EVALUATION OF THE POTENTIAL OF MILLLET THRESH WASTE PRODUCTION IN THE NIGERIAN SAVANNA

By

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DECLARATION

I hereby declare that this thesis has been written by me and that it is the record of my own research work. It has not been presented before in any previous application for a higher degree.

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The above declaration is affirmed.

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CERTIFICATION

This thesis entitled "EVALUATION OF THE POTENTIALS OF MILLET THRESH WASTE FOR CROP PRODUCTION IN THE NIGERIAN SAVANNA" by Tarfa Bitrus Dawi meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

To my parents, Mr and Mrs Lawan D. Tarfa, my wife Esther and members of my family for patience, understanding and support.

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ABSTRACT

The effect of Millet (Pennesetum americanum l,.) thresh waste (MTW) applied in different proportions with cow dung (CD) with and without inorganic fertilizers, on the growth, yield and yield components of maize (Zea mays L.) was evaluated in the green house and field at Samaru using two soil textural types a sandy loam from Minjibir Jigawa state (latitude 12°-8'N and longitude 8°-40'E a loam from Samaru Kaduna state (latitude 11°-11'N and longitude 7°-38,E. The treatments consisted of 100% MTW / 0% CD: 75% MTW / 25% CD; 50% MTW / 50% CD; *25%* MTW / 75% CD and *0%* MTW / 100% CD each applied at 5 and lOt ha"^{1} with and without inorganic fertilizer. There were three controls, .absolute control without amendment and Fertilizer, half and full doses of recommended rates of fertilizer for maize. Urea, ingle superphosphate and muriate of potash were used. The treatments were replicated three times in a randomized complete block design.

During the first cropping in the green house, maize plant height, *dry* matter yield (DMY) and nutrient uptake increased as the proportion of CD increased in the mixture irrespective of the rate and ferlllizer used. The reverse was the case as the proportion of MTW increased in the mixtures, tor DMY, values obtained with 100% CD / 0% MTW applied at lOt ha"^{1} was 161.40 and 130.80% higher than those obtained from absolute control for Minjibir and Samaru soils, respectively. For these parameters, mixtures containing 75% *CD* and above applied at 5t ha" with fertilizer gave values comparable to when the recommended dose of fertilizer was applied. When 100% CD

/ 0%MTW was applied at both 5 and l0 t ha , DMY was significantly higher than at half the recommended dose of fertilizer in Samaru soil. However, when 100% MTW /0% CD was applied at 5 and lO t ha-1 values compared favourably with half recommended dose of fertilizer. The trend during the second cropping was a reverse of what was obtained after the first cropping. For example, plant height, DMY and nutrient uptake increased as the proportion of MTW increased in the mixtures and decreased as the proportion of CD increased in the mixtures.

in the field study, grain and stover yields increased as the proportion of CD increased in the mixtures and decreased as the proportion of MTW increased in the mixtures. In the absence of fertilizer, only 100% CD at 5t ha-1 - and mixtures containing 75% CD applied at lOt ha-^{1} gave yields that compared favourably with the half and full doses of fertilizers. Addition of inorganic fertilizer to the mixtures generally increased plant height, grain and stover yields over their corresponding mixtures without fertilizer and the absolute control. All mixtures applied at both rates with fertilizer gave higher grain yields than the recommended dose of fertilizer, with the exception of 100% MTW / 0% CD at 5t ha-1. Correlation studies indicate that DMY and nutrient uptake were strongly correlated, irrespective of rate, fertilizer and soil. Similar result was observed between nutrient uptake and plant he ight.

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CHAPTER 1

INTRODUCTION

The Nigerian savanna stretches from latitudes 7^0N to 14^0N and longitude 4^0E to 14^0E, covering about three quarters of the country's total land area and includes four agroecological zones (southern Guinea, northern Guinea, Sudan and Sahel savanna). The soils of these zones are sandy in nature having been derived mainly from aeolian deposits. They are generally acid in reaction. They are low in organic matter, CEC and plant nutrients, generally poorly buffered and structured, hence major chemical, physical and biological limitations (Jones and Wild, 1975). They rapidly lose their fertility and productivity under cultivation. The zone is the major source of cereals and vegetable crops for the country.

Maize production in some parts of the savanna has increased tremendously over the last ten years with about 2-3 million hectares of land being cropped to maize Enwezor, *et al.* 1989). This situation has resulted in greater demand for more fertilizers. This has not been adequately met because of unavailability and poor distribution system of inorganic fertilizers. This has drastically reduced the land area put to maize production thereby increasing the production of other cereal crops like sorghum and millet which hitherto were giving way for maize, especially in the northern and southern Guinea savanna zones. In recent years, the demand for fertilizers has greatly out-stripped its supply in Nigeria. The small scale

farmers who today contribute 90% of Nigerian agricultural production hardly get enough for use.

In the circumstance, attention must be focused on the practicability of supplementing the little available inorganic fertilizer with organic materials such as crop residues (CR) farm yard manure (FYM) and compost especially as they contain substantial amounts of plant nutrients. Sorghum, millet, maize, cotton, groundnut and cowpea generate a substantial amount of residue annually and when returned to the soil increase its nutrient contents. Sadik and Hahn (1973) reported that the total amount of NPK in manure in developing countries in 1970 - 1977 season was about 6 - 8 times larger than the amount of nutrient used in chemical fertilizers during the same period.

Several workers have evaluated the use of organic materials such as sawdust, rice husk, cassava peels, fescue grass and sorghum, maize and millet stovers either alone or as supplements to inorganic fertilizers (Saminu, 1989; Agbim *et al.* 1989; Agbim, 1985; Iwuafor 1986, respectively). Millet thresh waste (MTW) is abundant in the savanna where a lot of millet is grown next to sorghum in importance. However, the use of millet threshed waste to improve soil productivity has never been evaluated.

It is estimated that about 5-5.5 million hectares of land is cropped to millet annually in Northern savanna (Enwezor *et al.* 1989). About 2.4t ha^{-1} of MTW is produced from millet field of 60,000 plants/ha. This represents 56% by weight of millet head after threshing. It is therefore evident that about 13.20 million tones of MTW is produced in Nigeria annually. These are commonly burnt off as it is not quite palatable as livestock feed. The use of this waste either alone or in combination with other richer

organic wastes and inorganic fertilizers may enhance the sustainability of these poor soils for increased and continuous production. It is within this setting that this study was undertaken to evaluate how the village farmer could take advantage of the abundant MTW in this environment to improve the soil fertility. The main objective of the study is therefore to investigate the potentials of MTW, with and without cow dung and inorganic fertilizers on maize performance and yield.

CHAPTER 2

2.0 REVIEW OF LITERATURE

2.1 Soils of the Nigerian Savanna

Four major soil types occur in the Nigerian savanna region. These are Entisols/Inceptisols, Alfisols, Ultisols and Vertisols (USDA Soil Survey Staff, 1976). As in the case with most lands which fall within the tropical latitudes, there is considerable micro-and macro variability (Tomlinson, 1965, Klinkenberg and Higgins, 1968).

The dominant soil types are well-drained but shallow, immature Entisols and Inceptisols (Harpstead, 1973) with little profile differentiation and derived primarily from recent aeolian deposits. They are generally coarse-textured, yellowish gray or yellowish brown in the first 0-20 cm layer and have red or reddish brown B horizons with higher clay content. The Vertisols which constitute about 2% of the country's soil resources, occur mainly in the north-eastern flank of the country bound by latitudes 8^0 N and 13^0 N and longitudes 10^0N and 14^0 N. They are generally deep, dark coloured, heavy clayey soils with very low water permeability/infiltration capacity and poor internal drainage. These soils are therefore, poorly structured and a few years of continuous cultivation leads to a rapid decline in soil productivity arising partly from declining soil fertility and partly from deterioration of soil physical condition (Lombin, *et al.* 1991).

Jones and Wild (1975) reported that organic matter content of the savanna soils range from 5.0g kg^{-1} in Entisols and Inceptisols

to about 20g kg^{-1} in Vertisols and hydromorphic soils. The Alfisols are generally shallow, coarse textured yellowish grey or brown in the surface layer and have red or reddish brown subsurface and lower horizons with higher clay content. Organic matter content is generally low, rarely reaching 2g kg^{-1} even in the surface soil and total nitrogen content rarely exceeds 1.0g kg^{-1}. Because the soil organic matter is low and in combination with low clay content which is mainly kaolinitic, CEC and buffering capacity, total N, S and P and exchangeable K are also low. CEC values as low as less than 5 cmol Kg^{-1} have been reported for most savanna soils (Jones and Wild, 1975). Native soil N is so low that all cereal crops respond to N fertilizer. Jones (1973) reported values ranging from 0.08 to 2.90g kg^{-1} with mean of 0.5g kg^{-1}. This is closely linked to the generally very low organic C of these soils. Average value of 4.70 ppm has been reported for phosphorus (Jones, 1973). Total potassium content of the savanna soils varies from 0.60 to 39.90g kg^{-1}. Exchangeable K values averaging 0.13 Cmol kg^{-1} soil for Mokwa soil have been reported (Iwuafor, 1986). Calcium and Mg deficiencies are not common (Jones and Wild, 1975). Micronutrient levels in these soils are still fairly high (Heathhcote and Smithson, 1974 and Heathcote (1972). The soil pH is slightly acidic, pH range of between 6.0 - 6.8 has been reported (Jones and Wild, 1975).

2.2 Crop residue production in the savanna:

The harvest residues (straws, stover and haulms) and

process wastes (groundnut shell, rice husk, oil cakes)are the two major components of crop residues found in the savanna. Balasubramanian and Nnadi (1980) reported that during the 1970-71 cropping season about 31.41 million metric tonnes of crop residue were produced in the Nigerian savanna alone. Substantial quantities of these were generated from sorghum, millet, cotton, maize, groundnut and cowpea. These represent 90% of the total crop residues produced in this region with sorghum and millet residues alone accounting for more than 60% of the total. Other minor sources are vegetables and sugar canes. Root crops like yams, cassava, cocoyams, potatoes and orchard crops give residue that are very insignificant and of local importance (Balasubramanian and Nnadi 1980). These residues can be directly applied to the field and ploughed in or used as fuel, animal feed, compost materials and other domestic purposes. Large quantities of crops residues are also disposed off through burning, especially during land clearing operations in the savanna (Balasubramanian and Nnadi,1980).

2.3 Nutrient contents of crop residues.

The productivity of soil is determined by the presence of adequate level of essential plant nutrients, moisture, optimum soil physical conditions and activity of biological organisms. The organic matter status of a soil has direct effect on all the three factors.

Crop residues represent a valuable resource that require careful management. They contain substantial amounts of the macro and micro nutrients. Estimates of various nutrient elements

contained in crop residues and animal dropping have been reported by Balasubramanian and Nnadi (1980), Singh and Balasubramanian (1980); Poulain (1980) and Larson *et al.* (1978). Iwuafor (1986); Charreau (1974), Kanwar and Chopra (1959) and Yayock and Awoniyi,(1974). Crop residues in general are rich in K, low in P and poor to medium in N. Residues of leguminous plants are richer in all nutrients than cereal crop residues. Leaves contain more nutrients than stem which contain slightly more nutrients than roots. About 40% N, 40%P, 86%K, 92% Ca, 72% Mg and 59% S removed from the soil by crops are contained in crop residues (Balasubramanian and Nnadi, 1980). The average consumption of NPK nutrients in form of fertilizers in 1970-71 season was 0.6kg ha^{-1} (FAO,1979 in Balasubramanian and Nnadi 1980). This gives a total consumption of 10.6 million kg of NPK for the northern states of Nigeria. The amount of NPK nutrients contained in crop residues (813 million kg) is 77 times as large as the nutrients applied through fertilizers (Balasubramanian and Nnadi, 1980). It becomes imperative therefore, that any system that removes crop residues must take into account the return of the nutrients associated with the residue if crop production levels are to be maintained.

2.4 Effect of crop residues on soil chemical properties.

The process of crop residue decomposition eventually leads to the synthesis of humus, the colloidal organic matter which plays a very significant role in soil exchange processes, chelation, buffer capacity and so on, particularly in acid soils of the tropics characterized by high iron and aluminium oxides contents and variable charge systems. The organic matter content of most mineral

soils account for about 30-65% of the total CEC (Mitchell, 1932, Allison, 1973). The effective cation exchange capacity (ECEC) of soil organic matter increases as it passes through successive stages of decomposition with the older and more humified fractions having higher CEC (Allison, 1973, Flaig et al, 1975). Values of CEC for humus ranges from 150-300 C mol Kg^{-1} (Allison, 1973) while for kaolinites, illites, vermiculites and montmorillonites clays, the values are in the ranges of 3-15, 10-40, 100-150 and 80-150 C mol Kg^{-1} respectively. The source of negative charges in the organic matter arises primarily from carboxyl and hydroxyl groups hence the electrical charges of the soil organic matter is pH dependent.

A metal chelate is a complex formed when a metal ion is bound to an organic component by more than one bond to form a ring or cyclic structure. Chelates are water soluble and metals are held by them with varying degree of stability. Chelates play a significant role in soil fertility especially in regards to micronutrient availability. Many of the cations chelated are essentially micronutrients and can be made available to plants by exchange which is quite different from the chemical cation exchange as a result of columbic attraction in a double layer (Tan, 1986). Organic matter resulting from the addition of crop residues was found to increase the chelation ability of soils (Lindsay, 1974).

The relationship between residue quality and the soil capacity to retain nutrient against leaching need to be further investigated in tropical environment because of its management implications. High residue quality (low C:N ratio) materials are likely to be a rapid source of nutrients for crops but may

contribute little to maintain nutrients against leaching. Low residue quality (high C:N ratio) may mean the apposite (Sanchez and Miller, 1986). Thus the higher the ECEC and chelating ability of the soil, the more cations the soil can retain against leaching.

(ii) Effect on soil pH

A number of studies have shown that crop residues do affect the pH of soil, especially those with low buffer capacity. In some cases there effects were positive as shown with cassava peels (Agbim,1981). When 120 kgN^{-1} from Ammonium sulphate fertilizer was applied, higher levels of cassava peels increasingly ameliorated the pH. The opposite effect was obtained with rice husk with the same rate of fertilizer (Agbim,1981). Studies with other crop residues have shown that often the significant pH improvement obtained with lighter soils were not obtained in heavier soils (Agbim,1981).

The colloidal organic matter resulting from the decomposition of crop residues would increase the buffer capacity of the soil which will inturn resist changes in soil pH. The resistance to pH change would therefore, be low in sandy soils, which are generally low in organic matter and CEC and high in fine-textured and high organic matter soils which have higher CEC. The sandy parent material and low organic matter content have given the savanna soils low buffering capacity, hence frequent changes in pH due to addition of nitrogenous fertilizers. Bache and Heatheote (1969) showed that continuous usage of $(NH_4)_2SO_4$ significantly decreased pH, exchangeable bases and increased the concentration of soluble

Al and Mn in these soils. Jones (1976) reported that calcium ammonium nitrate at the rate of 45 and 135kg ha^{-1} applied annually for 3 years significantly reduced exchangeable Mg and decreased soil pH. However, the application of organic residue was found to increase the pH at all depths studied. The effect was highly significant ($P < 0.001$) at 0-45 cm. The increase ranged from 0.48 to 0.82 pH units. The increase can be explained mainly by the increase in cation content as a result of mineralization of crop residues. The cations, especially Ca and Mg ions with bicarbonate (HCO_3) anion from Ca and Mg bicarbonates will increase the pH (Moehansyah, 1977). It has been observed that there seems to be a good correlation between soil organic carbon and pH ($r = 0.43$), (Jones, 1976).

2.5 Effect of crop residues on soil physical properties

Soil organic matter is responsible (directly or indirectly) for making the physical environment of soil suitable for the growth of crops. It exerts this benefit largely through its effects on soil aggregation which in turn influences soil structure, water infiltration, moisture content, drainage, tilth, aeration, temperature, microbial activities and root penetration.

(i) Effect on soil structure

Soils with low organic matter content are easily compacted than those with high organic matter content under similar climatic conditions. Organic matter affect structures differently depending on their textures and mineralogical composition. Apart from amount

and kind of organic matter, its distribution within the matrix is also important towards structure stability (Quirk and Panabokke, 1962) Turchenek and Oades (1978) showed that the concentration of organic matter in micro aggregates makes them resistant to sticking and dispersion. Biswas et al (1964) observed increased percentages of water soluble aggregates and permeability for alluvial soils of the northern India through continuous application of farm yard manure. Increased soil aggregation and soil structural stability through increased organic matter addition to the soil has been reported by Allison (1973); Lal, 1976) and Dunham and Aremu (1979). Increase in organic matter by continuous addition of crop residues has been shown to increase soil aggregation and stability of an Alfisol in South western Nigeria (Lal *et al.* 1980). Similar results were also reported for loess soils of northern Nigeria (Lawes, 1957). Application of sugar cane thrash (Sandhu and Bhumbla, 1967) and compost was observed to increase structural stability. However, only negligible improvement in structure resulted from addition of even large quantities of farm yard manure to sandy soils of Egypt, (Abdou and Metually, (1967). Most of the physical consequences of organic matter on soil are realized through the separate processes of aggregate formation and stabilization (Allison, 1973). Soil aggregates are formed mainly by physical forces which include mechanical binding by fungal mycelia, while stabilization is affected by several factors including organic materials, iron and aluminium oxides and clays (Lynch and Bragg, 1985). According to Sanchez and Miller (1986), the management or improvement of soil structure involves two aspects:- the protection of the soil surface

and the maintenance of continuous transmission pores. Management of organic input significantly contributes to both.

(ii) Effect of crop residues on soil and water conservation

De Vleschauwer et al (1978) indicated that the amount of mulch required for an effective soil and water conservation depends on the nature and quality of mulch material, the rate of its decomposition, soil properties and environmental conditions. Providing additional ground cover through residue mulching is an effective conservation measure for decreasing run off and soil loss. Both soil and water loss decrease exponentially with an increase in the rate of crop residue mulch. A mulch rate of 4t ha^{-1} can therefore, be an effective erosion preventive measure even for steep slopes (De Vleschauwer at al. 1978). Wischmeier and Mannering (1969) reported that the run off from cropped plots in various studies ranged from 3-30% of total precipitation and increasing the content of decomposed and partially decomposed organic residues substantially increased infiltration into moist soils. According to Larson et al (1978), proper use of crop residues is the most powerful tool available for reduction of run off erosion and transport of sediment to streams. Lal (1974, 1976) also reported that various crops could be grown successfully without tillage in Nigeria, but that adequate mulch cover was necessary to regulate soil temperature, run-off and soil loss if the system would perform satisfactorily.

Biswas and Ali (1967, 1969) reported that available water and water measured at any suction were consistently higher in soils of higher

organic matter than lower organic matter content. Lal, *et al.* (1980) reported that increase in organic matter content was found to increase hydraulic conductivity, accumulative infiltration and equilibrium infiltration rates, high sorptivity and transmissivity. The presence of crust in some soils decreases the water intake rate of the soil. Crust formation remarkably increases the resistance of the soil to erosion, inspite of increased run off and it should be regarded as an advantage rather than disadvantage, particularly at Samaru (Kowal, 1972). Incorporation of crop residues has been reported to reduce crust formation and increase water intake capacity of savanna soils (Kowal and Andrews, 1973). The average infiltration rate of cultivated soil at Samaru ranges from about 2.5 to 5.0cm hr^{-1} in fallow lands (Kowal and Andrews, 1973). De Vleschauwer *et al.* (1978) indicated that the infiltration capacity was maximum when residue mulch was applied at 6t ha^{-1} of dry straw than when soil amending chemicals (such as polyacrylamide) were used on the soil.

2.6 Effect of crop residues on biological properties of soils

The soil is one of the most dynamic sites for biological interaction and as such any programme geared towards organic fertilization must take cognisance of the soil microbial population. They are involved in the destruction of organic matter and therefore, in the nutrition of cultivated and uncultivated plants (Agbim and Adeoye, 1989). There are basically two important roles that micro-organisms play in organic fertilization. These are (1) the decomposition of organic residues added to the soil with

the release of the nutrient element constituents such as C, N, P, Ca, Mg, K, S, Fe, Zn, Mn, Mo, Cu, that can be utilized by the crop and a new generation of living organisms. The decomposition process begins to go very well if environmental conditions such as air supply, moisture, temperature and soil reactions are optimum. (ii) The formation of humus which to the house owner is an expression of how dark or fertile the soil is. With few exceptions, the organic matter added to the soil is not completely broken into simple inorganic constituents; some are used for the synthesis of biomass and a small fraction is converted into soil humus which has remarkable capacity to hold water and nutrient ions as already discussed. Majority of soil organisms are dependent upon the supply of decomposable organic materials to the soil, while others play vital role in break down and final decomposition of organic matter in soils. The kind and amount of organic matter present in the soil and environmental conditions markedly affect the numbers and kind of microflora present, which in turn affect the products from the organic matter decomposition. Allison F.E.(1973) showed that the amount of N released from soils of similar types is usually closely related to the amount of total N or organic matter in the soil. Odu, (1967) reported that soils of the savanna have low population of nitrifying bacteria, resulting to a slow rate of nitrification. Dommergues, (1956) however, suggested that they may be higher in areas of savanna wood land where grass is less dominant. Wild, (1972) found much higher population in soils under continuous arable cultivation than in those under grass fallow. The presence of grass appears to depress the population of nitrifiers Green

land, (1958).

Increased microbial population resulting from organic inputs would encourage the existence of some nematodes and release some plant growth hormones such as auxins, gibberellins and cytokinins and these could affect plants in various ways. Though difficult to quantify in terms of crop yield, the stimulation of microbial and faunal activities by soil organic matter and organic inputs are of considerable practical importance to soil fertility (Sanchez and Miller, 1986). Reduced yields have been attributed to toxic compounds leached from crop residues and /or to microbial production of toxic compounds during residue decomposition (Elliot *et al.* 1978). Lynch *et al.* (1980) reported that roots and leaves decomposing in soil generate relatively large amounts of acetic, propionic and butyric acids sufficient to have phytotoxic effect. To minimize or eliminate the phytotoxic effect it would be necessary to mix the crop residue as uniformly as possible with the soil and allow some period of incubation (weeks to months) before planting. High loading rates of crop residues may also induce phytotoxicity. Crop residues may also influence plant growth by being a food source for plant pathogens or by modifying the physical environment of the pathogens (Cook *et al.* 1978).

2.7 Decomposition of crop residues

The key to unlocking the tremendous amounts of nutrients in crop residues for plant use depends in almost all cases on the microbial decomposition of these residues. According to Parr and Papendick, (1978), soil and residue factors affect the

decomposition process. Soil factors include, the strain and population of micro-organism, moisture, temperature, pH, aeration and available nutrients. Other soil factors considered important by Mc Rae and Mc Huys, (1985) include soil or site factors such as elevation, slope aspect, texture, structure, compaction, native organic matter, humus content and history of the site, such as use of fertilizer, lime, mulches, pesticides, tillage and fire incidence.

Residue factors include chemical composition, lignin content, carbon to nitrogen (C:N) ratio, age of plant material, particle size and method of residue application; others may include quantity added per unit area, moisture content, mineral content, timing and also frequency of incorporation. Alexander (1977) reported that the C:N ratio of a crop residue can be useful in predicting decomposition rates Parr and Parpendick (1978) however stated that it should be used with caution since the ratio says nothing about the availability of the C or N to micro-organisms. Usually the higher the C:N ratio, the slower the decomposition rate. The N content of most mature crop residues is considerably less than the critical level of 1.5 -1.7% N (that is C:N ratio of 25 - 30). Hence, there is danger that the large amount of oxidizable C from such residues would create a microbiological demand for N which can immobilize residue N and available inorganic soil N for extended periods. This points out the importance of timing in residue incorporation. Yield may be depressed as a result of the immobilization of N if residue incorporation was done at the beginning of the rainy season or just before sowing. Due to the

problem of low soil moisture and the consequent soil hardiness, ploughing to incorporate residue at the end of the rainy season is likely to be advantageous only if the vegetative circle of the crop is shorter than the rainy cycle. Indications are that about 500mm of rain is enough to assure good decomposition of organic matter if the soil is wet at the time of ploughing. It may therefore, be possible to manipulate the cropping calendar to accommodate end of season ploughing in most of the ecological zones of the country.

The model by Parton *et al.* (1987) cited by Agbim *et al.* (1991) validated with the central US data and in tropical savanna conditions dominated by *Ultisols* and *Oxisols* partitions residue C into different pools depending on litter quality defined by the lignin: nitrogen ratio (L:N ratio). About 55 - 75% of the C of most crop residues and plant debris returning to soil is released as CO_2 over a one year period (Jenkinson, 1971; Jenkinson and Ayanaba, 1977; Paul and Van veen, 1978). A small amount of the residual carbon is present in biomass (5-10%) and the remainder is in form of undecomposed organic matter. Soil organic matter decomposes at the rate of 2-5% a year and the new organic matter decomposes faster than the old ones (Jenkinson and Rayner, 1977).

A more reliable index of the rate of organic matter decomposition is the C:N ratio. Lignin is a constituent of crop residues and increases with the age of the plant. The decomposition rate of crop residues are usually inversely proportional to their lignin content. High litter quality implies rapid mineralization, while low quality litter means the reverse. With high quality

litter, there may be little contribution to the slow and passive soil carbon. Marginal, erodible, sloping and gradually less productive soils would according to Parr et al (1986) benefit at least initially from application of low litter quality residues since these have a higher degree of microbial stability in soils. The high quality residues have a high nutrient availability index (NAI) while the low quality residues have a high organic stability index (OSI) associated with the slow and passive carbon in the model given by Parton et al (1987). We should then ensure that, while seeking greater crop yields, we should also aim at improving the soil by increasing its OSI. Parr *et al.* (1986) have thus suggested that to achieve the need for both attributes we need to combine low quality litters with high quality ones.

2.8 Causes of decline of organic matter in soils of northern Nigeria

The organic matter content of cultivated soils in the Tropics declines more rapidly than that of soils in the temperate regions. Consequently cultivated soils in the tropics generally show lower levels of organic matter (Bates, 1960; Greenland and Kowal, 1960; Jenny and Raychaudhuri,1960; Aina, 1979 and Smith, 1979). It is important to make a distinction between the factors that control the rate of decomposition of crop residues and those that affect the decomposition of different fractions of soil organic matter. Several factors are known to affect the decomposition and decline of organic matter in these soils.

(a) Soil erosion:

High climatic erosivity, low concentration of organic matter and clay in surface soils and undulating terrain render large areas of humid, sub-humid and semi-arid tropical Africa extremely vulnerable to erosion by water. Water erosion result in a preferential removal of the fine soils fraction comprised of the clay and soil organic matter content. Lal(1980) reported a linear decline in soil organic matter content with accumulative soil erosion. The sparse vegetative cover and the sandy nature of soils of northern Nigerian savanna also increase the effectiveness of wind erosion in removing freshly added and not incorporated crop residues.

(b) <u>High temperature:</u>

Jenny and Chaudhauri (1960) found an inverse relationship between soil organic matter content and mean annual temperature. Jones (1973) observed that decomposition rate in the humid tropical environment at Ibadan, Nigeria with mean annual temperature of 26^0C was about four times faster than in humid-temperature regions at Rothamsted, United Kingdom with mean annual temperature of 9^0C.

(c) <u>Cultivation:</u>

With cultivation and cropping, the organic carbon level of the soil will depend on the rate of annual additions and decomposition. Jones (1971) found that after 18 years of continuous cultivation, soil organic matter levels appeared to be still declining by as much as 3-5% per annum in unmanured plots. This may be because of

the practice of removing all crop residues from the field immediately after the harvest. The degradative effect of cultivation on organic matter in tropical soils has long been appreciated and was freely discussed by Nye and Greenland (1960). Decomposition of organic residue is faster through cultivation as a result of constant turning and exposure of new organic surfaces to agent of decomposition.

(d) Deforestation:

Cunningham (1963) working in the forest zone of Ghana, showed that even without cultivation and cropping, deforestation decreased in organic carbon levels by 25 - 57% for the top 0-15 cm soil depth in 3 years. Jones (1973) compared the organic matter content of virgin and cultivated fields and reported that the mean carbon content for virgin and cleared fields were 1.03 and 0.58%, respectively.

(e) Burning

Burning is widely practiced in northern Nigeria as a method of land clearing in traditional farming systems. This annual practice reduces the vegetative ground cover drastically.The soil organic matter which must have been added to the soil through crop residues are oxidized and lost through burning. Burning is known to volatilize most of the carbon, sulphur and nitrogen present in the vegetation; however, its harmful effect on soil organic matter content remain an open question. Thus the advantages and disadvantages of burning depends on degree of control, severity and

frequency of burning.

2.9 Alternative uses of crop residues and their consequences

There are attractive alternative uses of crop residues than their return to the field. Stovers of cereals such as maize, sorghum and millet are removed from the farm and utilized for fuel, housing, fencing and as fodder for livestock in the dry season. These removal results in soil deterioration leading ultimately to the decline in soil productivity. Jones (1971) reported that after 18 years of continuous cultivation, organic matter levels declined by as much as 3-5% per annum. He attributed this in part to the practice of removing all above ground crop residues from the field at the end of the season. The general implications of residues removal on nutrient depletion have been demonstrated (Jones, 1976). Balasubramanian and Nnadi (1980) reported that for 1970 - 71 season, crops in the Nigerian savanna area removed as much as 0.52, 0.07, 0.60, 0.15, 0.08 and 0.06 million tonnes of N,P,K, Ca,Mg, and S, respectively and that only a portion of nutrients is contained in the grain, nut and tubers and other economic produce. Therefore, complete removal of crop residues from farm land for other domestic uses denies the soil of all these nutrients. In addition to the loss in nutrients, organic matter is virtually reduced. This could lead to chemical, physical and biological deterioration of soils.

2.10 Effect of crop residues on crop yields

Many workers have reported on both positive and negative responses of various crops to the addition of crop residues. Agbim

et al. (1981) noticed a yield depression in maize during the first cropping and a dramatic reverse effect during the second cropping after incorporation of cassava peels in soils. Saminu (1989) also reported a higher dry matter yield of maize during the second cropping relative to the first crop with the incorporation of pre-incubated sawdust. Increased cocoyam yield for crops over that of first cropping has been reported by Agbim (1985) through incorporation of CD pre-incubated cassava peels. The micro-organisms immobilize the native soil N during the first cropping in decomposing the organic amendment added, as a result the N supply to the crops were reduced leading to poor yields (Agbim, 1989). During the second cropping which occurred much later after the incorporation of crop residues into the soil, the C:N ratio may have been sufficiently narrowed that N mineralization occurred to the advantage of the crops, thus increasing dry matter yield (Agbim, 1989).

The incorporation of rice husk for one year has also been observed to increase yield with increasing rate of application, but those increases were not appreciable enough until either NPK fertilizers or poultry dropping were used (Agbim 1989). The incorporation and ploughing in of vegetative matter was observed to increase the yield of maize by 66%, while it was only by 27% when the soil was ploughed without incorporation of the vegetative matter (Charreau and Nicou, 1971). However, in Samaru, addition of 2.5t ha^{-1} organic matter gave a yield increase of 29.30% over the control. Increased dry matter yield through the application of cow dung has also been reported by several workers (Aina and Egolum,

1980; Mbagwu, 1985; Agbim 1985). In situations where the cow dung was used with other crop residues, the dry matter yield generally increased as the proportion of the cow dung increased in the organic amendment. Omaliko and Agbim (1983) reported significant difference in yields as a result of rate of organic amendment x soil type interaction and also observed a generally lower yield at the second cropping. They also observed higher yield increases in poorer soils than the richer and less porous soil. The improvement in the soil physical attributes, even without fertilizer application may partly account for the yield increases of the first crops.

Crop yield in general, tend to be higher when crop residues are incorporated, used as mulch and burnt than when removed (Jones 1976; Heathcote, 1970, and Hooker et al, 1982). Charreau (1974) and Okigbo (1985) reported increases in crop yield resulting from various soil organic amendments.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 GREEN HOUSE STUDY

3.1.1 COLLECTION AND PREPARATION OF SOIL SAMPLES

The soil samples for the study were collected from two locations, Samaru, Latitude 11^0 $11^{'}$N and Longitude 7^0 $38^{'}$E in Northern Guinea Savanna and Minjibir Latitude 12^0 $8^{'}$N and longitude 8^0 $40^{'}$E in the Sudan savanna ecological zones.

The Samaru soil sample was collected from a site at the research farm of Ahmadu Bello University (ABU) Zaria which had been under fallow for three years after being used for cowpea production. The soils of Samaru are formed from loess underlain by *basement complex rocks (Awujoola 1979). In most cases the loess* forms the main parent material. The soils have been classified as Typic Haplustult (USDA) or Orthic Acrisol (FAO).The Minjibir sample, was collected from the Institute for Agricultural Research, Kano Station, Research Farm Minjibir. The soils of MInjibir are formed from fine cretaceous sediments and aeolian /colluvial and alluvial materials. The soils are well drained. The soils are classified as Typic Ustipsamments (USDA) and Dystric Regosols (FAO /UNESCO) systems of classification respectively (Malgwi *et al.* 1987). At both locations, samples were collected from 20 equally spaced points at 0-15cm depth, bulked and mixed thoroughly and allowed to air dry. The samples were sieved through 2mm stainless steel sieve and subsamples taken for characterization of the soils.

3.1.2. Collection and Preparation of organic residues

3.1.2(a) Millet thresh wastes (MTW) The residue consists of spike components of millet head left over after threshing and removal of the grains. The waste was collected after threshing millet harvested from a production field at the Institute for Agricultural Research (IAR) farm, Samaru. Large pieces of the waste such as broken stover, leaves and other foreign materials were removed. The material was stored for use after subsamples had been taken for chemical analysis.

3.1.2(b) Cow dung (CD):

The cow dung consists essentially of faeces and urine from cows and was collected during the dry season from cow pens at the Ahmadu Bello University Livestock farm at Samaru. All foreign materials were removed and the big lumps crushed and allowed to air dry. The dried CD was passed through a 10mm stainless steel sieve. It was thoroughly mixed and subsamples taken for chemical analysis, while the rest was stored for use in the green-house.

3.1.3 Treatments and Experimental design: The treatments consist of combination of various proportions of MTW and CD (100:0, 75:25, 50:50, 25:75 and 0:100) applied at two rates 5 and 10t ha^{-1} with and without fertilizer. The fertilizer rate was 60kgN ha^{-1} 30Kg P_2O_5 ha^{-1} and 30kg K_2O ha^{-1}. There were three controls of no amendment with and without fertilizer and another receiving only 120kgN ha^{-1}, 60kg ha^{-1} each of P_2O_5 and K_2O which is the fertilizer recommendation for maize production. The treatment combinations were arranged in a randomized complete block design and replicated three times.

3.1.4 Green house Technique:

First cropping:- Four kilograms of each soil were mixed with appropriate amounts of CD, MTW and fertilizer and put into appropriate plastic pots of about 5 litre capacity. The pots were placed on plastic receivers. The soils were wetted to field capacity during the three weeks of incubation in the green house. Maize (Zea mays L.) variety TZESR-Y was used as the assay crop. Eight seeds were planted symmetrically in the pots and thinned to four plants per pot seven days after planting. The first split dose of N fertilizer was applied in solution at planting and second dose at four weeks after planting. The soils were maintained at field capacity through regular watering. Any drained water in the receiver was returned into the pot. Plant height measurement taken from the soil surface to the last two diverging leaves of each plant with a ruler were observed at weekly intervals from fourteen days after planting. Daily observations were made on the plants for nutrient deficiency symptoms and also to keep pests in check. The shoot was harvested by cutting the stem from the soil surface at 5 weeks after planting. The samples were washed with tap water, rinsed in distilled water, placed in large envelopes and dried in an oven at 65^{0}C to constant weight. The dried samples were weighed and then ground with a stainless steel mill. The ground samples were stored in small plastic bags for elemental analysis.

Second Cropping: To assess the residual effect of the treatment, the mixture in each pot was emptied into a polythene sheet and roots picked out. The soil was repotted and watered to field capacity. The soil was incubated again for three weeks and planted

to maize as in the first cropping. Subsequent management and observations were as for the first cropping.

3.2. FIELD STUDY

3.2.1 Site description and history:

The field experiment was conducted at the Research farm of IAR, ABU, Samaru, Zaria. The field is fairly flat and had been under bush fallow for two years. The soil is classified as Oxic Haplustult/Orthic Acrisol under the USDA / FAO classification systems, respectively. The mean annual rainfall is 1090mm and a mean daily temperature of 24^{0C} (Kowal and Knabe 1972)

3.2.2. Treatments, design and cultural practices:

The treatment and design were as described for the green house study. The field was ploughed and harrowed twice. Plots of 4 x $4m^2$ were marked out on flat for the three replicates. Appropriate amounts of wastes were applied to appropriate plots and thoroughly mixed with the soil up to the plough depth. The incorporated wastes were allowed to incubate for three weeks before planting. Maize (Zea mays L.) variety TZESR-Y was planted at 3 seeds/hole at a spacing of 25cm within row spacing and 75cm inter row spacing. The seedlings were thinned to one plant/hole at fourteen days after planting.

With the exception of the second split dose of N, all other fertilizers were applied together with the organic waste at land preparation.

3.2.3. Observations and measurements:

Observations were made on plants tagged within the two middle rows. Plant height was taken at weekly intervals from fourteen days after planting by measuring from the soil surface to the whorl of the plants.

The maize crop was harvested at about 5 months after planting and dehusked. All plants in the two inner rows (net plot) were sun dried, shelled and grain yield at 5% moisture content calculated. Cob length and diameter were measured in cm. The 1000 - seed weight and stover yield were also recorded.

3.2.4. Soil and plant sampling:

Soil samples were taken at 0 - 15cm depth before land preparation and fertilizer application and from each plot after harvest. The samples were air-dried and sieved through a 2mm stainless steel sieve. The samples were stored in a plastic container for subsequent analysis.

Ear leaf samples from tagged plants in the inner rows were taken at 50% silking. These were washed in tap water and rinsed in distilled water, enveloped and dried in an oven at 65^{0C} for 48 hours. The dried samples were ground in a stainless steel mill. These samples were stored in plastic containers for subsequent laboratory analysis.

3.3 Soil and plant analysis:

The soil samples collected for the green house study and from the field before and after cropping were analyzed for various

parameters. Soil pH was determined in 1:2.5 soil: water and salt (0.01M $Cacl_2$) suspension with a glass electrode pH metre. Exchangeable bases were determined by extraction with neutral 1N NH_4OAc saturation method. Sodium and potassium were determined by the flame emission (Kundsen, Peterson and Pratt, 1982) while Calcium, Magnesium and the micronutrients were determined using the Perkin Elmer Model 403 Atomic Absorption spectrophotometer. Cation exchanged capacity was determined by the Ammonium displacement method, followed by distillation. Organic matter was determined by the wet oxidation method of Walkley and Black as described by Juo (1979). Available phosphorus was determined by Bray no 1 method. The P concentration in the extract was determined colorimetrically with a spectrophotometer. Particle size distribution was estimated by the hydrometer method of Bouyoucos (1951). The total N for the soil samples was determined by Kjeldahl procedure (Bremner and Mulvaney, 1982).

The total N for the MTW, CD and plant tissues were determined by the micro Kjeldahl wet digestion method, while P and K were determined from the $HClO_3$-HNO_3 digest by the molybdo-phosphoric yellow colour and flame emission method respectively. Calcium, magnesium and micronutrients were determined from the digest using perkin Elmer model 403 Atomic Absorption spectrophotometer.

3.4 Statistical analysis:

All data collected were subjected to analysis of variance (ANOVA) using the Genstat package for statistical analysis on the IAR computer and treatment differences were evaluated by the new

Duncan's multiple range test (DNMRT). Simple correlation studies were also run for some selected parameters.

CHAPTER 4

4.0 RESULTS

4.1 Green house studies.

4.1.1 Some physicochemical properties of the soils used in the green studies

Some of the physicochemical properties of both soils are shown in Table 1. The Minjibir soil is sandy loam, while that of Samaru is loam in texture. They are acidic in reaction with very low content of total N, organic carbon and available phosphorus. The cation exchange capacity (CEC) is also low (6.20 and 3.00 Cmol kg^{-1} for Samaru and Minjibir, respectively). Jones and Wild (1975) reported that savanna soils generally have CEC of less than 5.0 Cmol Kg^{-1} soil. This low level of CEC is not surprising considering the low level of organic matter in these soils. The importance of organic matter in influencing the exchange capacity of savanna soils have been reported (Fauck 1963). Fauck *et al.* (1969) showed that continuous cultivation for six years without proper management of organic matter dropped the CEC from 6.60 to 3.38 Cmol kg^{-1}. The exchangeable bases and the micronutrients were also found to be low. On comparative basis, however, the Samaru soil appears more fertile than the Minjibir soil.

4.1.2 Some characteristics of the waste materials used in the study

Some characteristics of MTW and CD are shown in Table 2. The amount of nutrients added by the application of the waste materials at 5 and 10t ha^{-1} are shown in Tables 4 and 5.

Table 1: Some Physico-chemical properties of the soils used for the studies

Property	soil samples		
	Minjibir	Samaru	Samaru field study
Sand (gKg^{-1})	620.00	300.00	180.00
Silt (gKg^{-1})	250.00	490.00	670.00
Clay (gKg^{-1})	130.00	210.00	150.00
Texture	Sandy loam	Loam	Silty loam
pH(1:2.5 H_2O)	4.50	4.80	4.80
pH{1:2.5 0.01M $Cacl_2$)	4.30	4.60	4.60
Ec dSm^{-1}	0.01	0.02	0.02
Organic carbon (gKg^{-1})	0.40	3.60	2.00
Total N (gKg^{-1})	0.10	0.50	0.20
Exchangeable K{$CmolKg^{-1}$)	0.02	0.04	0.03
Exchangeable Ca ($CmolKg^{-1}$)	0.08	0.02	0.02
Exchangeable Mg ($CmolKg^{-1}$)	0.02	0.06	0.05
Available P ($mgKg^{-1}$)	2.06	4.22	15.95
Extractable Zn ($mgKg^{-1}$)	6.40	7.00	5.00
Extractable Fe ($mgKg^{-1}$)	21.00	60.00	135.00
Extractable Cu ($mgKg^{-1}$)	0.52	0.74	0.70
Extractable Mn ($mgKg^{-1}$)	14.00	39.60	13.00
CEC Cmol (Kg^{-1})	3.00	6.20	4.70

Table 2: Chemical properties of the millet thresh waste and cow dung used

Waste	Nutrient composition										
Material	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu	C	C:N
	%					mg/kg					
CD	1.43	0.91	1.00	0.44	0.29	117.00	1000.00	216.00	16.74	60.00	47.62
MTW	1.26	0.59	0.40	0.13	0.14	55.00	500.00	50.00	12.04	20.50	14.34

Table 3: Amount of nutrients added by the application of waste material at 5t (Kg ha^{-1})

Waste	Nutrients (Kg/ha)								
Material	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu
CD	71.50	45.55	50.00	22.00	14.50	0.60	50.00	1.10	0.10
MTW	62.50	29.50	20.00	6.50	7.00	0.30	3.00	0.40	0.05

Table 4: Amount of nutrients added (Kg ha^{-1}) by the application of waste materials at 10t ha^{-1}

Waste	Nutrients								
Material	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu
CD	143.00	91.10	1000,00	44.00	29.00	1.20	100.00	2.20	0.20
MTW	125.00	59.00	40.00	13.00	14.00	0.60	5.00	0.50	0.10

respectively.

Results of the analyses show that CD contained more nutrients than MTW. Application of 10t ha^{-1} adds double the nutrients added by 5t ha^{-1} of any of the wastes. The values tend to be high but they are supplied slowly as mineralization will take place before the nutrients are made available.

GREEN HOUSE STUDIES

4.1.3 Effect of MTW, CD and fertilizer on plant height in Minjibir soil

First cropping: The effect of MTW and CD with and without fertilizer on plant height during the first cropping is shown in Figure 1. At both 5 and 10t ha^{-1}, with and without fertilizer, plant height increased as the proportion of CD increased in the mixture. With MTW alone and without fertilizer, plant height was least at all stages of measurement. This effect was more pronounced at the 10t ha^{-1}. Significantly taller plants were observed when fertilizer was added to the mixtures. At midseason (21DAP) CD alone at 10t ha^{-1} with fertilizer was superior by 119.43, 45.35 and 24.45% over the absolute control, half and full doses of fertilizer, respectively. With the corresponding mixture of MTW alone applied at 10t ha^{-1} with fertilizer, plant height increased by 45.14% over the absolute control.

Second cropping The residual effect of the treatments on plant height is shown in Figure 2. Unlike in the first cropping, plant

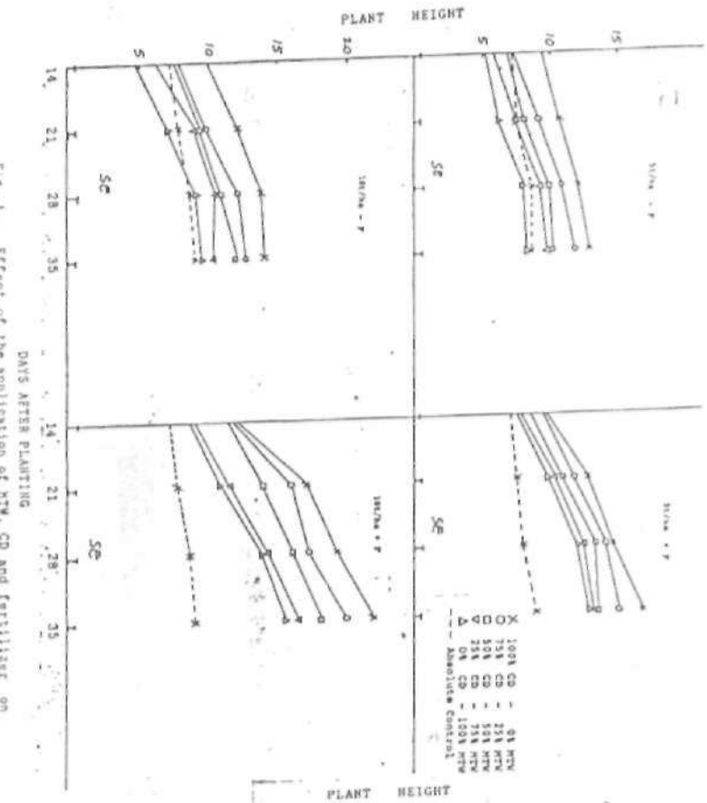


Fig. 1. Effect of the application of MTW, CD and fertilizer on plant height in Mindoro soil (first cropping).

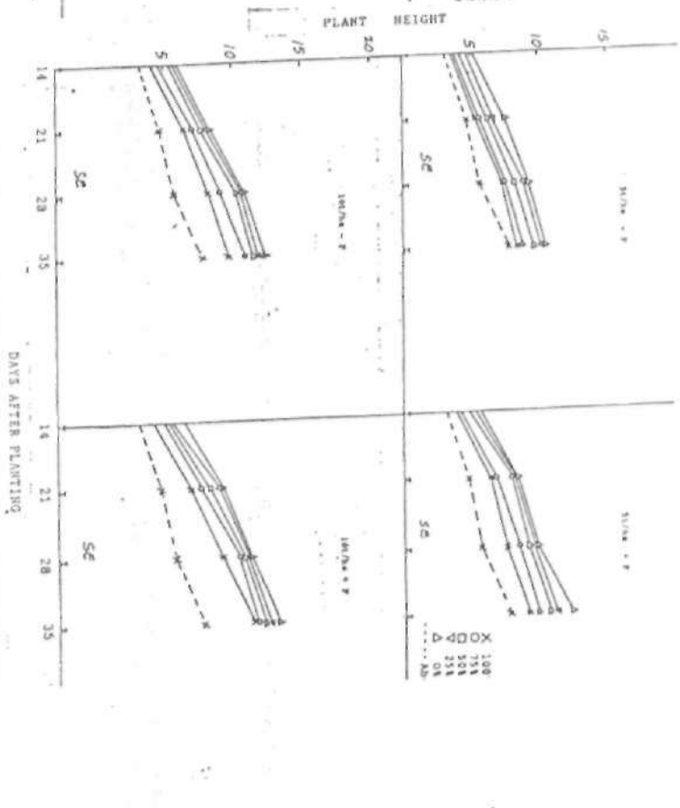


Fig. 2. Effect of the application of MTW, CD and fertilizer on plant height in Mindoro soil (second cropping).

height increased as the proportion of MTW increased in the mixtures. The mixtures applied at 10t ha^{-1} with and without fertilizer addition produced taller plants than the absolute control. Plants were generally shorter for the second cropping than the first. At harvest (35DAP) application of MTW alone at 5t ha^{-1} with and without fertilizer produced plants taller than the absolute control by 70.93 and 58.26%, respectively. At harvest, application of CD alone at 5t ha^{-1} with and without fertilizer produced plants taller than the absolute control by 19.46 and 9.10% respectively, while at 10t ha^{-1} with and without fertilizer plants were taller than the absolute control by 49.85 and 25.74%, respectively. With the MTW alone with fertilizer (ie 100% MTW / 0% CD + F) at both rates of application plant height increased by 12.72 and 22.14% over the full dose of fertilizer. The absolute control gave plants significantly shorter than all amended treatments.

4.1.4 Effect of MTW, CD and fertilizer on plant height in Samaru soil

First cropping: The effect of MTW and CD with and without fertilizer on plant height during the first cropping is shown in Figure 3. Increased plant height with increasing proportions of CD in the mixture was observed. Plants at all proportions and at both rates of application were significantly taller than the absolute control. Generally taller plants were observed when the mixtures were supplemented with fertilizer. At harvest (35DAP)

plants amended with MTW alone with fertilizer at 5 and 10t ha^{-1} were 35.24 and 41.84% respectively, taller than absolute control. When CD alone was applied at both rates with fertilizer, plant height was 58.08 and 86.89% respectively taller than absolute control. The addition of fertilizer to the mixtures (100%CD / 0%MTW) and (100%MTW/0%CD + F) at 5t ha^{-1} improved maize height by 20.69 and 17.52%, respectively over their corresponding mixtures without fertilizer, while at 10t ha^{-1} for the same mixture an increment in plant height of 23.33 and 38.47%, respectively was obtained over their corresponding mixtures without fertilizer.

Second cropping: The trend during the second cropping is shown in Figure 4. Taller plants were generally observed in treatments with higher proportions of MTW. There were little differences in plant height among all mixtures at both rates irrespective of fertilizer application.Plants were generally shorter in the second cropping than the first cropping. Addition of fertilizer to MTW alone at 10t ha^{-1} increased plant height by 37.52 and 18.95% over the absolute control and full dose of fertilizer, respectively.

4.1.5 Effect of MTW, CD and fertilizer on shoot dry matter yield in Minjibir soil

First Cropping: The effect of MTW, CD and fertilizer on shoot dry matter yield (DMY) is shown in Table 5. Generally, shoot DMY increased as the proportion of CD increased in the mixture. The reverse was the case as the proportion of MTW increased in the mixture. All mixtures at both 5 and 10t ha^{-1}

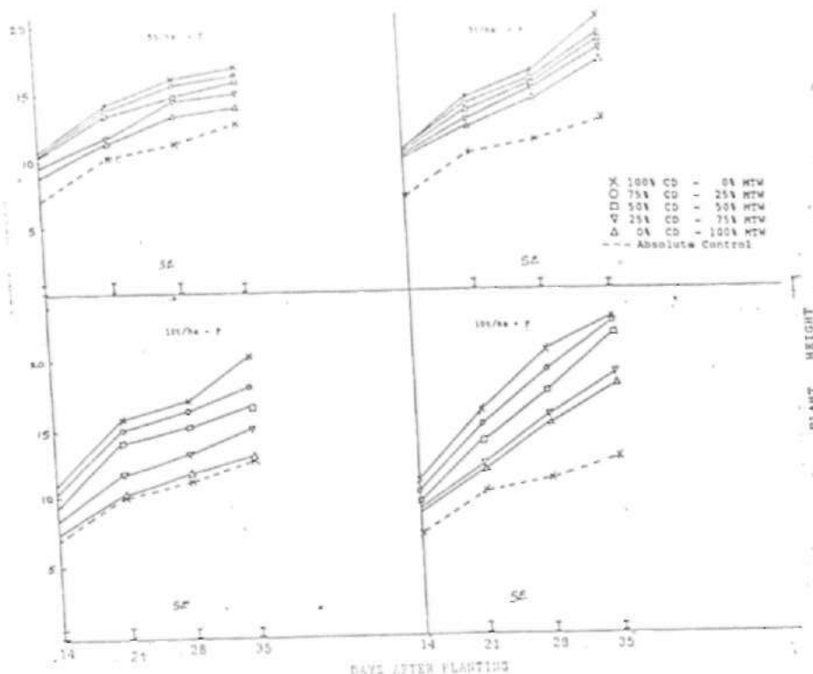


Fig. 3. Effect of the application of NTW, CD and fertilizer on plant height in Zaria soil (first cropping)

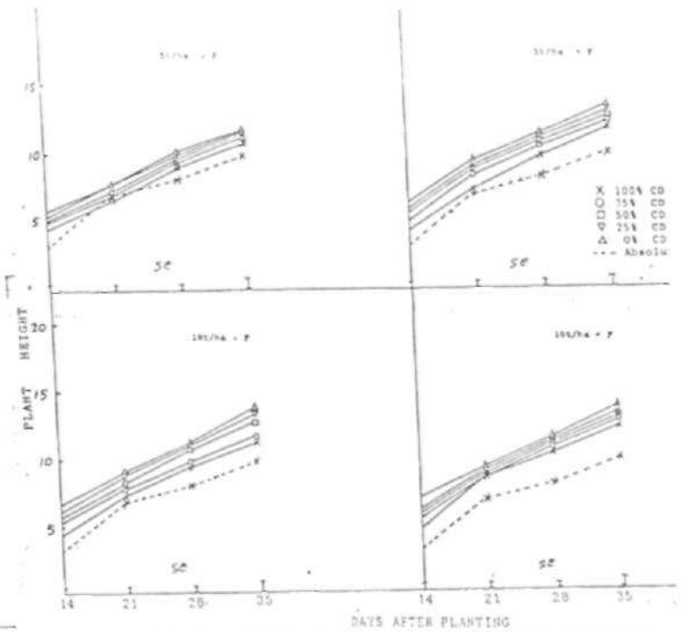


Fig.4. Effect of the application of NTW,CD and fertilizer plant height in Zaria soil (second cropping)

gave higher DMY than the absolute control except the mixture (0%CD/100%MTW).

Addition of fertilizer to the mixtures at both rates increased DMY significantly over absolute control. Significant differences were also observed between MTW with fertilizer and CD alone at each rate of application. Higher DMY were obtained with 10t ha^{-1} than 5t ha^{-1} for the same mixture with and without fertilizer. Dry matter yield increase resulting from the application of fertilizer alone was not significantly different from all mixtures with fertilizer at 5t ha^{-1}. Dry matter yield varied from 0.95g/pot for the mixture (0%CD/100%MTW+f) at 5t ha^{-1} to 8.5g/pot for the mixture (100%CD/0%MTW+f) at 10t ha^{-1}.

The mixture (100%CD/0%MTW) at both 5 and 10t ha^{-1} increased DMY by 103.75 and 151.96% respectively over the absolute control, while the mixture (0%CD/100%MTW) at both 5 and 10t ha^{-1} depressed yield by 17.18 and 11.07% respectively over the absolute control. Addition of fertilizer to the mixture (100%CD/0%MTW) at both rates further increased DMY by 289.10 and 167.04%, respectively over absolute control. The addition of fertilizer to the mixture (0%CD/100%MTW) tended to reduce the depressive effect of the MTW and increased shoot DMY by 253.97% over absolute control. When MTW and CD were applied at equal proportions with fertilizer, shoot DMY was equal to that obtained by application of full dose of fertilizer.

Second cropping: The shoot DMY for the second cropping is shown in Table 6. All MTW, CD and fertilizer amended soils increased DMY significantly over the absolute control, except for

Table 5: Effect of MTW, CD and fertilizer on shoot dry matter yield in Minjibir soil during the first cropping (gm)

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	2.34hi	1.73i-L	1.66i-L	1.34jkL	0.95L
5	+fert.	4.46cd	4.24cd	3.78d-g	3.33efg	3.06fgh
10	-fert.	2.99gh	2.02hij	1.84ijk	1.42jkl	1.02L
10	+fert.	8.58a	5.81b	4.65c	3.95cde	3.06fgh
0	-F = 1.15KL			SE(±) = 0.24		
0	+F = 3.84c-f					
0	full fert = 4.47cgh					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 6: Effect of MTW, CD and fertilizer on shoot dry matter yield in Minjibir soil during the second cropping (gm)

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.16jk	1.27ij	1.31hij	1.38ghij	1.6c-f
5	+fert.	1.36g-j	1.47e-i	1.49d-i	1.52d-h	1.70bcd
10	-fert.	1.30hij	1.44f-i	1.61c-f	1.68b-e	1.78bc
10	+fert.	1.38g-j	1.53d-g	1.64c-f	1.86b	2.11a
0	-F = 1.06K			SE(±) = 0.06		
0	+F = 1.29ij					
0	full fert = 1.44ghi					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

the mixture (100%CD/0%MTW) at 5t ha^{-1} without fertilizer. Generally, the DMY increased as the proportion of MTW increased in the mixture, while the reverse was the case as the proportion of CD increased in the mixtures.

Values varied from 1.06g/pot for absolute control to 2.11g/pot for the mixture (0%CD/100%MTW+F) at 10t ha^{-1}. Values at 10t ha^{-1} were generally higher than the 5t ha^{-1} rate. At both rates and for all mixtures, the residual effect of fertilizer was minimal, hence the non-significant difference observed between mixtures with and without fertilizer.

The mixtures (100%CD/0%MTW) and (0%CD/100MTW) at 5t ha^{-1} increased DMY by 10.03 and 52.23% respectively over absolute control while for the same mixtures at 10t ha^{-1}, DMY increased by 23.27 and 67.74% respectively over absolute control.

4.1.6 Effect of MTW, CD and fertilizer on shoot dry matter yield in Samaru soil

First cropping The effect of MTW, CD and fertilizer on shoot DMY is shown in Table 7. At both 5 and 10t ha^{-1}, DMY increased with increasing proportions of CD in the mixture. There was a corresponding decrease as the proportion of MTW increased in the mixture. This was more pronounced at the higher rate of 10t ha^{-1}. At both rates significantly higher yields than the absolute control were obtained with those mixtures having 75% CD or more either with or without fertilizer. Dry matter yields for treatments with 75% CD or more with fertilizer at 10t ha^{-1} were

significantly higher than their corresponding treatments with fertilizers at 5t ha^{-1}. The addition of fertilizer to all mixtures significantly increased DMY over their corresponding treatments without fertilizer and also the absolute control. At 5t ha^{-1}, the addition of fertilizer to CD alone (100%CD/0%MTW) and MTW alone (0%CD/100%MTW) increased DMY by 182.68 and 99.40%, respectively over the absolute control. The corresponding values at 10t ha^{-1} rate for the same mixtures were 294.99 and 89.65% respectively. The full dose of fertilizer significantly increased DMY over all treatments except for the mixtures (100%CD/0%MTW+F) and (75%CD/25%MTW+ F) at 10t ha^{-1}.

Second cropping: The shoot DMY during the second cropping is shown in Table 8. Generally, DMY was lower with the second cropping than the first. In the second cropping shoot DMY varied from 1.20g/pot for the absolute control to 3.43g/pot for the mixture (0%CD/100%MTW+F) at 10t ha^{-1}. Values increased as the proportion of MTW increased in the mixtures . There was a corresponding decrease as the proportion of CD increased in the mixture. All mixtures with and without fertilizer gave higher DMY than absolute control. At both rates and for all mixtures, the residual effect of fertilizer was minimal, hence the non-significant differences observed between mixture with and without fertilizer. At 5t ha^{-1}, the mixtures (100%CD/0%MTW+F) and (0%CD/100% MTW+F) increased DMY by 24.11 and 97.00%, respectively over the absolute control. The corresponding values at the 10t ha^{-1} were 57.69 and 185.12%, respectively for the same mixtures.

Table 7: Effect of MTW, CD and fertilizer on shoot dry matter yield in Samaru soil during the first cropping (gm)

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	4.78efg	3.72ghi	3.64gfhi	2.88ijk	2.40jk
5	+fert.	6.66bc	5.82cde	5.44def	5.38ef	4.70efg
10	-fert.	5.44ef	4.16gh	3.15hij	2.40jk	2.03k
10	+fert.	9.21a	8.44a	6.58bcd	5.43ef	4.47fg
0	-f = 2.35jk			SE(±) = 0.33		
0	+F = 2.69ijk					
0	full fert = 7.07b					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 8: Effect of MTW, CD and fertilizer on shoot dry matter yield in Samaru soil during the second cropping (gm)

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.46gh	1.56fgh	1.59e-h	1.76c-h	2.08c-g
5	+fert.	1.49gh	1.54fgh	1.90d-g	2.06d-g	2.37b-e
10	-fert.	1.35efg	1.92d-g	2.17c-f	2.41b-e	2.70bc
10	+fert.	1.90d-g	2.04d-g	2.50bcd	2.83ab	3.43a
0	-F = 1.20h			SE(±) = 0.18		
0	+F = 1.52gh					
full fert = 1.56fgh						

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

4.1.7 Effect of MTW, CD and fertilizer on N concentration(%) in maize shoot in Minjibir soil.

First cropping: Maize shoot N concentration as influenced by MTW, CD and fertilizer is shown in Table 9. The N concentration decreased as the proportion of CD increased, while the reverse was the case as the proportion of MTW increased in the mixtures. Nitrogen concentration was higher in mixtures applied at 10 than at 5t ha^{-1} irrespective of fertilizer treatment. The values ranged from 1.26 for the mixture (100%CD/0%MTW) at 5t ha^{-1} to 2.03% for the mixture (0%CD/100%MTW+F) at 10t ha^{-1}. Application of MTW and CD alone at 5t ha^{-1} decreased N concentration by 42.0 and 19.22% respectively over the absolute control. At both rates application of fertilizer increased shoot N concentration in all mixtures. When fertilizer was added to MTW alone and applied at 5 and 10t ha^{-1}, N concentration decreased by 22.17 and 21.91%, respectively over the value for absolute control. With CD alone plus fertilizer applied at the same rates, there were increases of 10.67 and 14.21% respectively, over the absolute control. The application of CD alone at both 5 and 10t ha^{-1} with and without fertilizer significantly decreased N concentration.

Second cropping: Shoot N concentrations after second cropping is shown in Table 10. At both 5 and 10t ha^{-1} values decreased as the proportion of MTW increased in the mixture. There was a corresponding increase in N concentration as the proportion of CD increased in the mixture. The N concentration for second crops varied from 0.91% for the mixtures (0%CD/100MTW) at 5t ha^{-1} to 1.16%

Table 9: Effect of MTW, CD and fertilizer on N concentration (%) in maize shoot, in Minjibir soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.25e	1.31de	1.34de	1.44de	1.49b-e
5	+fert.	1.46cde	1.47cde	1.60a-e	1.80d-e	1.97abc
10	-fert.	1.33de	1.42de	1.55a-e	1.68d-e	1.96abc
10	+fert.	1.46cde	1.62a-e	1.65a-e	1.70a-e	2.03a
0	-F = 1.78abc			SE(±) = 0.14		
0	+F = 1.40de					
0	full fert = 1.26e					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 10: Effect of MTW, CD and fertilizer on N concentration (%) in maize shoot in Minjibir soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.16b	1.16b	1.13bc	1.09dc	1.00fg
5	+fert.	1.00fg	1.01fg	0.99g	0.98g	0.91h
10	-fert.	1.10cde	1.05ef	1.00fg	0.98g	0.91h
10	+fert.	1.06e	0.98g	0.91h	0.91h	0.84i
0	-F = 0.98g			SE(±) = 0.01		
0	+F = 1.12cd					
0	full fert = 1.26a					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

for the mixture (100%CD/0%MTW) at 5t ha^{-1} without fertilizer. Generally higher N values were observed at 5 than at 10t ha^{-1}. The application of CD and MTW alone at 5t ha^{-1} and CD alone at 10t ha^{-1} increased N concentration by 18.36, and 2.04% respectively, above the absolute control, while the application of MTW alone at 10t ha^{-1} decreased N concentration by 7.69% below the absolute control.

4.1.8 Effect of MTW, CD and fertilizer on N concentration in maize shoot in Samaru soil.

First Cropping: The effect of the addition of MTW, CD and fertilizer on N concentration in maize shoot is shown in Table 11. At both 5 and 10t ha^{-1} N concentration decreased as the proportion of CD increased, while the reverse was the case as the proprtion of MTW increased in the mixture. Nitrogen concentration was significantly higher in mixtures applied at 10t ha^{-1} than at 5t ha^{-1}. The application of CD alone at both 5 and 10t ha^{-1} decreased N concentration by 98.10 and 35.71% respectively, over absolute control. When MTW alone was applied at 5 and 10t ha^{-1}, N concentration decreased by 38.06 and 10.63% respectively when compared to the absolute control. When CD alone was applied at 5t ha^{-1} with some fertilizer, N concentration tended to double when compared with the value without fertilizer. Generally supplementing the MTW and CD mixtures with fertilizer increased N concentration at both 5 and 10t ha^{-1}. Fertilizer alone gave the highest value (2.50%). Addition of fertilizer to CD alone at both

5 and 10t ha^{-1} increased N concentration by 12.40 and 2.10% respectively, over the absolute control, while with MTW alone at both rates, N concentration increased by 24.61 and 27.89% respectively above the value for absolute control.

Second cropping: Nitrogen concentration in maize shoot at second cropping is shown in Table 12. Unlike in the first cropping, at both 5 and 10t ha^{-1} with and without fertilizer values increased as the proportion of CD increased in the mixture. There was also a corresponding decrease in N concentration as the proportion of MTW increased in the mixture. Generally N concentrations for the second crops were lower for the controls compared to the first cropping. The residual effect of fertilizer on CD alone at 5 and 10t ha^{-1} increased N concentration by 417.07 and 121.95% respectively, over the absolute control, while the residual effect of fertilizer on MTW alone at both 5 and 10t ha^{-1} increased N concentration by 95.12 and 121.95% respectively, over the absolute control.

4.1.9 Effect of MTW, CD and fertilizer on P and K concentrations in maize shoot in Minjibir Soil

First Cropping: The effect of the application of MTW, CD and fertilizer on P and K concentrations in maize shoots is shown in Tables 13 and 17, respectively. Phosphorus and K concentrations increased as the proportion of MTW increased in the mixture at both 5 and 10t ha^{-1}, with and without fertilizer. The reverse was the case as the proportion of CD increased in the mixture. Values

for both elements were higher in all mixtures than the absolute control. Phosphorous concentration ranged from 0.217% for absolute control to 0.834% for MTW alone at 10t ha^{-1} without fertilizer, while K concentration varied from 1.33% for absolute control to 2.11 for MTW alone applied at 10t ha^{-1}. Addition of fertilizer to the mixtures at both 5 and 10t ha^{-1} decreased p concentration significantly, compared with mixtures that did not receive fertilizer. However, addition of fertilizer to mixtures at 5t ha^{-1} gave higher K concentration than mixtures without fertilizer, while mixtures at 10t ha^{-1} with fertilizer decreased K concentration below that of mixtures without fertilizer.

The application of CD alone at both 5 and 10t ha^{-1} increased P concentration by 138.71 and 168.66% respectively, over the absolute control. In the case of K, the increase over absolute control was by 19.06 and 34.78%, respectively. On the other hand, application of MTW alone at both 5 and 10t ha^{-1} increased P by 162.67 and 284.33% respectively over absolute control, while for K at the same rates, the increase was by 25.87 and 52.68% respectively, over the absolute control.

The addition of fertilizer to CD alone at both 5 and 10t ha^{-1} increased P concentration by 27.19% over absolute control, while K increased by 29.49 and 9.42% respectively, over the absolute control. On the other hand MTW alone applied at both 5 and 10t ha^{-1} increased P concentration over absolute control, by 136.36 and 181.81% while K concentration increased by 38.19 and 49.28%, respectively over the absolute control. The addition of fertilizer to the mixtures at both 5 and 10t ha^{-1} diluted P concentrations

significantly below that of the full dose of fertilizer. The application of the mixtures at both rates with and without fertilizer significantly increased K concentration over the absolute control, except for CD alone at 5t ha^{-1} without fertilizer.

Second cropping: The P and K concentrations in maize shoot as influenced by the application of MTW,CD and fertilizer is shown in Tables 14 and 18, respectively. Phosphorus and K concentrations increased in maize shoot as the proportion of CD increased in the mixture at both 5 and 10t ha^{-1} with and without fertilizer. There was a corresponding decrease in values as the proportion of MTW increased in all mixtures. The P and K concentrations for the second crop were generally lower than for the first crop. values were higher for mixtures applied at 10t ha^{-1} than at 5t ha^{-1}.

All mixtures with and without fertilizers increased P and K concentrations over the absolute control. The application of CD alone for both 5 and 10t ha^{-1} without fertilizer increased P concentrations by 40.48 and 98.41% respectively, over the absolute control, while K increased by 23.08 and 34.62% respectively, over the absolute control. On the other hand, application of MTW alone at both 5 and 10t ha^{-1} increased P concentration by 17. 46 and 79.37% respectively, over the absolute control, while K increased by 9.62 and 20.19% respectively, over the absolute control.

The residual effect of fertilizer on the mixtures significantly increased the P concentration at 10t ha^{-1} compared with mixtures that did not receive fertilizer at the same rate. However, K concentration was not significantly affected by the

residual effect of fertilizer. At 5 and 10t ha^{-1} addition of fertilizer to CD alone increased P concentration by 48.41 and 173.02% respectively, over the absolute control. For the same mixture and rate, K concentration was increased by 13.46 and 26.92% respectively, over the absolute control. The full dose of fertilizer increased P concentration significantly over all mixtures.

4.1.10 Effect of MTW, CD and fertilizer on P and K concentrations in maize shoot in Samaru soil.

First Cropping The P and K concentrations in maize shoot as influenced by the application of MTW, CD and fertilizer in Samaru soil are shown in Tables 15 and 19 respectively. The concentrations of these elements decreased slightly as the proportion of CD increased in the mixture irrespective of rate and fertilizer. Corresponding increases were obtained as the proportion of MTW increased in the mixtures. In all mixtures applied at 5t ha^{-1}, P concentration was significantly higher than in the absolute control. At 5 and 10t ha^{-1} for all mixtures, values for K were significantly higher than in absolute control. The highest P concentration of 0.61% was obtained with MTW alone at 10t ha^{-1} without fertilizer, while the highest K concentration of 2.15% was obtained with the full dose of fertilizer treatment.

At both rates supplementing the mixtures with fertilizer generally decreased the P concentration, while K concentration increased. The application of CD alone at 5 and 10t ha^{-1} increased P concentration by 59.76 and 13.79% respectively, over the absolute

control, while K concentrations increased by 11.84 and 24.94% respectively, over the absolute control. On the other hand, the application of MTW alone at 5 and 10t ha^{-1} increase P concentration by 108.03 and 113.79% respectively, over the absolute control, while at the same rate, K concentration increased over the absolute control by 18.14 and 130.45% respectively. Addition of fertilizer to MTW at 5 and 10t ha^{-1} increased P concentration by 5.76 and 8.03% respectively over the absolute control, while K concentration increased by 28.47 and 32.49% respectively, over the absolute control.

Second cropping: The effects of MTW, CD and fertilizers on shoot P and K concentrations are shown in Tables 16 and 20 respectively. Phosphorus and K concentrations increased as the proportion of CD increased in the mixtures. The reverse was the case as the proportion of MTW increased in the mixtures. Phosphorus and K concentrations in all mixtures with and without fertilizer were significantly higher than in absolute control except for K concentration in mixtures with 75% or more of MTW applied of 5t ha^{-1} with and without fertilizer and also at 10t ha^{-1} without fertilizer. The P and K concentrations were higher

Table 11: Effect of MTW, CD and fertilizer on N concentration (%) in maize shoot, in Samaru soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.68j	0.80ij	0.82ij	0.93hi	0.98ghi
5	+fert.	1,23b-f	1.28b-e	1.33bcd	1.33bcd	1.37b
10	-fert.	1.00f-i	1.03fgh	1.07e-h	1.12c-h	1.22b-f
10	+fert.	1.12c-g	1.13c-h	1.20b-g	1.24b-f	1.40b
0	-F = 1.10d-h			SE(±) = 0.01		
0	+F = 2.50a					
0'	full fert = 1.35bc					

Means not followed by the same letter are significantly different at *P=0.05* by *DNMRT*

Table 12: Effect of MTW, CD and fertilizer on N concentration (%) in maize shoot, in Samaru soil during the second croping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.00b-e	0.98cde	0.98cde	0.94de	0.80f
5	+fert.	1.12ab	1.00b-e	0.98cde	0.98cde	0.91ef
10	-fert.	1.12ab	1.09abc	1.05a-d	0.98cde	0.91ef
10	+fert.	1.05a-d	0.98cde	0.98cde	0.98cde	0.91ef
0	-F = 0.41g			SE(±) = 0.03		
0	+F = 1.16a					
0	full fert = 1.16bc					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 13: Effect of MTW, CD and fertiizers on P concentration (%) in maize shoot, in Minjibir soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.52bc	0.54bc	0.55bc	0.56c	0.57bc
5	+fert.	0.28de	0.29de	0.29de	0.29de	0.29de
10	-fert.	0.58bc	0.57bc	0.70ab	0.72ab	0.83a
10	+fert.	0.28de	0.28de	0.29de	0.30de	0.30de
0	-F = 0.22e			SE(±) = 0.06		
0	+F = 0.29de					
full fert = 0.29de						

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 14: Effect of MTW, CD and fertilizer on P concentration (%) in maize shoot, in Minjibir soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.18fg	0.17gh	0.17gh	0.16hi	0.15ij
5	+fert.	0.18fg	0.18fg	0.18fg	0.18fg	0.17gh
10	-fert.	0.25c	0.25c	0.24cd	0.23de	0.23de
10	+fert.	0.34a	0.30b	0.30b	0.29b	0.26c
0	-F = 0.13j			SE(±) = 0.01		
0	+F = 0.16ghi					
0	full fert = 0.20f					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 15:Effect of MTW,CD and fertilizers on P concentrations (%) in maize shoot,in Samaru soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.46bcd	0.50abc	0.50abc	0.57ab	0.60a
5	+fert.	0.29e	0.29e	0.29e	0.30e	0.31e
10	-fert.	0.33e	0.37de	0.47bcd	0.60a	0.61a
10	+fert.	0.29e	0.30e	0.30e	0.31e	0.31e
0	-F = 0.29e			SE(±) = 0.03		
0	+F = 0.51abc					
0	full fert = 0.41cd					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 16:Effect of MTW,CD and fertilizers on P concentrations (%) in maize shoot,in Samaru soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.22bc	0.20de	0.20de	0.18gh	0.16i
5	+fert.	0.22bc	0.20de	0.19de	0.18gh	0.16i
10	-fert.	0.22bc	0.23ab	0.21cd	0.20de	0.19de
10	+fert.	0.24a	0.23ab	0.20de	0.19efg	0.19de
0	-F = 0.14j			SE(±) = 0.004		
0	+F = 0.15ij					
0	full fert = 0.24a					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 17: Effect of MTW, CD and fertilizer on K concentration (%) in maize shoot, in Minjibir soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.64bce	1.66bcd	1.66bcd	1.71a-d	1.74a-d
5	+fert.	1.79abc	1.83ab	1.85ab	1.85ab	1.91ab
10	-fert.	1.86ab	1.87ab	1.90ab	1.94ab	2.11a
10	+fert.	1.51bcd	1.56bcd	1.59bcd	1.63bcd	2.06a
0	-F = 1.33cd			SE(±) = 0.12		
0	+F = 1.35d					
0	full fert = 1.84aba					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 18: Effect of MTW, CD and fertilizer on K concentration (%) in maize shoot, in Minjibir soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.13b-c	0.12b-f	0.12b-f	0.11c-f	0.11c-f
5	+fert.	0.12b-f	0.11c-f	0.11def	0.11c-f	0.11c-f
10	-fert.	0.14b	0.14b	0.14b	0.13b-e	0.11c-f
10	+fert.	0.13bcd	0.13bcd	0.12b-f	0.12b-f	0.11c-f
0	-F = 0.10f			SE(±) = 0.01		
0	+F = 0.11def					
0	full fert = 0.98a					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 19: Effect of MTW, CD and fertilizer on K concentration (%) in maize shoot, in Samaru soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.14fg	1.50f	1.52f	1.55ef	1.56ef
5	+fert.	1.56ef	1.64de	1.67abc	1.69abc	1.70abc
10	-fert.	1.65cd	1.65cd	1.71abc	1.72abc	1.73abc
10	+fert.	1.69abc	1.72abc	1.73abc	1.74abc	1.75a
0	-F = 1.32h			SE(±) = 0.02		
0	+F = 2.15a					
0	full fert = 1.41g					

Means not followed by the same letter are significantly different at P=0,05 by DNMRT

Table 20: Effect of MTW, CD and fertilizer on K concentration (%) in maize shoot, in Samaru soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.12abc	0.13abb	0.13abc	0.12bcd	0.11d
5	+fert.	0.13abc	0.13abc	0.13abc	0.12bcd	0.12bcd
10	-fert.	0.13abc	0.13abc	0.13abc	0.12bcd	0.12bcd
10	+fert.	0.13abc	0.13abc	0.13abc	0.13abc	0.13abc
0	-F = 0.11d			SE(±) = 0.003		
0	+F = 0.12bcd					
0	full fert = 0.13abc					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

at 10t ha^{-1} than 5t ha^{-1} for mixtures without fertilizers. The application of CD alone at 5 and 10t ha^{-1} increased P concentration by 52.22 and 12.12% respectively, over the absolute control. Application of MTW alone at the same rates increased P concentration by 67.31 and 32.22% respectively. At both rates P and K concentrations in mixtures with fertilizers did not differ significantly from those without fertilizers. The only exceptions are mixtures containing 75% and above of CD.

4.1.11 Effect of MTW, CD and fertilizer on N uptake (mg/pot) in maize shoot in Minjibir soil.

First cropping: At both rates with and without fertilizer, values increased as the proportion of CD increased in the mixture, while as the MTW increased in the mixtures N uptake was reduced (Table 21). The uptake of N was higher at 10t ha^{-1} than at 5t ha^{-1}. Nitrogen uptake ranged from 14.15mg/pot for the mixture 0%MTW/100% CD to 125.27 mg/pot from the application of CD alone with fertilizer at 10t ha^{-1}. The addition of fertilizer to the mixtures at both 5 and 10t ha^{-1} gave significantly higher N uptake values than their corresponding mixtures without fertilizer. With the exception of mixtures that have 75% or more of MTW, application of the mixtures at 10t ha^{-1} with fertilizer significantly increased N uptake over the 5t ha^{-1} rate with fertilizer. Nitrogen uptake was significantly higher in mixtures applied at 5 and 10t ha^{-1} with fertilizer than the absolute control.

Second cropping Nitrogen uptake after second cropping increased with increasing proportions of MTW in the mixtures irrespective of

rates and fertilizer (Table 22). The reverse was the case as the proportion of CD increased in the mixtures. Generally N uptake was higher when mixtures were applied at the 10 than at 5t ha^{-1} rates. At both 5 and 10t ha^{-1} there were no significant differences in N uptake in mixtures with and without fertilizer. Nitrogen uptake in all amended treatments was significantly higher than the absolute control.Nitrogen uptake was generally lower for the second cropping relative to the first cropping. Values for the uptake ranged from 1.34mg/pot for the absolute control to 5.54 mg/pot for the application of MTW alone at 10t ha^{-1} with fertilizer.

4.1.12 Effect of MTW, CD and fertilizer on N uptake in maize shoot in Samaru soil.

First cropping: The effect of MTW, CD and fertilizer on N uptake in Samaru soil is shown in Table 23. At both rates with and without fertilizers, N uptake values increased as the proportion of CD increased in the mixtures, while as the MTW increased in the mixture N uptake was reduced. Values were higher for all mixtures applied at 10 than at 5t ha^{-1} rates. Nitrogen uptake was significantly higher in mixtures that received fertilizer than in those without fertilizers irrespective of rate of application. At both rates, mixtures with 50% CD and above gave values that were significantly higher than the absolute control irrespective of fertilizer. The lowest uptake of 25.96mg/pot was observed for the absolute control, while the highest uptake was obtained with the

Table 21: Effect of MTW, CD and fertilizer N uptake in maize shoot (mg/pot) in Minjibir soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	29.25g	22.66gh	22.24gh	19.30hi	14.15i
5	+fert.	65.56bd	62.33d	60.48de	59.61de	60.28de
10	-fert.	39.23f	28.68g	28.52g	23.86gh	19.89hi
10	+fert.	125.27a	93.54b	76.26c	66.76d	61.92
0	-F = 20.59hi			SE(±) = 2.23		
0	+F = 53.76e					
0	full fert = 59.47de					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 22: Effect of MTW, CD and fertilizer on N uptake by maize shoot (mg/pot) in Minjibir soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	13.46i	14.39ghi	14.69f-i	15.04e-h	16.10c-f
5	+fert.	13.60hi	14.84f-i	14.65f-i	14.90e-i	15.38d-g
10	-fert.	14.30ghi	15.12e-h	16.10c-f	16.46cde	16.52cde
10	+fert.	14.52f-i	14.90e-i	14.92e-i	16.93bcd	17.64bc
0	-F = 10.39j			SE(±) = 0.45		
0	+F = 14.55ghi					
0	full fert = 18.14b					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

application of CD alone at 10t ha^{-1} with fertilizer. The full dose of fertilizer equally increased N uptake as much as the 75%CD/25%MTW) mixture.

Second cropping: Nitrogen uptake after second cropping increased with increasing proportion of MTW in the mixture irrespective of rate of application of the mixture and fertilizer (Table 24). A reverse situation was obtained as the proportion of CD increased in the mixtures. Nitrogen uptake for all mixtures was significantly higher than in control. Nitrogen uptake was significantly higher in mixtures applied at 10t ha^{-1} than in mixtures applied at 5t ha^{-1} irrespective of fertilizer application.

4.1.13 Effect of MTW, CD and fertilizer on P and K uptake (mg/Pot) by maize shoot in Minjibir soil.

First cropping: Phosphorus and K uptake increased as the proportion of CD increased in the mixtures applied at both 5 and 10t ha^{-1} with and without fertilizer (Table 25 and 29 respectively). There was a corresponding decrease in P and K uptake as the proportion of MTW increased in the mixture. Generally for both elements mixtures applied at 10t ha^{-1} with and without fertilizer had higher values than those applied at 5t ha^{-1}.

The addition of fertilizer to the mixtures increased uptake of both elements over similar mixtures without fertilizer. This was more pronounced with K. When fertilizer was added to the mixtures values were significantly higher than the absolute control. Phosphorus uptake ranged from 2.52mg/pot to 23.67mg/pot while K

Table 23: Effect of MTW, CD and fertilizer on N uptake by maize shoot (mg/pot) in Samaru,during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	32.44L	29.76M	29.85m	26.8N	23.32P
5	+fert.	81.92c	74.50e	72.49f	71.55f	63.92h
10	-fert.	54.40i	42.85j	33.71k	26.88N	24.77op
10	+fert.	103.15a	96.22b	78.96d	67.33g	64.58h
0	-F = 25.96no			SE(±) = 0.43		
0	+F = 67.25g					
0	full fert = 95.12b					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 24: Effect of MTW, CD and fertilizer on N uptake by maize shoot (mg/pot) in Samaru soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	14.60L	15.19L	15.58kL	16.54jk	16.64jk
5	+fert.	16.69jk	18.77gh	18.45hi	20.09i	22.20e
10	-fert.	20.83f	20.93f	22.79de	23.62cd	24.48c
10	+fert.	19.85fg	19.99f	24.50c	27.73b	31.21a
0	-F = 4.92M			SE(±) = 0.35		
0	+F = 17.63hij					
0	full fert = 17.27ij					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

values ranged from 15.87mg/pot to 129.56mg/pot.

Second Cropping: Phosphorus and K uptake after the second cropping increased as the proportion of MTW increased in the mixtures irrespective of rate and fertilizer (Tables 26 and 30 respectively). Values were higher at 10 than at 5t ha^{-1}. Mixtures applied at 5t ha^{-1} and supplemented with fertilize significantly increased P uptake over absolute control. All mixtures applied at 10t ha^{-1} significantly increased P uptake over the absolute control. The uptake of K generally increased through addition of fertilizer to the mixtures. However, the uptake of P and K were generally lower for the second cropping compared with the first cropping. Phosphorus uptake ranged from 1.3 to 5.54 mg/pot, while values for K ranged from 1.10 to 2.39 mg/pot.

4.1.14 Effect of MTW, CD and fertilizer on P and K uptake by maize shoot in Samaru soil.

First Cropping: The effect of the application of MTW, CD, and fertilizer on P and K uptake in Samaru soil is shown in Tables 27 and 31 respectively. Values for P and K uptake increased as the proportion of CD increased in the mixture irrespective of rate and fertilizer. There was a corresponding decrease as the proportion of MTW increased in the mixtures. Values for both

elements were generally higher at 10 than at 5t ha^{-1}. Uptake values for both elements were higher in mixtures that received fertilizer than in those that did not receive fertilizer. The potassium uptake increased from 35.12mg/pot for the mixture 100% MTW at 10t ha^{-1} without fertilizer to 78.23 mg/pot for the same mixture with fertilizer.

Second Cropping: During the second cropping, uptake of both elements increased as the proportion of MTW increased in the mixture irrespective of rate and fertilizer. There was a corresponding decrease as the proportion of CD increased in the mixtures (Tables 28 and 32, respectively). The application of the mixture generally increased P and K uptake over the absolute control. With the exception of mixtures with 75% CD and more, mixtures applied at 10t ha^{-1} generally increased K uptake significantly over their respective mixtures at 5t ha^{-1} without fertilizer. The P uptake ranged from 1.69 to 6.48 mg/pot,while potassium uptake ranged from 1.34 to 4.29 mg/pot.

4.2 CORRELATION STUDIES

4.2.1 Relationship between dry matter yield,and plant height dry matter yield and nutrient uptake, plant height and nutrient uptake and N,P and K uptake in maize shoot

The correlation coefficients among the various parameters are shown in Table 33. Dry matter yield was significantly correlated with plant height in all mixtures and both soils. Values for 100%CD/0%MTW mixtures were ($r=+0.974^{**}$) and ($r=+0.964^{**}$) for Minjibir and Samaru, respectively. Correlation

Table 25: Effect of MTW, CD and fertilizer on P uptake by maize shoot (mg/pot) in Minjibir soil during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	12.12de	9.44ij	9.13ij	7.44k	5.41L
5	+fert.	12.90de	11.99de	10.73fgh	9.52hij	8.57jk
10	-fert.	17.20b	11.86def	12.32cd	10.27ghi	8.51jk
10	+fert.	23.67a	16.30b	13.58c	11.75def	9.04ij
0	-F = 2.52M			SE(±) = 0.36		
0	+F = 11.12efg					
0	full fert = 13.81c					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 26: Effect of MTW, CD and fertilizer on P uptake (mg/pot) by maize shoot, in Minjibir soil, during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	2.07hij	2.15hij	2.16hij	2.21hij	2.38hij
5	+fert.	2.48ghi	2.65fgh	2.66fgh	2.71fgh	2.87fgh
10	-fert.	2.92e-h	3.55d-g	3.77c-f	3.54d-g	4.00b-e
10	+fert.	4.71abc	4.73abc	4.91ab	5.37a	5.54a
0	-F = 1.34j			SE(±) = 0.32		
0	+F = 2.10hij					
0	full fert = 2.90e-h					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 27: Effect of MTW, CD and fertilizer on P uptake (mg/pot) by maize shoot, in Samaru soil, during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	22.10d	18.60ef	18.32ef	16.42ghi	14.56jkl
5	+fert.	19.31e	17.07fgh	15.98hij	16.32ghi	14.41jkl
10	-fert.	17.95fg	15.53h-k	14.81i-l	14.48jkl	12.38M
10	+fert.	27.01b	25.32c	19.96e	16.65gh	14.01kl
0	-F = 6.85n			SE(±) = 0.46		
0	+F = 13.631m					
0	full fert = 29.22a					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 28: Effect of MTW, CD and fertilizer on P uptake (mg/pot) by maize shoot, in Samaru soil during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	3.19gh	3.07h	3.14gh	3.26gh	3.44gh
5	+fert.	3.32gh	3.62fgh	3.65fgh	3.75e-h	3.91d-g
10	-fert.	4.38c-f	4.41cde	4.45cde	4.47cde	5.01bc
10	+fert.	4.48cde	4.66bcd	5.03bc	5.38b	6.4a
0	-F = 1.69i			SE(±) = 0.22		
0	+F = 2.33i					
0	full fert = 3.72e-h					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 29: Effect of MTW, CD and fertilizer on K uptake (mg/pot) by maize shoot, in Minjibir soil, during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	38.37i	28.72ijk	27.56jk	22.78kl	16.53lm
5	+fert.	78.76cd	77.59cd	69.93def	61.61fgh	57.45h
10	-fert.	58.47h	37.76i	34.96ij	27.87jk	21.52kl
10	+fert.	129.56a	90.64b	73.94de	64.38e-h	62.83fgh
0	-F = 15.87lm			SE(±) = 3.02		
0	+F = 66.05efg					
0	full fert = 86.18bc					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 30: Effect of MTW, CD and fertilizers on K uptake (mg/pot) by maize shoot, in Minjibir soil, during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.49efg	1.52efg	1.56d-g	1.57d-g	1.84b-f
5	+fert.	1.60d-g	1.68def	1.66def	1.66d-g	1.76c-f
10	-fert.	1.82b-f	1.99b-f	2.12def	2.14bcd	2.18bcd
10	+fert.	1.81c-f	1.92b-f	2.03b-e	2.27bc	2.39bgh
0	-F = 1.00g			SE(±) = 0.16		
0	+F = 1.44fg					
0	full fert = 1.41fg					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 31: Effect of MTW, CD and fertilizer on K uptake (mg/pot) by maize shoot, in Samaru soil, during the first cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	70.60efg	55.70fgh	55.33fgh	44.06gh	37.44gh
5	+fert.	104.56cd	95.45cde	91.02cde	90.92cde	79.90def
10	-fert.	89.76cde	69.89efg	53.87fgh	41.28gh	35.12gh
10	+fert.	155.65a	145.17b	113.83c	95.15cde	78.23def
0	-F = 31.15gh			SE(±) = 8.05		
0	+F = 57.84fgh					
0	full fert = 99.69cd					

Means not followed by the same letter are significantly *different at P=0.05 by DNMRT*

Table 32: Effect of MTW, CD and fertilizer on K uptake (mg/pot) by maize shoot, in Samaru soil, during the second cropping

Rate (tha-1)	Fertilizer	CD/MTW Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.96fg	2.01fg	2.04fg	2.16fg	2.33efg
5	+fert.	2.00fg	2.32efg	2.39d-g	2.52def	2.93cd
10	-fert.	2.49def	2.50def	2.78cde	2.94cd	3.23bc
10	+fert.	2.46d-g	2.65c-f	3.20bc	3.59b	4.29a
0	-F = 1.34h			SE(±) = 0.16		
0	+F = 1.88g					
0	full fert = 1.98fg					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 33: Matrix of coefficient of correlation (r) between DMY and plant height, DMY nutrient and uptake, plant height and nutrients uptake and N,P and K uptake in maize shoot, when 100%CD/0%MTW; 50%CD/50%MTW and 0%CD/100%MTW was applied to Minjibir and Samaru soils.

Parameters	Minjibir			Samaru		
	100%CD/ 0%MTW	50%CD/ 50%MTW	0%CD/ 100%MTW	100%CD/ 0%MTW	50%CD/ 50%MTW	0%CD/ 100%MTW
1. Dry matter yield vs.N uptake	0.995**	0.974**	0.893**	0.797*	0.824**	0.879**
2. Dry matter yield vs.P uptake	0.847**	0.744*	0.848**	0.864**	0.846**	0.850**
3. Dry matter yield vs.K uptake	0.978**	0.982**	0.693*	0.970**	0.951**	0.951**
4. Dry matter yield vs.plant height	0.973**	0.957**	0.965**	0.968**	0.930**	0.959**
5. N conc. vs.K concentration	0.595	0.311	0.778*	0.856**	0.787*	0.834**
6. N uptake vs. P uptake	0.806**	0.687*	0.686*	0.718*	0.764*	0.764*
7. N uptake vs.K uptake	0.958**	0.930**	0.735*	0.835**	0.949**	0.949**
8. N uptake vs. plant height	0.951**	0.939**	0.913**	0.755*	0.873**	0.873**
9. P uptake vs. K uptake	0.866**	0.776*	0.620	0.802**	0.758*	0.772*
10. P uptake vs. plant height	0.874**	0.812**	0.837**	0.791*	0.730*	0.779*
11. K uptake vs. plant height	0.997**	0.929**	0.769*	0.968**	0.964**	0.975**

* : Significant at 0.05 level
** : Significant at 0.01 level

between DMY and N,P and K uptake were also significant in all mixtures and both soils. Correlation coefficients of ($r=+0.974^{**}$) and ($r=+0.824^{**}$) were observed between DMY and N uptake with the application of 50%CD/50%MTW to Minjibir and Samaru soils, respectively. Similar results were observed between DMY and P and K uptake.

There was a strong relationship between plant height and N,P and K uptake in all mixtures and both soils. The correlation coefficients between plant height and P uptake in the 0%CD/100%MTW mixtures for example were, ($r=+0.837^{**}$) and ($r=+0.779^{*}$) for Minjibir and Samaru soils, respectively. For the same mixture, the correlation coefficients between plant height and K uptake were ($r=+0.769^{*}$) and ($r=+0.975^{**}$) for Minjibir and Samaru soils, respectively. However, the relationship between N and K concentrations were not significant in all mixtures evaluated in Minjibir soils.

4.3 FIELD STUDY

4.3.1 Effect of MTW, CD and fertilizer on plant height

At both 5 and 10t ha^{-1}, with and without fertilizer, plant height increased as the proportion of CD increased in the mixture (Figure 5). Values obtained for all mixtures were significantly higher than the absolute control. This effect was higher for mixtures with fertilizers. Maize height varied from 117.00cm in absolute control to 222.0cm in the full recommended dose of fertilizer treatment.

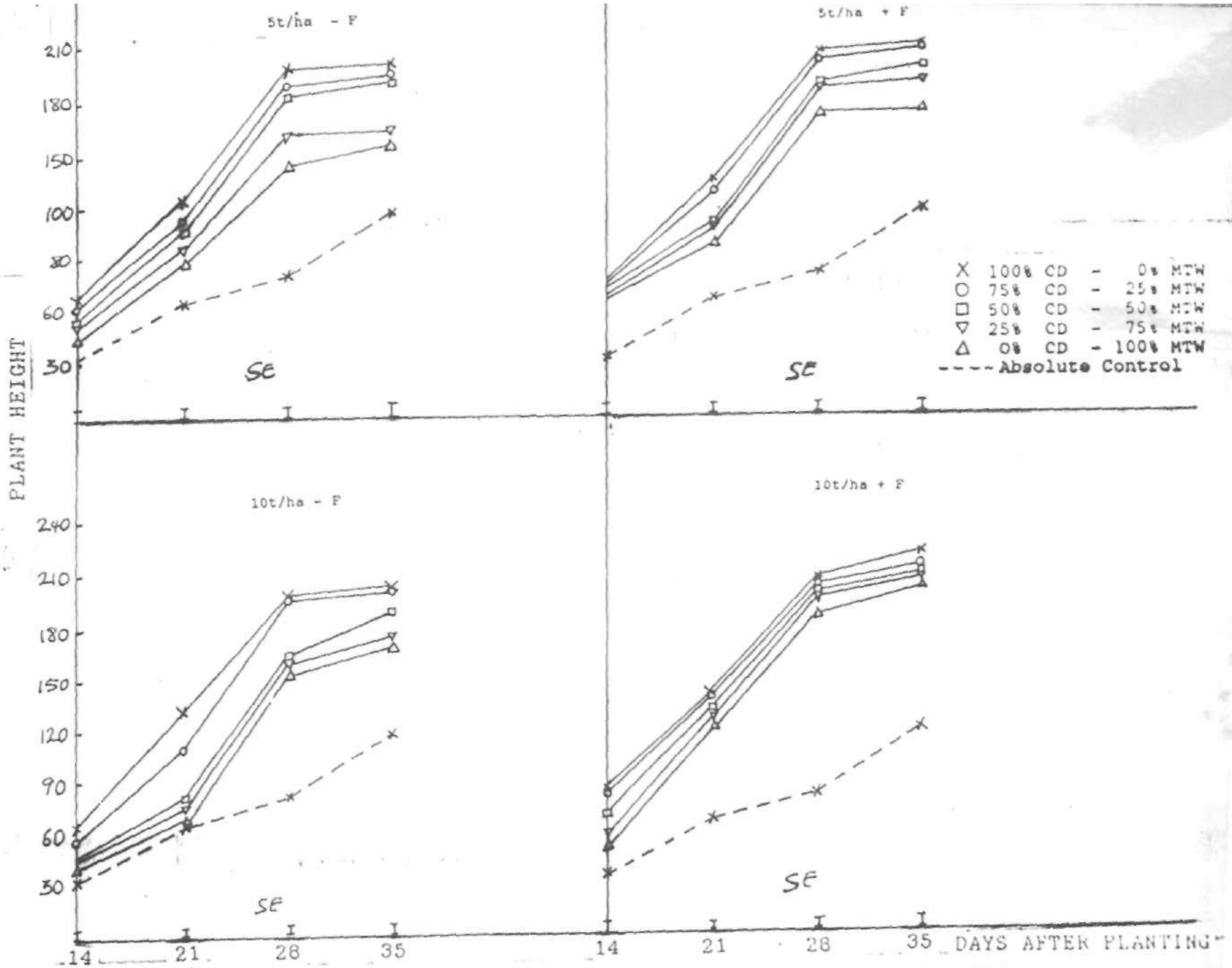


Fig. 5. Effect of field application of MTW, CD and fertilizer on height.

4.3.2 Effect of application of MTW, CD and fertilizer on stover yield (kg ha^{-1})

The effect of field application of MTW, CD and fertilizer on stover yield is shown in Table 34. Values ranged from 2142.0kg ha^{-1} for the absolute control to 6067.0kg ha^{-1} for CD alone at 10t ha^{-1} with fertilizer. All mixtures with and without fertilizer applied at 5 and 10t ha^{-1} gave significantly higher stover yield than the absolute control. Values increased as the proportion of CD increased in the mixture irrespective of fertilizer and rate of application. The reverse was the case as the proportion of MTW increased in the mixture. For all mixtures, increasing the rate of application did not significantly increase stover yield. Values were, however, slightly higher for 10 than 5t ha^{-1}. At 5 and 10t ha^{-1}, stover yield generally increased with the addition of fertilizer to the mixtures. Values at half and full doses of fertilizer were significantly higher than the absolute control.

4.3.3 Effect of application of MTW,CD and fertilizers on maize grain yield (kg ha^{-1})

The effect of MTW, CD and fertilizers on maize grain yield is shown in Table 35. Generally grain yield increased as the proportion of CD increased in the mixture. The reverse was the case as the proportion of MTW increased in the mixtures. Values ranged from 374.00kg ha^{-1} for the absolute control to 1363kg ha^{-1} for CD alone at 10t ha^{-1} with fertilizer. With the exception of

Table 34: Effect of MTW, CD and fertilizer on maize stover yield ($Kg\ ha^{-1}$)

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	4104f	4304ef	4504def	4575def	4733b-f
5	+fert.	4246ef	4683c-f	5204a-f	5533a-b	5717abc
10	-fert.	4513def	4675c-f	4979a-f	5121a-f	5717abc
10	+fert.	4879b-f	4879b-f	5258a-e	5853ab	6067a
0	-F = 2142g			SE(±) = 325.88		
0	+F = 5019a-f					
0	full fert = 5079b-f					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 35: Effect of MTW, CD and fertilizer on maize grain yield ($Kg\ ha^{-1}$)

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	484ij	623hij	839e-h	880d-h	918c-g
5	+fert.	1071b-f	1135a-d	1174abc	1238ab	1319a
10	-fert.	516ij	643ghi	809fgh	873d-h	951c-f
10	+fert.	1104a-d	1178abc	1195abc	1250ab	1363ab
0	-F = 374j			SE(±) = 82.42		
0	+F = 1037b-f					
0	full fert = 1098a-e					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

mixtures having 75% of MTW and above, applied at 5t ha^{-1} and MTW alone applied at 10t ha^{-1} without fertilizer. All mixtures gave yields that were significantly higher than the absolute control. Generally, higher grain yield was obtained when mixtures were applied at 10t ha^{-1} than at 5t ha^{-1}. Fertilizer addition to the mixtures gave higher yields than when no fertilizer was added. Addition of fertilizer to MTW alone at 5t ha^{-1} increased grain yield by 121.28%, while addition of fertilizer to CD alone at the same rate increased grain yield by 48.47% respectively. At 10t ha^{-1} addition of fertilizer to MTW alone increased grain yield by 113.95%, while addition of fertilizer to CD alone at the same rate increased grain yield by 38.70% respectively. Generally lower yield increment was obtained with the 10t ha^{-1} rate. Maize grain yield for CD alone at 5t ha^{-1} with fertilizer gave higher yield than the full dose of fertilizer.

4.3.4 Effect of application of MTW, CD and fertilizer on 1,000-seed weight (gm)

Generally, 1,000 seed weight increased as the proportion of CD increased in the mixture (Table 36). Values ranged from 142.70gm for the absolute control to 237.70gm with CD alone at 10t ha^{-1} with fertilizer. Addition of fertilizer to the mixtures in most cases significantly increased 1000-seed weight over the absolute control. Fertilizer addition to the mixtures generally gave higher seed weight than their respective treatments which did not receive fertilizer.

4.3.5 Effect of field application of MTW, CD and fertilizer on N concentration(%) in maize stover

Nitrogen concentration in maize stover as affected by the application of MTW, CD and fertilizer is shown in Table 37. Values decreased as the proportion of CD increased in the mixture irrespective of rate and fertilizer applications. There was a corresponding decrease as the proportion of MTW increased in the mixture. Higher N concentrations were observed for all mixtures applied at 10 than at 5t ha^{-1} with or without fertilizer. Values ranged from 0.23% for the absolute control to 0.45% for MTW alone at 10t ha^{-1}.

4.3.6 Effect of application of MTW,CD and fertilizer on P and K concentrations (%) in maize stover

Phosphorus and K concentrations in maize stover decreased as the proportion of CD increased in all the mixture (Tables 38 and 39, respectively). The reverse was the case as the proportion of MTW increased in all the mixtures. Values obtained when the mixtures were applied were higher than values in the absolute control. Phosphorus concentration was reduced by the addition of fertilizer to the mixtures at both 5 and 10t ha^{-1}. However, decreased K concentration from the addition of fertilizer, to the mixtures occurred at the 5t ha^{-1} rate and with mixtures containing 75%CD or above applied at 10t ha^{-1}. The P concentration ranged from 0.022 for the absolute control to 0.102% for the full dose of fertilizer, while K concentration ranged from 0.227 for the absolute control to 0.613% for MTW

Table 36: Effect of field application of MTW, CD and fertilizer on 1000 seed weight (gm)

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	156.70ef	179.30c-g	184.70b-g	170.00ef	188.00b-f
5	+fert.	208-00a-e	184.00b-g	216.70abc	225.20ab	237.0ab
10	-fert.	172.00eg	180.70c-g	172.00efg	173.30d-g	186.00b-f
10	+fert.	198.70a-f	206.00a-c	220.70a-d	237.30abc	245.70a
0	-F = 142.70f			SE(±) = 12.62		
0	+F = 201.30a-e					
0	full fert = 207.70a-e					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 37: Effect of field application of MTW, CD and fertilizes on N concentration (%) in maize stover

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.38bc	0.29d-g	0.27fg	0.25fg	0.24g
5	+fert.	0.40bc	0.38bc	0.35b-e	0.33b-f	0.30c-g
10	-fert.	0.40bc	0.36bcd	0.31b-g	0.30c-g	0.28d-g
10	+fert.	0.45a	0.38bc	0.36bcd	0.32b-e	0.32b-e
0	-F = 0.23g			SE(±) = 0.03		
0	+F = 0.35bc					
0	full fert = 0.24g					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 38: Effect of field application of MTW CD and fertilizer on P concentration (%) in maize stover

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.08bc	0.08cbc	0.06bcd	0.06bcd	0.06bcd
5	+fert.	0.07bcd	0.06bd	0.05bcd	0.05bcd	0.05bcd
10	-fert.	0.09b	0.08bc	0.07bcd	0.05bcd	0.05bcd
10	+fert.	0.096	0.07bcd	0.05bcd	0.05bcd	0.04cd
0	-F = 0.02d			SE(±) = 0.01		
0	+F = 0.06bcd					
0	full fert = 0.10a					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 39: Effect of field application of MTW, CD and fertilizer on K concentration (%) in maize stover

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.53ab	0.45abc	0.42bc	0.40bcd	0.37bcd
5	+fert.	0.42bc	0.40bcd	0.39bcd	0.38bcd	0.37bcd
10	-fert.	0.52ab	0.50ab	0.42bc	0.41bc	0.40bcd
10	+fert.	0.61a	0.51ab	0.48ab	0.38bcd	0.34bcd
0	-F = 0.23d			SE(±) = 0.53		
0	+F = 0.29cd					
0	full fert = 0.45abc					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

alone with fertilizer at 10t ha^{-1}.

4.3.7 *Effect of MTW,CD and fertilizer on N concentration (%) in maize ear leaves*

The effect of MTW, CD and fertilizer on N concentration of ear leaves is shown in Table 40. Results indicate that N concentration generally increased as the proportion of CD increased in the mixtures. Nitrogen concentration was generally higher in those mixtures that received fertilizer than in those without fertilizer. The addition of fertilizer to CD alone at 10t ha^{-1} gave the highest N concentration of 2.59%, while the lowest N concentration of 1.20% was obtained in the absolute control. Nitrogen concentration was significantly higher in the full dose than for the half dose of fertilizer.

4.3.8 *Effect of field application of MTW, CD and fertilizers on P and K concentrations (%) in maize ear leaves*

The concentrations of P and K in maize ear leaves increased as the proportion of CD increased in the mixtures (Tables 41 and 42). Values decreased as the proportion of MTW increased in the mixtures. Mixtures applied at 10t ha^{-1} gave higher P and K concentrations than at 5t ha^{-1}. Phosphorus and K concentrations in mixtures that received fertilizer were higher than in same mixtures without fertilizer. The application of full dose of fertilizer did not significantly increase K concentration over the absolute control. Values for P concentration ranged from 0.30% for the half dose of fertilizer to 0.73% for MTW alone at

Table 40: Effect of field application of MTW, CD and fertilizers on N concentration (%) in maize ear leaves

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	1.21j	1.28ij	1.39h-j	1.43g-f	1.52f-j
5	+fert.	1.75d-h	1.76d-h	1.79d-h	1.83c-g	1.95b-c
10	-fert.	1.54f-j	1.59e-j	1.67e-i	1.74d-h	1.86b-f
10	+fert.	1.89b-f	1.98b-e	1.97b-c	2.23abc	2.59a
0	-F = 1.25j			SE(±) = 0.12		
0	+F = 2.14bcd					
0	full fert = 2.27ab					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 41: Effect of field application of MTW, CD and fertilizer on P concentration (%) in maize ear leaves

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.50c-f	0.47def	0.46ef	0.43ef	0.35f
5	+fert.	0.64a-b	0.59bcd	0.52b-f	0.47def	0.44f
10	-fert.	0.60abc	0.54b-f	0.50c-f	0.46ef	0.43f
10	+fert.	0.73a	0.68a	0.57b-c	0.52c-f	0.49e-f
0	-F = 0.50c-f			SE(±) = 0.04		
0	+F = 0.30g					
0	full fert = 0.50c-f					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

10t ha^{-1} with fertilizer. Values for K concentration ranged from 0.60% for the absolute control to 0.97% for CD alone at 10t ha^{-1} with fertilizer.

4.3.9 Effect of field application of MTW,CD and fertilizers on organic carbon content of the cropped field

The organic carbon content of the cropped field after harvest is shown in Table 43. With the exception of mixtures having 75% MTW and above, applied at 5t ha^{-1} without fertilizer, organic carbon in all amended soils was significantly higher than in absolute control. At both rates of application, the organic carbon status was higher for mixture with high proportion of MTW. There was a corresponding decrease in organic carbon as the proportion of CD increased. Higher organic carbon status was observed when mixtures were applied at 10 than at 5t ha^{-1}. The addition of fertilizer to all mixtures significantly increased the organic carbon content. Application of the mixture at 10t ha^{-1} with fertilizer significantly increased organic carbon over the same mixtures applied at 5t ha^{-1} with fertilizer.

4.3.10 Effect of field application of MTW,CD and Fertilizer on cation exchange capacity cmol kg^{-1} of the cropped soil

At both 5 and 10t ha^{-1}, the CEC increased as the proportion of MTW increased in the mixtures (Table 44) Higher proportions of CD resulted to lower CEC values at both rates of application. All mixtures, with and without fertilizer increased CEC values more than the absolute control. Application of the mixture at 10t ha^{-1}

Table 42: Effect of field application of MTW, CD and fertilize on K concentration (%) in maize ear leaves

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.70fi	0.72e-h	0.73efg	0.82cde	0.86bcd
5	+fert.	0.66hi	0.77d-g	0.78d-g	0.85bcd	0.90abc
10	-fert.	0.80c-f	0.83cdc	0.85bcd	0.94ab	0.95ab
10	+fert.	0.70fi	0.80c-f	0.81c-f	0.83cde	0.97a
0	-F = 0.60i-f			SE(±) = 0.03		
0	+F = 0.67ghi					
0	full fert = 0.77d-g					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 43: Effect of field application of MTW, CD and fertilizer on organic carbon (%) status of the cropped field

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	0.33gh	0.31h	0.23i	0.05j	0.01L
5	+fert.	0.75c	0.75c	0.51f	0.39g	0.33gh
10	-fert.	0.91b	0.75c	0.63d	0.56e	0.35gh
10	+fert.	0.99a	0.84b	0.83b	0.71b	0.56e
0	-F = 0.11j			SE(±) = 0.01		
0	+F = 0.09j					
0	full fert = 0.15j					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

without fertilizer gave higher CEC values than the same mixtures applied at 5t ha^{-1}. Generally, values were higher when fertilizer was applied to the mixtures than when not applied.

4.3.11 Effect of the application of MTW,CD and fertilizer on the pH of the cropped soil.

The pH of the cropped plots as affected by the application of MTW, CD and fertilizer is shown in Tables 45. The values generally increased as the proportion of CD increased in the mixtures irrespective of rate and fertilizer. With the exception of the mixture 50%MTW-50%CD, applied at 5t ha^{-1} without fertilizer, pH values in other mixtures containing 50%CD and above were significantly higher than the absolute control. There were no significant differences between all mixtures containing 75%MTW and above and the absolute control.

Values were generally higher in mixtures applied at 10 than 5t ha^{-1}. The addition of fertilizer to the mixtures generally depressed pH. Values were about 0.20 pH units or more lower than their respective mixtures without fertilizer. The full recommended dose of fertilizer treatment was 0.1 and 0.27 pH units lower than the half recommended dose of fertilizer and the absolute control treatments respectively. The pH values ranged from 4.20 pH units in the mixture 100%MTW-0%CD+F at 5t ha^{-1} to 5.63 pH units in the mixture 0%MTW-100%CD applied at 10t ha^{-1}.

Table 44: Effect of residual application of MTW, CD and fertilizer on the residual cation exchange capacity (CEC) of the cropped field soil (Cmol kg^{-1})

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	5.20b-c	4.30c-g	4.30d-g	4.20fg	4.10g
5	+fert.	6.00ab	5.70abc	5.60a-d	5.00c-f	4.80c-g
10	-fert.	6.00ab	5.90ab	5.70abc	5.00c-f	4.90c-f
10	+fert.	6.50a	6.33a	6.30a	6.00ab	5.60a-d
0	-F = 4.00g			SE(±) = 0.24		
0	+F = 4.70d-g					
0	full fert = 5.00c-f					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

Table 45: Effect of residual application of MTW, CD and fertilizer on pH of the cropped field soil.

Rate (tha-1)	Fertilizer	MTW/CD Mixture (%)				
		100-0	75-25	50-50	25-75	0-100
5	-fert.	4.37def	4.63c-f	4.83b-f	5.03a-e	5.60a
5	+fert.	4.20f	4.37def	4.97a-e	4.97a-e	5.40ab
10	-fert.	4.50def	4.80b-f	5.30abc	5.30abc	5.63a
10	+fert.	4.40def	4.60c-f	5.03a-e	5.07a-d	5.10a-d
0	-F = 4.57c-f			SE(±) = 0.21		
0	+F = 4.40def					
0	full fert = 4.33ef					

Means not followed by the same letter are significantly different at P=0.05 by DNMRT

CHAPTER 5

5.0 DISCUSSION

5.1 Green House Study

5.1.1 Effect of MTW, CD and fertilizer on plant height and Dry matter yield

Plant height and DMY increased as the proportion of CD increased in the mixtures irrespective of rate, soil and fertilizer, while the reverse was the case as the proportion of MTW increased in the mixtures. This is expected, since the CD contained more nutrients than the MTW. Its lower C:N (14.34) ratio may have also resulted in faster decomposition and mineralization thereby releasing nutrients for immediate crop use. The MTW with high C:N (47.62) ratio will not decompose as fast in which case its nutrients are made available at a later growth stage. Agbim (1981) reported the quicker transformation of CD with low C:N ratio to release nutrients as against cassava peels with higher C:N ratio.

During the second cropping, plant height and DMY generally increased as the proportion of MTW increased in the mixtures. This may suggest the desirability of incubating crop residues such as MTW for a fairly longer period, so that all nutrients contained are released for the benefit of the crop during the growing season. The result also indicates that the residual effect of CD in this study was not much as the crop performed poorly during the second cropping. Saminu (1989) reported better maize performance after residues with high C:N ratios were incubated for quite a long period before cropping. This suggest that significant residual effect can be achieved when high C:N

ratio crop residues such as MTW are incorporated in the soils for a longer time before cropping.

Amendment with the organic residues did not give significant difference in plant height in both soils during the first week after planting. This is expected as nutrient release from the amendments may not have commenced as to influence early crop development. Mbagwu (1985) reported that germination and early crop development were not influenced by amendments. Differences in plant height as a result of the treatments were however noticed from the midseason up to the harvest stage. This indicates that by midseason, nutrient release from the mixtures to maize had commenced. This points out the importance of timing in residue incorporation. Plant height and DMY were generally higher when amendments were applied at 10 than at 5t ha^{-1}. This is expected, since higher nutrients were applied at 10 than at 5t ha^{-1}. However, application of MTW alone at 10t ha^{-1} depressed plant height and DMY. This is probably due to immobilization of plant nutrients by the MTW with high C:N ratio. Depression of plant development by highly carbonaceous materials has been reported (Akinyemi and Adewale, 1981; Saminu, 1989 and Agbim, 1988). It has therefore, been suggested that this situation can be ameliorated through addition of mixtures of residues with high and low C:N ratios or supplementing organic residues with inorganic fertilizers (Parr *et al*. 1986).

In both soils during both croppings, values of plant height and DMY were higher when the mixtures were supplemented with inorganic fertilizers. Values compared favourably with plants

that received full dose of fertilizer. Increases in DMY over mixtures that did not receive fertilizer were as much as 102.16% with respect to the mixture 100%MTW / 0% CD at 10t ha^{-1} in the Samaru soil. This suggests that positive interaction exist between the mixtures and inorganic fertilizer. Several workers (Lombin and Abdullahi, 1978; Hartley, 1937; Agbim, 1989) have reported the efficiency of inorganic fertilizers in soils when applied along with organic materials. The depressive effect of MTW on maize growth may therefore be reduced when it is applied with some inorganic fertilizers. The inorganic fertilizer supplies the immediate requirement of the soil micro-organisms thereby quickening the decomposition rate of the residue, thus averting the net immobilization of nutrients. Faster rate of decomposition of crop residue through application of inorganic fertilizers has been reported (Stosky and Norman, 1961; Sanchez and Miller, 1986; Omaliko and Agbim, 1983 and Agbim, 1980). In both soils plant height and DMY were best with the mixture 100% CD / 0% MTW + F at 10t ha^{-1}. At harvest, plant height and DMY in Samaru soil were generally higher than those in Minjibir soil. This may be due to higher fertility status of the Samaru soil (Table 1). However, DMY relative response in Minjibir soil was higher (288.70%) than in Samaru soil in the full dose of recommended fertilizer treatment. This result corresponds with the findings of Omaliko and Agbim (1983), where they reported higher yield increases in poorer soils than richer and less porous soils.

5.1.2 Effect of MTW, CD and fertilizer application on Nutrient element concentration in maize shoot

The N, P and K concentrations in maize shoot increased as the proportion of MTW increased in the mixtures irrespective of rate fertilizer treatment and soil type. The reverse was the case as the proportion of CD increased in the mixtures. As earlier indicated, the DMY increased as the proportion of CD increased in the mixtures. This means more vigorous growth with addition of CD. The nutrient concentration per unit DMY may have been reduced as explained by the dilution effect theory reported by Kumar *et al.* (1985). The negative correlation obtained between DMY and NPK concentrations may support the dilution theory. High nutrient concentrations in maize shoot may thus not necessarily signify adequate nutrient level for maximum crop performance. This is also supported by the non-significant correlation between DMY and nutrient concentrations. The shoot N, P and K concentrations were lower in absolute control pots than in other treatments. This may indicate that addition of either CD or MTW or mixtures of both to the soil increased the contents of these nutrients in the soil. Cheng (1987) reported that the addition of pre-incubated sawdust with high C:N ratio increased N,P,K Ca and Mg contents of the growing medium and therefore their uptake by plants. Aina and Egolum (1980) also reported increases in NPK concentrations in the shoots and roots of plants due to both manuring and fertilization. Increased nutrient concentration in maize through application of organic

and Saminu (1989). Thus the application of even MTW alone to the soil will always be of advantage to the nutrition of the crop, than its non application.

The supplementation of the mixtures with fertilizers increased K concentration while N and P did not change appreciably. The higher K concentration observed with addition of fertilizer may be associated with the luxury consumption common with K nutrition.

The NPK concentration during the second cropping decreased as the proportion of MTW increased in the mixture irrespective of rate, soil and fertilizer. This was a reverse of what was observed during the first cropping. During the second cropping more luxuriant growth was observed with increasing proportion of MTW resulting in higher DMY. Under this condition lower nutrient concentrations were obtained probably because of dilution effect. Generally the shoot NPK concentrations were lower during the second cropping than the first cropping. However, P concentration increased significantly in most cases. The build up of soil organic - P and P added may have contributed to this than the mobile N and K in soil as reported by Lombin *et al.* (1989).

5.1.3 Effect of MTW, CD and fertilizer on nutrient uptake in maize shoot

The uptake of N, P and K in maize shoot increased as the proportion of CD increased in all mixtures irrespective of rate, soil and fertilizer. The magnitude of increase was quite high for the mixtures with the highest percentage of CD. Values were higher at 10 than at 5t ha^{-1}, probably due to higher nutrients

released with increasing amount of the amendment. In all cases, values were also higher for all the amendments than the absolute control. Uptake of these nutrients was lower as the proportion of MTW increased in the mixture. Presumably a large part of the nutrient was not available for uptake which may be due to immobilization by MTW decomposing organisms. Keulen et al (1982) reported similar findings.

Nutrient uptake increased through the addition of fertilizer to the mixtures. This should be expected because of increase in nutrients from the fertilizer applied. In addition, the nutrient supplied by fertilizer may have quickened the decomposition and release of more nutrients in the mixtures to the benefit of the crop. Stosky and Norman (1961) reported similar results.

During the second cropping N, P and K uptake increased as the proportion of MTW increased in the mixtures irrespective of rate, fertilizer and soil. The reverse was the case as the proportion of CD increased in the mixture. It is possible that complete decomposition of the highly carbonaceous MTW took place during the second cropping resulting in higher release of more nutrient which gave rise to greater uptake. Parr and Parpendick (1978) reported similarly that residues with high C:N ratio are usually associated with slow decomposition rate and nutrient from such residues are quickly assimilated and immobilized by micro-organisms when incorporated. However, nutrients immobilized are released to the subsequent crop in the season. This points out the importance of timing in crop residue management as suggested by Agbim *et al.* (1989). Generally nutrient uptake values during

the second cropping were lower than those of the first cropping. The result indicates that the residual effect of CD in this study was not much since the crop performed poorly during the second cropping. Highest N, P and K uptake was obtained with the mixture 0% MTW / 100% CD + F at 10t ha^{-1} during the first cropping.

During the first cropping N, P and K uptake positively and significantly correlated with each other in all mixtures irrespective of rate and fertilizer. This confirms that for N to be maximally utilized by maize for dry matter production, P and K must be available at sufficient levels.

5.2 FIELD STUDY

5.2.1 Effect of MTW, CD and fertilizer on plant height, stover yield, Grain yield and yield components

Plant height and stover yield increased as the proportion of CD increased in the mixtures irrespective of rate and fertilizer. The reverse was the case as the proportion of MTW increased in the mixtures. Similar results were obtained with grain yield and 1,000 seed-weight. This is expected, since CD contained more nutrients and decomposed faster having lower C:N (14.34) ratio than the MTW which has higher (47.62) C:N ratio. All mixtures with and without fertilizer had taller plants, higher stover and grain yield and 1,000 seed-weight than the absolute control. It is possible that the organic residues on decomposition increased the nutrient status of the soil in addition to improving some soil physical properties. Olsen, *et al.* (1970) reported an increase in organic N, available P and exchangeable K, Ca and Mg

due to addition of organic materials. The beneficial effect of organic matter in crop production has been emphasized by Greenland (1972); Charreau, (1974); Okigbo, *et al.* (1980) and Iwuafor, (1986). Where 10t ha^{-1} residue was applied, plants were taller, stover yield and yield components were also higher than where 5t ha^{-1} was applied. This may probably be due to the higher nutrient applied through 10t ha^{-1} as indicated in tables 4 and 5. Agbim (1981) obtained increases in maize plant height with increasing rate of cassava peel + CD mixtures. Taller plants and higher stover yield and grain yield and yield components were obtained when fertilizer was added to the mixtures than when mixtures were applied alone. The available nutrients added through fertilizer apart from supplying the nutrients needs of the plants, allowed quicker decomposition and release of more nutrients from the mixtures as reported by Mbagwu, 1985). The significantly higher yield increases obtained when fertilizer was added to the mixture indicates the complementary effect of crop residues and inorganic fertilizer as reported by Lombin and Abdullahi (1978) and Djokoto and Stephens (1961). Egarva, (1976) emphasized the benefits of supplementary use of inorganic and organic fertilizers in promoting faster decomposition of the later and hence increase in nutrient status and better soil properties. In India it has long been established that using organic manures along with inorganic fertilizer under intensive agriculture would raise farmers yields by about 25% over and above those obtained using fertilizer alone. Addition of fertilizer to the mixture is effective in

correcting early nutrient deficiency and also buffering the soil against unfavourable pH fluctuations as reported by Bache and Heathcote (1969) and Heathcote (1970).

The shorter plants obtained with the absolute control indicate the inherent low fertility of the savanna soils. Low fertility status of savanna soils have been reported by Jones and Wild (1975). Plants on plots that received mixtures containing 50% CD and above with some fertilizer were as tall as plants in plots that received full dose of recommended fertilizer. Similar results were obtained for stover yield, grain yield and some yield components. This result indicates that if available organic manures are supplemented with some inorganic fertilizer, some reasonable improvement in the performance and yield of crops may be expected.

5.2.2 Effect of MTW, CD and fertilizer application on nutrient concentrations of maize ear leaf

For all mixtures, irrespective of rate of application and fertilizer, N, P and K concentrations increased as the proportion of CD increased in the mixtures and decreased as the proportion of MTW decreased in the mixtures. This pattern was quite different from what was observed for nutrient concentrations in the green house. This difference in pattern might be due to the changes in their absorption from the soil resulting from change in availability and/or to the changes in the translocation of the elements from the roots to the shoots. Nutrient concentrations were higher in plants grown in plots that received amendments than in plots of absolute control. This may be due to increased

nutrient status of such soils as a result of the addition of the amendments. Similar result has been reported (Olsen *et al.* (1970). Aina and Egolum (1980) also reported that application of manure increased nutrient content of the plants. Values were also slightly higher at 10 than at 5t ha^{-1} application rate. Highest NPK concentrations of 2.60, 0.73 and 0.97% respectively, were obtained through the application of CD alone at 10t ha^{-1} with fertilizer.

Supplementation of the mixtures with fertilizers generally increased N, P and K concentrations compared with their respective mixtures without fertilizer. This may be as a result of the added fertilizer nutrients and their effects in facilitating decomposition and release of more nutrients from the mixtures. Thus greater beneficial effect could be derived through supplementing the mixtures with inorganic fertilizer than when either is applied alone. Lombin and Abdullahi (1978) have reported similar result.

Nitrogen and K concentrations were in all treatments below the critical levels for maize reported by Agboola (1972). However, P concentration was adequate. The generally lower yield obtained may be associated with the low levels of N and K.

5.2.3 Effect of MTW, CD and fertilizer application on N, P and K concentrations in stover

The concentration of N, P and K in stover decreased as the proportion of CD increased in the mixtures irrespective of rate and fertilizer. The reverse was the case as the proportion of MTW increased in the mixtures. As earlier indicated, stover

yield increased as the proportion of CD increased in the mixtures. This means more vigorous growth and stover production with addition of CD. The nutrient concentration per unit stover yield may have been reduced as explained by the dilution effect theory reported by Kumar *et al.* (1985). Accumulation of nutrients per unit stover yield may be expected with the MTW which had less vigorous plants and lower stover yield. The higher N, P and K concentrations in the stover of mixtures applied at 10 than at 5t ha^{-1} may be as a result of increased nutrient supply at 10t ha^{-1}. Cheng (1987) reported similar result.

Supplementation of the mixtures with fertilizer generally increased N, P and K concentrations compared with their respective mixtures without fertilizer. This may be as a result of the added fertilizer nutrients and their effects in facilitating decomposition and release of nutrients from the mixtures. Similar results have been reported by Stosky and Norman (1961). Generally, N, P and K concentrations in stover were much lower than that of ear leaves. Larson et al (1978) reported similar observations. Nitrogen, P and K concentrations were highest (0.45, 0.09 and 0.61%) respectively, with MTW alone with fertilizer at 10t ha^{-1}. The P concentration for full dose of fertilizer was significantly higher than for all mixtures. The full dose of P applied in inorganic form may be responsible for the high P concentration in the stover. The luxury consumption of K may be responsible for the non-significant difference in K concentrations in all mixtures and fertilizers.

5.2.4 Effect of field application of MTW, CD and fertilizer on organic carbon content and cation exchange capacity (CEC) of the cropped soil

The OC and CEC of the cropped soils changed slightly as a result of the treatment imposed. The trend was increasing values of both parameters as the proportion of MTW increased in the mixtures. The increase with increasing proportions of CD was lower compared to MTW. It is possible that by the end of the season, some of the MTW were not completely decomposed resulting in higher OC since it has higher C:N ratio than the CD which may have completely decomposed thereby having less C in the soil. Jenkinson (1971); Jenkinson and Ayanaba (1977) and Paul and Van Veen, (1978) reported that about 55-75% of the C of most crop residues and plant debris returned to soil is released as CO_2 as decomposition progresses over a one year period. The high root production expected from application of the mixture may have also contributed to higher OC status of the cropped soil. The increase in OC after cropping was from 0.11 for the initial content to 0.99% when 100%MTW was applied at 10t ha^{-1} . Triplett and Mannering (1978) reported that root biomass constitutes a significant proportion of crop residues and crops such as corn and sorghum may have top/ root ratio as high as 6:1 or 21:1. The total rhizosphere deposition may amount to three to four times as much organic substances as is found in the roots at harvest (Shammot et al, 1968; Hale and Moore, 1979).

Generally OC and CEC were higher for mixtures applied at 10 than 5t ha^{-1}. This is expected as more of the residues are applied through the 10t ha^{-1}. Tiarks et al, (1974) reported that

OC content of soils increased markedly with manure application with the increase being linear with increasing amounts of the manure applied. Iwuafor (1986) made similar observations. The OC and CEC of plots that received half and full dose of fertilizer were lower than where the amendments were applied. Mbagwu and Ekwealor, (1990) reported higher OM in soils that received brewer's spent grain (BSG) than those that received only complete fertilizer and the controls. It is possible that the fertilizer fastened the decomposition rate of an already low innate OM in the soil resulting in lower OC content. Mbagwu (1985) reported that addition of inorganic fertilizer to crop residues fastens the decomposition rate.

5.2.5 Effect of the application of MTW, CD and fertilizer on the pH of the cropped soil

The pH values vary little among treatments, except for plots with extreme proportions of MTW and CD. Values generally increased as the proportion of CD increased in the mixtures. This may be because CD contains higher cations than MTW, since pH is related to base saturation. Ridder *et al.* (1990) reported similar findings. The pH values of the half and full doses of recommended fertilizer were lower than the absolute control. The lower pH value must be attributed to the acidifying effect of the fertilizer. Ridder, *et al.* (1990) and Agbim, *et al.* (1991) also reported depressed pH through application of fertilizer.

pH values were depressed in all 100%MTW treatments. The decomposition of the MTW may release some acid forming functional

groups which may increased the activity of the H^+ ion and thus depressed pH. Similar result was obtained with rice husk (Agbim *et al.* 1981). However, with increasing proportion of CD pH values increased over absolute control. Thus CD ameliorates soil acidity better than MTW.

CHAPTER 6

6.0 Summary and Conclusion

The emphasis of this study was to investigate how to manage the huge amounts of MTW left over after threshing to the benefit of the farmer in terms of maintaining his soil fertility for increased crop production.

A green house study was carried out in Samaru, IAR, ABU Zaria with two soil samples from different ecological zones (Sudan and Northern guinea savanna). The treatments consisted of the application of MTW or CD alone or combinations of both in different proportions at 5 and 10t ha^{-1} with and without inorganic fertilizer. All possible combinations of the factors were arranged in a randomised complete block design and replicated three times. There were two croppings.The treatment combination and design were evaluated on the field at Samaru.

Soil and plant samples from the green house and field trials and samples of the organic amendment were analysed for nutrient contents. Observations were taken on DMY, plant height, yield and yield components and nutrient concentrations and uptake. The results from the green house study during the first cropping showed that plant height and DMY were higher in mixtures with higher proportions of CD and lower in mixtures with higher proportions of MTW after the first cropping. However, after the second cropping the effect was reversed. Results from the field study showed that plant height, grain and stover yields also increased as the proportion of CD increased in the mixture irrespective of rate and fertilizer. The reverse was the case as

the proportion of MTW increased in the mixtures. Incorporation of MTW alone at both rates decreased maize growth and yield. Complementing the mixtures with some inorganic fertilizer gave higher yields than their corresponding mixtures without fertilizer. Yield and yield components were generally higher in mixtures applied at 10 than at 5t ha^{-1}. Application of 75% MTW / 25% CD+ F at 5t ha^{-1} gave grain yield higher than the recommended dose of inorganic fertilizer. The general yield increase observed as the proportion of CD increased in the mixture indicate that CD contained more nutrients than the MTW. Its lower C:N ratio will have also resulted in faster decomposition and mineralization thereby releasing nutrients for immediate crop use. The MTW with high C:N ratio will not decompose as fast in which case its nutrients are made available at a later growth stage.

This may suggest the desirability of incubating MTW for a fairly longer period (5-6 weeks) before cropping, so that all nutrients contained are released for the benefit of the crop during the season. Plant height, yield and yield components were higher in mixtures applied at 10 than at 5t ha^{-1} because of higher nutrient supply by mixtures applied at 10t ha^{-1}. Plant height, DMY, yield and yield components were higher when mixtures were complemented with inorganic fertilizers. Depressive effect of MTW on crop growth can therefore be ameliorated through addition of CD or liberal amounts of inorganic fertilizer.

Although 100% CD/0% MTW + F at 10t ha^{-1} gave grain yield better than any mixture, the problem is that of availability of

sufficient quantities of CD. Moreover, continuous application of high rates of dung could lead to problems of high salt content in the soil (Mathers and Stewart, 1970). Application of 75% MTW/25% CD + F at 5t ha^{-1} yielded higher than full recommended dose of inorganic fertilizer. The annual incorporation of this mixture in savanna soils may therefore be recommended for good yield and sustenance of soil fertility.

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