110	83	30
A4	2.40	0.43	3.52	0.57	0.21	83	115	85	35
CNS									
A0	2.21	0.42	3.17	0.26	0.34	75	110	80	30
A1	2.63	0.46	3.29	0.30	0.32	77	115	83	32
A2	2.77	0.52	3.45	0.42	0.30	79	117	85	34
A3	3.00	0.56	3.56	0.51	0.27	82	118	87	34
A4	2.89	0.63	3.72	0.69	0.26	85	121	87	36
LSD 0.05	0.22	0.01	0.04	0.01	0.01	ns	ns	ns	ns

Table 20: Nutrient element concentration of roots as affected by ash with and without fertilizer

Treatment	Nutrient element concentration								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	%					ppm			
N0									
Control	0.82	0.15	0.61	0.10	0.14	510	150	90	50
A1	0.90	0.20	0.96	0.13	0.13	515	152	93	53
A2	1.09	0.25	1.10	0.15	0.12	523	153	97	55
A3	1.18	0.28	1.21	0.17	0.12	529	155	98	57
A4	1.28	0.32	1.32	0.19	0.10	535	157	100	62
N1									
A0	0.80	0.20	0.80	0.10	0.20	500	155	93	52
A1	1.47	0.26	1.09	0.18	0.17	517	157	95	55
A2	1.70	0.31	1.21	0.24	0.15	519	159	98	56
A3	1.90	0.35	1.33	0.30	0.13	525	162	100	58
A4	2.19	0.38	1.74	0.37	0.11	534	165	105	64
N2									
A0	0.80	0.18	0.79	0.10	0.21	505	153	90	50
A1	1.70	0.28	1.19	0.21	0.19	516	158	95	56
A2	1.87	0.32	1.28	0.29	0.17	521	160	99	57
A3	2.30	0.37	1.40	0.35	0.15	525	165	104	59
A4	2.68	0.38	1.63	0.40	0.13	535	167	106	65
CNS									
A0	2.60	0.39	1.16	0.27	0.22	520	160	97	56
A1	2.75	0.41	1.21	0.33	0.21	532	163	100	57
A2	3.06	0.46	1.42	0.37	0.18	529	165	104	57
A3	3.37	0.52	1.60	0.44	0.16	534	167	106	62
A4	3.70	0.57	1.82	0.46	0.15	537	170	110	65
LSD 0.05	0.04	0.02	0.03	0.01	0.01	ns	ns	ns	ns

significantly reduced with increasing levels.

Neither ash nor fertilizer had any significant effect on Fe, Mn, Zn and Cu concentrations in all three plant parts. There were, however, slight increases in their concentration as a result of increasing levels of ash and fertilizer. Generally, fertilizer significantly complemented the effect of ash as shown by the significantly increased concentrations of N, P, K and Ca where fertilizer was added.

The concentration of the macronutrient elements were generally highest in the leaves and lowest in the roots. Manganese and Zn concentrations were highest in the leaves but lowest in the stems. Copper and Fe concentrations were highest in the roots. Iron concentration was lowest in the stem while Cu concentration was least in the leaves.

CHAPTER FIVE

DISCUSSION

5.1. Effect of organic amendments with and without fertilizer on crop performance

Amendments either alone or with fertilizer did not produce significant differences in plant height and girth at 10 and 17 DAE during both the first and second croppings. This indicates that amendments did not influence early crop development probably because the nutrients had not yet been released from the amendments. Mbagwu (1985) reported that germination and early crop development were not influenced by amendments. As from 24 DAE, plant height and girth were significantly different with addition of amendments either alone or with fertilizer showing that the amendments had influence on later plant development probably as a result of release of nutrients by mineralisation. Mbagwu (1985) reported similar observations. Aina and Egolum (1980) on the other hand, reported no significant increase in plant height on treated top soil 48 days after planting.

Poultry droppings, CD and RS generally improved plant height and girth while SD depressed both parameters. Organic materials are generally known to improve soil physical and chemical properties. Wallingford et al. (1975) reported on the positive effect of manure on soil

permeability, water holding capacity, soil aeration and micronutrient content of soils. Olsen et al. (1970) reported an increase in organic N, available P and exchangeable K, Ca and Mg due to the addition of organic material. The significant increase in crop growth (plant height and girth) may have resulted from the improvement in soil properties in one or more of the above ways when amendments were applied. Poultry droppings gave the tallest plants with biggest girths, followed by CD then RS. This may be due to the differences in the amounts of nutrients contained in the amendments (Table 2). Sawdust depressed plant height relative to the control. Its high C:N ratio (127.67) might have encouraged N immobilisation and thus its unavailability. According to Parr and Papendick (1978) residues with high C:N ratio (30 and above) are usually associated with slow decomposition rate and the N from the straw is quickly assimilated and immobilised by microorganisms. Addition of available nutrients such as N,P, and S can accelerate the decomposition of organic substrates in the soil (Stotsky and Norman,1961). However, addition of fertilizer to saw dust resulted in significantly decreased plant height and girth as compared to control with fertilizer probably as a result of immobilization of the nutrients supplied in the fertilizer by the microorganisms in the process of decomposition.

The generally taller plants with bigger girths observed

on Maiaduwa soil compared to Dambatta for comparable treatments may be due to initial fertility levels of the two soils (Table 1). Generally, plants were significantly taller and had bigger girths during the second cropping compared to the first. This may be as a result of subsequent mineralisation of the amendments. This trend therefore suggests the desirability of incubating organic materials for a fairly long time if most of the benefits are to be derived during a growing season.

The significant differences observed in dry matter yields of the three plant parts were in agreement with the findings of Aina and Egolum (1980). They reported increased dry matter yield with the addition of cattle feedlot manure and attributed this to the differential plant growth and morphology such as stem thickness or girth. Similar results were reported by Mbagwu (1985). These yield differences may have resulted from the differences in plant growth and development. Sawdust on the other hand, resulted in decreased dry matter yields of all the three plant parts. As earlier explained, this may be due to its high C:N ratio.

Comparable treatments gave higher dry matter yields on Maiaduwa compared to Dambatta soils. This may again, be due to differences in the initial fertility levels of the two soils. The dry matter yields after the second cropping were generally higher than those obtained from the first cropping probably because of the greater availability of nutrients

which resulted in better crop performance.

5.2. Effect of amendments with and without fertilizer on nutrient element concentration of maize

The nutrient concentrations of the shoot and root for both the first and second croppings significantly increased as a result of the addition of amendments.This may be due to the nutrients released by the organic residue on decomposition. Cheng(1987) reported that the addition of organic amendments increased N, P, K, Ca and Mg contents of growing medium and therefore their uptake by plants. Aina and Egolum (1980) reported increases in N, P and K concentrations in the shoot and roots of plants due to both manuring and fertilization.

Where fertilizer was added in addition to the amendments, nutrient concentrations were higher than when only amendments were applied. This may be as a result of the accelerated decomposition of the organic material due to fertilizer addition and also as a result of the nutrients added by the fertilizer. Stolzy and Norman (1961) reported that addition of available nutrients can accelerate the decomposition of organic substrates in soil.

Poultry dropping, CD and RS resulted in increases in the nutrient concentrations with PD>CD>RS. This agrees with the order in which the amendments varied in their nutrient

contents. The differences in nutrient concentration may therefore be as a result of variation in the amount of nutrients supplied by the respective materials. As earlier stated, the very high C:N and C:P ratios of SD might have been responsible for the reduction it brought about in the nutrient concentration of the plant parts.

5.3 Effect of ash with and without fertilizer on maize performance

The significant increase in plant height and girth where ash was added as compared to the controls indicate the effectiveness of ash in enhancing crop performance. Loneragan and Loneragan (1964) reported increases in the growth of eucalyptus seedlings by 25 - 51 percent due to addition of ash. Cromer (1970) also reported similar findings.

Increases in soil pH and available nutrients are common after burning crop residues. Smith (1970) and Nye and Greenland (1964) attributed this to the deposition of ash. Some of the benefits derived by plants are attributable to the stimulatory effects of ash on activities of microorganisms (Raison, 1979). The increased plant growth due to ash addition may have occcurred due to one or more of the above reasons. Plant performance became more dramatic

with the application of N fertilizer. This may be expected especially ,as a lot of mineral N is lost on burning of plant residues. Allen (1964), Wehrmann and Johannes (1965) reported ash to be generally low in mineral N content.

The better plant performance with increasing levels of ash might have been as a result of greater availability of nutrients from the ash itself or from increased pH due to its addition.

The fact that complete nutrient solution resulted in the best performance of the crop compared to 240ppm and 120ppm N indicates its superiority over the two probably beacuse it also supplied other nutrients in addition to N.

The increased dry matter yields of the three plant parts due to addition of ash was also reported by others (Okoro,1981 and Biederberk et al.,1980). This increase may have occured as a result of the effect of ash in increasing soil pH and or available nutrients or due to its stimulatory effects on activities of microorganisms. Okoro(1981) reported a significant increase in dry matter yield of maize on addition of 1126 and 2252 kg ash/ha applied either by broadcast or mixing. Biederberk et al. (1980) also reported increased wheat yield due to burning of residues in the field and attributed this to an increase in NH_4-N, and bicarbonate extractable P released as ash during burning.

5.4. Effect of ash with and without fertilizer on nutrient element concentration of maize

Nutrient contents followed similar trends with plant growth and dry matter yields. Addition of ash gave significantly higher N, P, K and Ca contents in the leaves, stems and roots. Okoro (1981) did not observe any significant effect of ash addition on concentrations of N, P, K, Mn and Zn in the plants. Ash addition significantly reduced concentration of Mg in all three plant parts. Okoro (1981) reported similar observations for Ca and Mg. The depressive effect of ash on Mg concentration could be as a result of high K content of the ash which might have depressed Mg uptake. Dewit et al. (1963) reported on the depressive effect of K on Ca and Mg in monocots. Concentration of Fe, Mn, Zn and Cu were not significantly affected by ash addition. This may be as a result of the low micronutrient content of the ash itself. Raison (1979) commented on the low micronutrient content of ash. Nutrient concentrations were generally higher with addition of fertilizer than with ash alone. Where CNS was added, the differences in nutrient content among ash levels although significant, were not as spectacular as in other cases probably because most of the demands of the plants were already satisfied with the nutrients supplied by it.

Nutrient concentration was highest in the leaves with

the exception of Fe and Cu which were highest in the roots. The occurrence of such high levels of nutrients in the roots could be as a result of their accumulation.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

Two greenhouse experiments were carried out during the studies. In the first experiment, the effects of organic materials in restoring the productivity of degraded soils were investigated. Sandy soils from Maiaduwa and Dambatta were used. The organic materials used were poultry droppings cow dung, rice straw and sawdust. These were either used alone or combined with chemical fertilizer. The twenty treatment combinations were randomly arranged in blocks and replicated three times. After application of amedments, the soil was incubated at field capacity for four weeks to allow for decomposition before planting the test crop (maize).

Plant heights and girths were measured at weekly intervals beginning from 10 DAE. Crops were harvested after seven weeks of growth. The dry matter yields of leaves, stems and roots were taken after drying the samples for 2 days at 65 C. The dried samples were ground in a mill and the tops and roots were analysed for macro- and micro-nutrients.

A second cropping was done after harvesting the first crop and remixing of the soil. All treatments were the same except that no organic amendments were added. Similar

observations were taken during the second cropping.

In the second experiment, the effectiveness of crop residue ash as a nutrient source and in improving crop growth was tested. The soil used in this study was from Samaru. The ash obtained by burning crop residues in a drum was applied at 1000, 2000, 3000 and 4000 kg/ha. This was applied either alone or in combination with N fertilizer at the rates of 0, 120, 240ppm and then a complete nutrient solution (CNS). Maize was used as the test crop.

Plant height and girth were measured at weekly interval starting from 10 DAE. At 38 DAE, after taking the last readings, plants were harvested and separated into leaves, stems and roots and the dry matter yields were determined . The samples were milled and analysed for N, P, K, Ca, Mg, Fe, Mn Cu and Zn.

From the study, the following findings were made:

1. The four amendments used contained nutrients in the order PD>CD>RS>SD.
2. Three of the amendments PD, CD and RS improved crop performance as measured by increased plant height, girth and dry matter yield. Crop performance was best enhanced by PD followed by CD then RS.
3. Fertilizer addition complemented the effects of these amendments.
4. Saw dust when used alone depressed crop performance

but when fertilizer was added, it slightly increased crop growth compared to the untreated control but reduced it compared to the control with fertilizer.

5. Nutrient concentrations in the shoot and root were generally higher with PD, CD and RS but were decreased with SD addition.

6. Greater crop performance was observed on Maiaduwa soil compared to Dambatta for corresponding treatments.

7. Crop performance was generally better during the second cropping for comparable treatments.

8. Generally the addition of ash significantly improved crop performance, which increased with increasing levels of ash. The addition of fertilizer further complemented ash effect.

9. Ash significantly increased N, P, K and Ca contents in the leaves, stems and roots, decreased Mg content and had no significant effect on concentrations of Fe, Mn, Zn and Cu.

From the foregoing, the following conclusions can be drawn:

1. The soils used for the study were poor in nutrient elements and therefore needed amelioration with external sources of nutrients.

2. Three of the organic materials, namely: poultry droppings,cow dung and rice straw can be used to improve the productivity of these degraded soils while the fourth, sawdust may not be quite suitable. The addition of fertilizer to the amendments is recommended because

of its complementary effect on the amendments.

3. Since effectiveness of the amendments was greater in the second cropping, it may be desirable to incorporate these into the soil for a much longer period than four weeks for proper decomposition.

5. Ash has been found to be a good source of nutrients and that its effect can be complemented by the addition of N fertilizer.

The organic materials poultry droppings, cow dung and rice straw are effective in correcting degradation but the availability of enough quantities may be a major constraint. Nonetheless, the little that can be procured should be returned to the soil to guard against soil degradation and improve soil structure. However, where materials with high C:N ratio such as straw are to be used, they should be applied well in advance of planting to allow for decomposition.

Crop residue ash is effective as a nutrient source.With the rising cost of fertilizers, ash could provide a ready supplement to supply plant nutrients. However, the limiting factor in the use of ash may be the necessity of having to supply N through some other source because of the low N content of the ash and also the difficulty of obtaining enough amounts. Added to this is the danger of making the soil alkaline when too much is used because of its effect in

raising soil pH. This can bring about micronutrient deficiencies.

The conclusions from these studies have to be taken with caution because they are based on greenhouse experiments and may not necessarily be the case in the field. Therefore, further studies using varying levels especially for the organic amendments may be necessary both in the greenhouse and under field conditions.

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