EFFECT OF STYLO COVER AND N-FERTILIZATION ON SOIL PHYSICAL PROPERTIES, WATER USE AND YIELD OF MAIZE AT SAMARU

BY

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A Thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in partial fulfillment of the requirements for the degree of Master of Science in Soil Science

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DECLARATION

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

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CERTIFICATION

This thesis entitle "Effect of stylo cover and N-fertilization on soil physical properties, water use and yield of maize at Samaru" by Sule Ismaila meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To

Soil Scientists around the world

ACKNOWLEDGEMENT

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ABSTRACT

An investigation was carried out at the Institute for Agricultural Research Farm in Samaru, Zaria, during the 1992 rainy season to determine the effect of a stylo cover crop (Stylosanthes hamata) and N-fertilization on soil physical properties, water use and yield of maize. The field on which the trial was conducted was divided into two parts: one part (stylo fallowed) had been under stylo pasture for two years before the treatments of four levels of N- 0, 40, 80 and 120KgNha"[1] were imposed. The stylo pasture was also planted as a treatment cover crop. The second part of the field had been under grass fallow for two years before the treatments of only four levels of N were imposed.

The treatments were combined and replicated four times giving a total of thirty six plots on the stylo fallowed field and four plots on the grass fallowed field. The design used was the Randomised Complete Block Design, Moisture use was closely monitored to a depth of 130cm by the use of a Neutron Probe moisture meter. Physical properties of the soil were measured both in the field and in the laboratory.

The stylo cover was observed to increase infiltration rate, total porosity, saturated hydraulic conductivity and lower the bulk density of the soil. N levels did not, however, affect these soil properties.

Maize cropped on the stylo fallowed plots used more water than that cropped on the grass fallowed plots, but the maize intercropped with the pasture crop used less water than the sole cropped maize. The intercropped maize was, however, found to have higher water use efficiency than the sole cropped maize. Addition of N significantly increased the crop water use over the no N treatment although the three levels of N produced statistically the same water use.

Grain yield was found to be higher on the stylo fallowed than the grass fallowed plots. Addition of N increased the grain yield but. the result was higlily variable.

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CHAPTER ONE

INTRODUCTION

Samaru (Lat. 11° 11'N, Long. 7° 38'E) lies within the northern guinea savanna ecological zone of Nigeria. The climate of this region is characterised by highly variable rainfall which is poorly distributed and often low in total amounts. The soils of the Nigerian savanna are predominantly Alfisols and Ultisols. These soils are low in organic matter and are fragile. They are, therefore, easily degraded by tropical rainstorms through the breakdown of soil aggregates, compaction and sealing of the soil surface thereby decreasing infiltration which in turn increases run-off and soil erosion (Lawes, 1966; Adeoye, 1986).

Due to the increasing pressure on land as a result of the increasing population, the soils in this region are subjected to continuous cultivation with its concormitant soil deterioration effects. Studies have shown that there is often a decline in the productivity of soils under continuous cultivation even when supplementary fertilizers are used. (Stephen, 1969; Le Mare, 1972). Measures to protect the soil surface and prevent its deterioration include straw and live mulching. Studies in the savanna by Adeoye (1984) have proved the beneficial effects of straw mulch in moisture conservation, in providing buffering effects against

raindrop impact and in reducing run-off and soil loss. The large amounts of straw needed per hectare, however, coupled with residue degradation by termites and other micro-organisms make the use of straw on a large scale unfeasible. In some areas crop residues are used for building and fencing purposes and in some cases for feeding livestock. These problems have necessitated the search for alternative and more practical methods of soil conservation. For example the use of certain legumes as live mulch (Akobundu, 1982).

Maize (Zea mays L.) is one of the principal cereal crops grown in the Nigerian savanna. Growth and yield components of field grown maize were reported to be enhanced by N fertilization ranging from 50 to 200KgNha^{-1} (Ogunlela et al, 1988). Ear diameter, Kernel depth, grain stover ratio, number of ears per plant, plant height and dry matter production increased as N fertilization rate was increased up to 100 or 150KgNha^{-1}. Remison and Kayode (1982) showed that number of cobs, weight of cobs and yield were increased with the application of N up to 75KgNha^{-1}. Reports on the amount of water use by maize have been variable. For example in western Nigeria, Nwa (1979) reported that maize used 330mm of water to produce a good crop. In northern Nigeria, however, Kowal and Kassam (1973) reported that the total water use by the crop during 117 days from sowing to harvest was 486mm.

Against this background, this experiment sets out to asses the effect of a stylo cover crop and N-fertilization on soil physical properties and on yield and water use by maize at Samaru.

CHAPTER TWO

LITERATURE REVIEW

2.1 Effect of legume cover crops on soil physical properties.

2.1.1 Aggregate Stability, Soil Structure and Porosity.

Aggregate size and stability are dynamic soil properties which change in response to aggregating factors in the field environment (Gish and Browing, 1948; Stickling, 1950). Degree of aggregation is also a time variable property as aggregates form, disintegrate, and reform periodically (Hillel, 1980). Russell (1973) reported that the resistance of aggregates or crumbs to the slaking and dispersive effects of water is important for maintaining a porous structure in arable soils. This is mostly prominent in the soil surface where the stress exerted by raindrop impact (Ghadiri and Payne, 1977) combined with the effects due to water absorption (Brewer and Blackmore, 1956), can cause aggregate breakdown and translocation of fine material. Seed germination and crop emergence may be adversely affected by the impeded exchange of gas and water between the soil system and the atmosphere if this results in loss of pore space at the soil surface (Bakker and Hidding, 1970). Soils that lack stable structural properties slump when wet, disperse readily, and become cemented on drying. They are characterised by high erodibility,

low infiltration and low productivity. Thus, physical fitness of soil for crops is governed largely by structural stability.

Leguminous cover crops have been reported to improve soil aggregate stability (Wade and Sanchez, 1983). Any deterioration in soil structure following land clearing has been shown to be ameliorated by growing cover crops (Juo and Lal, 1977; Lal et al., 1979). Wilson et al., (1982) concluded that cover crops improved soil structure and porosity. The improvement in porosity was brought about by an increase in transmission pores 5μm in radius. Soil improvement was larger in deep rooted legume covers than in shallow rooted grasses.

2.1.2 Bulk density

Bulk density of the soil is one of the most important physical properties affecting the growth of plants. Cotton (Gossypium hirsutum L.) yields were reported to decrease as soil bulk density increased from 1.5 to 1.60Mgm^{-3}. Taylor (1974) and Gerard et al (1982) observed that root growth rates are affected by soil strength (mechanical impedance) and bulk density. Compact soil layers that develop a high mechanical impedance can restrict root development and reduce crop yields (Chancellor, 1977).

Increases in bulk density have been associated with decline in organic matter content of the soil (Skidmore et al., 1986). Cultivation ultimately decreases pore space and correspondingly increases bulk density (Page and Willard, 1946). Effects of legume cover crops on bulk density have been slight and limited to the top 0 - 10cm of the soil. Where such effects have been noted at all, they have not been observed to last for long periods. For example, Touchton et al (1984) reported that winter legumes produced no measurable changes in soil bulk density due to cover crops. Mohammed Saleem and Otsyina (1986) and Mohammed - Saleem et al. (1986) observed that maize in plots that had previously been planted with stylo performed better than that sown on land that had been under natural vegetation. They attributed this to an improvement in bulk density among other things. Obi and Nnabule (1988) reported that the bulk densities of the top 0 - 10cm soil depths were slightly reduced in plots under 13 years of Panicum maximum and Centrosema pubescens covers. Hulugalle et al. (1986) and Jordan et al. (1956) also reported that legume cover help in amelioration of compacted soils.

2.1.3 Infiltration and Hydraulic Conductivity.

Infiltration is the process whereby water enters into the soil through its surface (Swartzendruber and Hillel, 1973). The infiltration characteristics of the soil is of considerable importance in crop production especially

in irrigated agriculture. Many factors affect the infiltration of water into the soil. The dominant among these include the initial soil moisture content, hydraulic conductivity of the soil profile, texture, porosity, degree of swelling of the soil colloids and organic matter, vegetation cover, duration of irrigation or rainfall (Michael, 1978). Pore size distribution has been recognised to influence infiltration rate (Kowal, 1972; Wilkinson, 1975; Adeoye 1986). This seems to be through its resistance to water flow. For example Grismer (1986) reported that for a typical fine textured soil, pore size distribution skewed towards smaller pores resulting in decreased infiltration, while distribution skewed towards larger pores enables water to penetrate rapidly and can increase infiltration rates several times.

Infiltration rate has been reported to be significantly higher on soils grown with forage legumes than on natural grass fallows (Adeoye and Mohammed-Saleem, 1988). Bridge et al., (1983) found that soils on which pastures of Stylosanthes hamata var. verano or Alysicarpus vaginalis were grown had greater infiltration rates than those containing S. humilis. Obi and Nnabule (1988) reported a significant increase in filtration rate under a centrosema cover over a bare fallow.

Saturated hydraulic conductivity has been shown to be increased by appropriate soil covers (Pereira et al., 1954, 1967; Wilkinson, 1975). Sene et al. (1985) observed high correlation co-efficients between yield increase in maize and saturated hydraulic conductivity ($r=0.85^{xx}$).

2.1.4 Role of cover crop in run-off and soil erosion.

The effectiveness of conservation practices for erosion control is determined in part by the physical condition of the soil surface. It has been observed that the bulk density, porosity, and aggregation of the surface soil are more important in determining surface run-off and infiltration than is the moisture storage capacity (England and Lesesne, 1962). Soil surface properties among other factors, affect a soil's susceptibility to wind and water erosion. The soil surface properties are in turn, affected by many factors which include crops grown, cropping systems, tillage methods, and surface residues. One of the most effective methods of controlling accelerated erosion is the use of perennial grasses and legumes which have a remarkable ability to reduce run-off and to prevent erosion once they are established. The role of cover crops in erosion control is to dissipate the tremendous energy in falling raindrops and to retard the rate of overland flow (Barnett, 1965).

One purpose of including legumes in conservation tillage systems is to reduce soil erosion. Blevins et al. (1990) maintained that use of legumes as cover crops has environmental advantages such as reduction in soil erosion and nitrate losses. Research has shown that soil losses can usually be reduced if perennial legumes are used in crop rotation (Power et al., 1983). These authors have attributed this to several reasons which include reduced run-off because of residue cover, increased evapotranspiration, improved water infiltration, and improved hydraulic conductivity. Legumes used as cover crops affect water balance in other ways. In areas with relatively high precipitation, a legume cover crop not only reduces runoff but also increases evapotranspiration, the net effect being reduced percolation. Loss of soil and valuable plant nutrients can both be reduced. In drier regions, however, water use by the legume may deplete surface soil water to the extent that germination and growth of the following crop are restricted (Power et al., 1983). Legume cover crops can contribute to water conservation by reducing percolation through their effect on the water retention characteristics of the soil. Research results have shown that legume covers enhance the water retention capacity of soils. For example, Adeoye and Mohammed - Saleem (1988) showed that soils grown with legume covers retained slightly higher moisture between zero and 0.1 bar suctions than soils under natural fallow.

2.2 Role of cover crops in weed control

Live mulch is one of the biological methods of weed control. Living plants have for long been used in tree crop plantations for ground cover management (Watson, 1957; Moore, 1962; Mason, 1964). Their use in food crops has however, not been common because of the interference between live cover crops and the main crops (Akobundu, 1987). Efforts to minimise this interference has been through the use of chemicals to suppress the growth of the cover crops.

Information on the specific use of legume covers for weed suppression is scarce. Research results have generally shown that live mulch crop production in the tropics suppresses weeds and reduces weeds seed population in the soil (Akobundu, 1984). The role of intercropping maize with legumes for keeping down weeds has been reported by Singh and Premchard (1969) and Pandey et al., (1981). Akobundu (1982) has also demonstrated the importance of legume cover crops in weed control. Blevins et al., (1990) concluded that one of the advantages of using legumes as soil covers is better weed control.

2.3 Nitrogen contribution by leguminous crops.

A special feature of leguminous crops is their ability to fix atmospheric N in their tissues.

Extensive evidence abound to indicate that legumes incorporated in a cropping sequence increase soil N content (Rao and Sharma, 1978; Dhillon and Dev. 1979) and the yield of succeeding crops (Nair et al, 1979; Giri and De, 1979). Vallis and Gardener (1984) reported that legume pastures lead to the accumulation of soil N which can also be exploited for crop production. Martin and Touchton (1983) observed that the immediate yield response of crops following legumes is due mainly to the ability of many legumes, when infected with specific strains of Rhizobia bacteria, to convert atmospheric N into plant proteins and other compounds containing N. Then as the legume plant material decomposes, the N it contains is released for use by the following crops. In a study that included four legumes and one non-legume cover crop treatment, Hargrove (1986) found that the calculated fertilizer N replaced by the four legumes averaged 72KgNha^{-1}. Mohammed - Saleem and Otsyina (1986) reported that maize grain yields were significantly higher following one to three years of stylosanthes than after natural fallow of repeated cropping.

The N fixation system is sensitive to the presence of inorganic N in the root environment, particularly nitrate (McAuliffe et al., 1958). There is a variable range of nitrate concentrations where nodulation and

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N fixation are optimised (Allos and Bartholomew, 1959). Mallarino and Wedin (1990) found that fertilizer N reduced annual fixed N yield in legume-grasses mixtures. Boller and Nooberger (1987) reported that N fertilization decreased N fixation of field grown clover-grass mixtures. Searle et al., (1981) also reported that N applied to intercropped legumes appeared inhibitory to N fixation, both directly from increased soil N and indirectly from increased soil N and indirectly by stimulation of maize growth and shading of intercropped legumes.

2.4 Yield of crops intercropped with legumes.

Increases in yield of crops intercropped with or grown after a legume fallow have been reported. For example, Mohammed-Saleem and Otsyina (1986) reported that maize grain yields were significantly higher following one to three years of stylosanthes than after natural fallow or repeated cropping. Nnadi et al. (1981) found the yield of maize following grain legumes to be significantly higher than that of maize following sorghum. Tarawali (1991) reported that maize following stylosanthes pastures out yielded that on natural fallow.

Other workers have, however, reported yield reductions when crops are intercropped with legumes. Shelton and Humphreys (1975a) reported that vegetative growth of rice sown in mixed culture with Stylosanthes guyanensis was negatively related to stylo density over

the range 0 to 81 stylo plants per m^2. Rice grain yield varied from 98.4gm/m^2 in monoculture to 63.4gm/m^2 when grown with 81 stylo plants per m^2. Shelton and Humphreys (1975b) reported that simultaneous under sowing of upland rice with S. guyanensis at Khon north east Thailand did not affect vegetative growth of rice but reduced grain yield by 19%.

Yield increases of crops intercropped with or following a legume fallow have largely been attributed to the accumulation of soil N by the legumes. Vallis and Gardener (1984) reported that legume pastures lead to the accumulation of soil N which can be exploited for crop production. The use of this concept to increase the yield of subsequent crops has been extensively documented (Heichel et al., 1981; Hoyt and Leitch, 1983; Groya and Sheaffer, 1985; Nnadi and Hague, 1988; Hulugalle, 1989). Valis (1972), Myers (1976), Wetselaar (1967) have shown significant increase in available soil N and total N in soils on which legumes have been grown. Work by Hoyt and Leitch (1983) showed that the N contributed by legumes greatly increased the yields of barley. Other effects of legumes beyond the simple N effects may contribute to the increased yields often observed (Bowen et al., 1988). These include: (i) improve availability of other nutrients for crop growth (Wade and Sanchez, 1983), (ii) improved soil aggregate stability (Burns and Davis, 1986), (iii) amelioration of compacted soils (Hulugalle et al., 1986; Jordan et al., 1956), (iv) reduced nematode infestations (Reddy et al., 1986).

Reductions in yield due to intercropping with legumes have been shown to depend amongst other factors, on the extent of root development of the legumes which affects its competition for water. For example, Vigna trilobata (I) Verdc. is a short harbaceous legume. Its capacity to grow deep roots allows it to compete strongly for soil water and decrease the yield of the main crop. Leach and Foale (1987) reported that under-sown V. trilobata hastened soil drying resulting in the extraction of 21mm more water by maturity time than sorghum (Sorghum bicolor (L.) Moench) and sunflower (Helianthus annuss L.). These authors concluded that a shallow rooting plant would be prefered as a ground cover.

2.5 Moisture Use by Maize

Numerous data abound on water use by the maize plant. Nwa (1979) reported that about 330mm of water either from irrigation or from well distributed rainfall is sufficient to produce a good crop of maize in W. Nigeria. Downey (1971) in Griffith Australia, reported an evapotranspiration of 560mm by maize between planting and harvest. Many workers (Cackett and Meterlerkamp, 1964; Chaudhry and Macksond, 1967; Moolany and Behl, 1968) have shown that a crop of maize will use about 500mm of water in evapotranspiration during the growing period.

These reports generally indicate that the amount of evapotranspiration would depend, among other factors, on the evaporation demand of the atmosphere and the amount of water supplied. Hillel and Guron (1973) reported a threshold evapotranspiration of 250 - 300mm for maize below which production was negligible and above which production rose linearly with the amount of water supplied.

A number of factors have been reported to affect water use by maize. Downey (1971) found that evapotranspiration by maize was not significantly affected by density but was slightly higher at high densities when ground cover was less than 50%. Carlson et al. (1959) also reported that neither N fertilizer nor plant density appreciably affected the evapotranspiration rate of corn. The water use efficiency was, however, appreciably increased by using a high plant density and N fertilizer. Montgomery and Kiesselbach (1912) and Kiesselbach (1916) showed that soil fertility affected the water requirements of corn. These workers found that the water requirement was lowered by the addition of fertilizers supplied either as animal manure or mineral fertilizer. In poor soils the water requirement was reduced nearly one half by the use of fertilizer but in highly productive soils the reduction was slight. Hillel and Guron (1973) reported that water use efficiency of maize increased with higher quantities of irrigation provided, if soil aeration was not impeded and potential evapotranspiration was not exceeded.

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2.6 Effect of soil moisture on maize yields

Soil moisture depletion to the wilting percentage by field corn at certain physiological growth stages can markedly depress grain yields (Robins and Domingo, 1953). As much as 22% yield reduction resulted due to moisture deficits for periods of one or two days during tasseling or pollination and such deficits for periods of six to eight days gave a yield reduction of 50%. Yield reduction due to lack of available water after the fertilization period appeared to be related to the maturity of grain when the available water was removed. Following maturity, the depletion of the available soil moisture had no effect upon yield and did not influence the moisture content of the grain, cob or stalk and had little influence upon the leaf moisture content. Low moisture conditions, have been reported to cause reduced yields and reduced N response (Krantz, 1949). Alessi and Powers (1965) found that grain yields were directly proportional to the total available soil moisture and the yields were linearly related to soil moisture at planting plus seasonal precipitation. The relationship was little influenced by population, fertilization or soil type.

Work by Letey and Peters (1957) showed that corn yields were closely related to the reserve soil moisture conditions at the beginning of the growing season and

to the soil moisture stress to which the plant is subjected during the growing season. The moisture stress effect upon growth was found to be closely related to seasonal weather. The effect of soil moisture stress at different stages of growth on the development and yield of corn were studied by Denmead and Shaw (1960). They observed delay in enlargement of plant parts under moisture stress and recovery when the plants received ample water supply. The reduced plant size, occasioned by moisture stress in the vegetative stage of growth was accompanied by lower production of dry matter and lower grain yields. All the treatments reduced grain yield significantly. Plants subjected to moisture stress at silking were the most severely affected as far as grain yield was concerned.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted on the Institute for Agricultural Research Farm at Samaru, Zaria, Nigeria (Lat. 11° 11'N, Long 7°38'E). The physico-chemical properties of the site are provided in appendices I and II. The land on which the trial was conducted was divided into two parts: one part (stylo fallowed) had been under stylo pasture for two years before the treatment of four levels of N-0, 40, 80 and 120KgNha^{-1} were imposed. The stylo pasture was also planted as a treatment cover crop. The second part of the field had been under grass fallow for two years before the treatment of only four levels of N were imposed.

3.2 Treatments

The experiment consisted of four levels of N, using Stylosanthes hamata as a cover crop in maize.

N - levels ($KgNha^{-1}$	Treatment Code on stylo fallowed plots	Treatment Code on grass fallowed plots
0	F_o	G_o
40	F_1	G_1
80	F_2	G_2
120	F_3	G_3

Crops	Code
Maize	M_z
Stylo	S

3.2.1 Treatment Combination

The treatments were combined as indicated below and replicated four times giving a total of thirty six plots on the first part of the field and four plots on the second part. Each plot was 6m wide and 15m in length. The design used was the Randomised Complete Block Design.

Treatment Combination on stylo fallowed plots	Treatment Combination on grass fallowed plots.
M_z/F_o	M_z/G_o
M_z/F_1	M_z/G_1
M_z/F_2	M_z/G_2
M_z/F_3	M_z/G_3
$M_z/S/F_o$	
$M_z/S/F_1$	
$M_z/S/F_2$	
$M_z/S/F_3$	
S (Sole stylo)	

3.3 Field Studies

3.3.1 Land preparation and planting

The land was cleared with cutlasses and rakes. A basal dose of 35KgPha^{-1} was applied by broadcasting. Planting was done on 18/6/92 as soon as the rains had established. Maize (Var. TZB) was planted at 25cm interval in six rows 75cm apart on flat plots. Two seeds were planted per stand and later thinned down to one after two weeks of emergence. Prior to planting the maize, stylo seeds were broadcasted on the plots that contained them as treatment.

3.3.2 Weeding

A pre-emergence herbicide, primagram, was applied at the rate of 5 litres/ha in each plot. This was done to suppress the early establishment of the stylo either from shed seeds or from regrowth of persisting stalks. Manual hoe weeding was done at 3 and 6 weeks after emergence.

3.3.3 Agronomic parameters

Four maize plants per plot were tagged at random and the following measurements performed on them at 28, 42 and 66 days after emergence (DAE) after which the means were determined for each plot.

3.3.3.1 Plant height

Plant height was measured from the base to the end of the flag leaf.

3.3.3.2 Leaf number

This was measured by physically counting the number of leaves per plant.

3.3.3.3 Leaf area

Leaf area was measured by measuring the broadcast part of the leaf and multiplying it with the length. This was then multiplied by a constant (Correction factor) of 0.8 (Watson, 1947).

3.3.3.4 Grain weights

These were taken after drying in the open sun and expressed in $Kgha^{-1}$.

3.3.4 Moisture use

This was closely monitored by the use of Neutron probe moisture meter. Two access pipes were installed to a depth of 130cm per plot. Readings were taken regularly twice a week at 15cm increments up to the desired depth. Calibration of the Neutron probe moisture meter had earlier been done by Jensen et al (1990).

3.3.5 Infiltration measurements

The double ring infiltrometer (Eijelkamp Agrisearch Equipment No.09.04) method was employed for this test. After carefully observing the soil surface for presence of cracks or biopores, three sets of infiltrometers were installed on each plot at reasonable distances apart. Each set consisted of an inner and an outer ring with the following dimensions: First set; Inner ring, 28cm, outer ring, 53cm; second set; Inner ring, 30cm, outer ring, 55cm; third set; Inner ring, 32cm, outer ring, 57cm. The inner ring of each set was placed on the surface with the cutting edge downward. A driving plate was attached on top by means of adjustable screws.

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An impact absorbing hammer was used to strike the inner rings firmly so that they entered the soil at right angles to a depth of approximately 10cm. The outer rings were similarly hammered into the ground.

To start the infiltration measurements, water was poured into the outer rings to saturate the soil. Water was then poured into the inner ring about three quarters full. Polythene sheets were lined in the inner rings to avoid puddling and sealing of the surface soil. A measuring bridge (including float and measuring rod) was attached to the inner rings using adjustable screws. The measurement was started by carefully removing the polythene sheets and noting the initial position (in cms below reference level) against the reference time 0, and subsequently the receeding of the water level during a fixed period of time.

3.4 Laboratory studies

3.4.1 Physical measurements

At the end of the infiltration measurements, the rings were removed using a withdrawal clamp. After allowing reasonable drainage, four soil samples were taken from each site using core sampler. The core samplers with dimensions 50mm by 51mm were fixed in a ring holder and gently pushed into the wet soil and dug out.

Both edges of the samplers were trimmed with a sharp spatula to remove the protruding soil, care was taken not to smear the surfaces. The core samplers were capped and brought to the laboratory for analysis.

3.4.1.1 Hydraulic conductivity

This was determined by the constant head method using the ICW laboratory permeameter (Eijelkamp Agrisearch Equipment No. 09.02). The equipment operates on the principle that a pressure difference created on both sides of a well saturated soil sample causes water to flow through the sample which is measured over a certain period of time. From the dimensions of the soil sample and the difference in pressure head, K, the hydraulic conductivity was calculated using the well known Darcy's flow equation.

$$K = \frac{VL}{AtdH}$$

where V is volume of water, cm^3; A is the cross sectional area of the soil sample (equal to area of the core ring), cm^2; T is time allowed to collect a specified amount of water; L is the length of soil column (equal to the height of the core ring), cm and dH is the differential head in cm.

3.4.1.2 Soil moisture characteristics

The water retention properties of the soil were determined using the sand, and Kaolin box apparatus (Eijelkamp Agrisearch Equipment No. 08.01 and 08.02) and pressure plate apparatus.

The cutting edges of the sample rings containing the sand samples were covered with pieces of nylon cloth which were held in place with use of O - rings. The cloth was pulled tightly so that it was completely smooth and evenly in contact with the sample. The samples were placed in the sand-box and the rings pressed lightly downwards to form a good contact between the samples and the sand. The suction level regulator was then set at pF 0.8 (0.0063 bar). This suction was impossed and left for 24 hours during which time the water held below this suction was sucked out. The samples were weighed to determine the loss in weight. Similarly, the water held below suctions 0.01, 0.032, 0.063 and 0.1 bar corresponding to pF 1.0, 1.5, 1.8 and 2.0 was determined. Using the same procedure the water held below pF 2.3 and 2.7 (0.2 and 0.5 bar) was determined using the Kaolin box apparatus. For pressures of 1, 3, 5, 7, 10 and 15 bars, the pressure plant apparatus was used.

At equilibrium the moisture held at the corresponding pressures of 1, 3, 5, 7, 10 and 15 bars was determined and a graph of pressure against moisture content was plotted to give the moisture characteristics curve.

At the lower pressures the diameter in mm of the largest water-filled pore at each equilibrium was calculated by:

$$dp = 46 \times 10^5 / Pwgh$$

where 6 and Pw are surface tension (JM^{-2}) and density (Mgm^{-3}) of water, g is the gravitational acceleration (MS^{-2}), and h is the matric suction (cm of water). The fraction of total pore space filled with water, Ov/St, was ploted as a function of pore diameter to express the pore size distribution (Danielson and Sutherland, 1986).

3.4.1.3 Bulk density

After the moisture release characteristics were determined the soil samples were dried in the oven for 24 hours at 105°C. The dried samples were weighed and the volume obtained by calculating the volume of the core samplers. The bulk density was calculated by the formula.

$$Pb = \frac{\text{weight of core + dry soil - Wt. of empty core}}{\text{volume of core.}}$$

3.4.1.4 Total porosity

The total porosity was calculated by the formula:

$$f = (1 - Pb/Ps) \times 100$$

where, f is the total porosity, Pb is the bulk density and Ps particle density.

3.4.1.5 Particle size distribution

Particle size distribution was determined by the hydrometer method (Day, 1965). 100mls of Calgon (Sodium hexametaphosphate) solution was added to 50g of soil and stirred. The suspension was left to stand for 3 minutes and again stirred for 5 minutes with a stirring machine. It was poured into a 1000-ml measuring cylinder and made to mark with distilled water.

Readings were taken with a hydrometer after 40 seconds and 8 hours.

$$\% \text{ Silt} = \frac{\text{Corrected 40 - second hydrometer reading}}{\text{wt. of soil.}} \times 100$$

$$\% \text{ Clay} = \frac{\text{Corrected 8 hour hydrometer reading}}{\text{wt. of soil.}} \times 100 - \% \text{ silt}$$

$$\% \text{ Sand} = 100 - (\% \text{ silt} + \text{clay})$$

3.4.1.6 Water Use

Water use (wu) can be determined using the water balances equation, which is normally written as:

$$P - O - U - E + DW = 0 \quad \text{--------} \quad (1)$$

where DW is the change in soil water storage (initial minus final) during the period under study and for the depth of measurement, and P, O and U are the precipitation, run-off, and deep drainage respectively. U is defined as the amount of water passing beyond the root zone or for experimental purposes, the amount passing below the lowest point of measurement. E is the water use (evaporation plus transpiration).

The above equation can be more precisely written as:

$$\int_{t_1}^{t_2} (P-D) - E - V_z \; d_t = \int_{t_1}^{t_2} \int_{o}^{z} \frac{do}{d_t} \; d_z d_t \quad \text{---} \quad (2)$$

where (t_2-t_1) is the time interval over which the measurements are made (sec.), z is the depth to the lowest point of measurement (cm), V_z is the net downward flux of water at depth z (cm $sec.^{-1}$) and O is the volumetric soil water content (cm^3 water cm^3 soil). P, O, and E now are in units of cm $sec.^{-1}$ or gcm^{-2} $sec.^{-1}$.

Rose and Stern (1965) have given the normal equation for vertical flow of water, V_z as:

$$V_z = K + K\ (dh/d_z) \quad \text{_____} \quad (3)$$

where V_z is the rate of downward flow in cmsec.$^{-1}$), K is the hydraulic conductivity (cmsec.$^{-1}$) and (dh/d_z) is the rate of change of soil suction (h cm) with depth (z cm).

The use of equation (3) to compute downward flux of water was not possible in this experiment because the rate of change of soil suction with depth (dh/d_z) was not measured due to lack of equipment. Therefore, equation (2) could not be used for computation of water use. Deep drainage was assumed to be negligible . Runoff was also assumed to be negligible because the field was relatively flat. The water balance equation was therefore simplified and the water use determined as:

$$Wu = R + Sw$$

where R was rainfall and SW was the change in mm of stored water to 1.2m between planting and harvest (Table). This is similar to the method used by Morris et al. (1990) in determining water use by cowpea.

In most experiments involving measurements of evapotranspiration from the water balance equation

deep drainage and runoff are usually assumed to be negligible. These assumptions are, however, erroneous and may drastically affect the results. For example Wilcox (1960) reported that the deep drainage term (U) is, in many cases, not negligible.

3.4.2. Chemical measurements

Soil samples were collected from 0 - 15 and 15 - 30cm layers. They were air-dried, ground and sieved to remove materials greater than the 2mm fraction. The following analysis were carried out.

3.4.2.1 Soil pH

Soil pH was determined potentiometrically on 1:1 soil to solution ratio using glass electrode and Coleman matric IV pH meter, in distilled water and 0.01m calcium chloride ($Cacl_2$) solution.

3.4.2.2 Available P.

Available P was determined by the Bray No.1 method (Bray and Kurtz, 1945).

3.4.2.3 Organic C.

Organic C was determined by the Walkley-Black method (Jackson, 1958). Soil organic matter was digested by potassium dichromate ($K_2\ C_2\ O_4$) using conc sulphuric acid to increase the temperature and hasten the reaction. Percent organic C was determined using the

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formula:

$$\text{Org. C \%} = \frac{\text{(Blank titre - Actual titre) x 0.3 x m x f}}{\text{Grams of air dry soil}}$$

where m = concentration of ferrous ammonium sulphate

f = correction factor = 1.33.

3.4.2.4 Exchangeable cations

Exchangeable Ca, Mg, K and Na were determined with 1N NH_4 OAC (pH 7.0) using 1:10 soil: solution ration. Calcium and Mg were determined using atomic absorption spectrophotometer while Na and K were determined with flame emission photometry (Chapman, 1965).

3.4.2.5 Micronutrients

The double acid method was used. Five grams of the soil was weighed into a test tube and 20mls of mixture of HCL and H_2SO_4 added. The solution was mechanically shaken for 1 hour, after which it was filtered and the filtrate read with atomic absorption spectrophotometer.

3.4.2.6 Total N:

This was determined by the regular Macro-Kjeldahl method. Percent N was obtained by the formula:

$$\% \text{ N} = \frac{0.014 \text{ x VD x N x 100 x TV}}{\text{weight of soil x AD.}}$$

where, VD = volume of digest 10ml

N = Normality of acid 0.05N HCL

AD = Aliquot of digest 100.

CHAPTER FOUR

RESULTS

4.1 Soil physical properties

4.1.1 Bulk density

Data on bulk density are given in Table 1. Analysis of the result shows that the grass fallowed plot with treatment M_z/G_o had the highest bulk density. This was followed by plots with treatments M_z/F_1, M_z/F_3 and M_z/F_2 and treatments M_z/F_o, M_z/F_2 and $M_z/S/F_o$ on the stylo fallowed plots whose bulk density values were not statistically different. Plot with treatment S (i.e. sole stylo) had the lowest bulk density which was not statistically different from plots with treatments M_z/F_3, $M_z/S/F_1$, $M_z/S/F_2$ and $M_z/S/F_3$ on the stylo fallowed plots.

The grass fallowed plots had the highest mean bulk density ($1.55gcm^{-3}$) (Table 2). This followed by the sole maize plots ($1.49gcm^{-3}$). The maize with stylo plots produced the lowest mean bulk density ($1.45gcm^{-3}$).

4.1.2 Total porosity

Although plot with treatment S had the highest porosity, it was not statistically different from plots with treatments M_z/F_3, $M_z/S/F_1$, $M_z/S/F_2$ and $M_z/S/F_3$ on the stylo fallowed plots. The plot with treatment M_z/F_o had lower total porosity but was not

statistically different from plots that had treatments M_z/F_1, M_z/F_2 and $M_z/S/F_o$ and the grass fallowed plots that had treatments M_z/G_1, M_z/G_2 and M_z/G_3. Treatment M_z/G_o on the grass fallowed plots produced the lowest total porosity in the whole experiment (Table 1).

The maize with stylo plots and the sole maize plots had statistically the same mean total porosity value (Table 2). The grass fallowed plots had the lowest mean total porosity (41.58%).

4.1.3 Infiltration rate

Steady state infiltration was attained after about 90 minutes on the stylo plots. The plot with treatment $M_z/S/F_3$ had the highest steady state infiltration rate ($42.9 mmhr^{-1}$) but was not statistically different from plots with treatments M_z/F_3, $M_z/S/F_1$, $M_z/S/F_2$ and S (Table 1). The plot with treatment M_z/F_1 had lower mean infiltration rate which was not statistically different from plots with treatments M_z/F_o, M_z/F_2 and $M_z/S/F_o$. On the grass fallowed plots steady state infiltration rate was attained after 75 minutes. The plot that had treatment M_z/G_3 gave the highest steady state infiltration rate which was not statistically different from the plot that had treatment M_z/G_2. The plot with treatment M_z/G_o had the lowest steady state infiltration rate in the whole experiment which was not statistically different from the grass fallowed plot with treatment M_z/G_1.

On the average, plots with maize and stylo had highest mean steady state infiltration rate ($40.4 mmhr^{-1}$). This was followed by the sole maize plots ($37.2 mmhr^{-1}$). The grass fallowed plots had the lowest steady state infiltration rate ($32.6 mmhr^{-1}$) (Table 2).

4.1.4 Saturated hydraulic conductivity (K).

Result of the tests on saturated hydraulic conductivity (Table 1) follows the same pattern with the infiltration test result. Although the plot that was cropped with sole stylo gave the highest saturated K, it was not statistically different from the stylo fallowed plots with treatments M_z/F_3, $M_z/S/F_1$, $M_z/S/F_2$ and $M_z/S/F_3$. The plot with treatment M_z/F_o had lower saturated K which was not statistically different from the plots with treatments M_z/F_1, M_z/F_2 and $M_z/S/F_o$ which, in turn, were not statistically different from the grass fallowed plots that had treatments M_z/G_1, M_z/G_2 and M_z/G_3. The grass fallowed plot with treatment M_z/F_o had the lowest saturated K in the whole experiment.

On the average, the maize with stylo plots had higher saturated K ($5.49 cms^{-1}$) than the sole maize plots ($4.46 cms^{-1}$) although the difference was not statistically significant. The grass fallowed plots had the lowest saturated K ($2.73 cms^{-1}$).

Table 1: Soil physical properties as influenced by stylo cover.

Treatments	Infiltration rate ($mmhr^{-1}$)	Bulk den. gcm^{-3}	Porosity %	Saturated K ($cms^{-1} \times 10^{-4}$
M_z/F_o	35.9b	1.52b	42.55b	3.46b
M_z/F_1	35.7b	1.51b	43.21b	3.95b
M_z/F_2	36.3b	1.50bc	43.30b	4.20b
M_z/F_3	40.7a	1.44d	45.66a	6.21a
$M_z/S/F_o$	36.6b	1.50bc	43.30b	4.21b
$M_z/S/F_1$	40.3a	1.45cd	45.52a	5.82a
$M_z/S/F_2$	40.4a	1.45cd	45.47a	5.91a
$M_z/S/F_3$	42.9a	1.42d	46.61a	6.00a
S	42.8a	1.41d	46.79a	6.34a
M_z/G_o	28.9c	1.60a	39.53c	1.48c
M_z/G_1	30.6c	1.54b	41.98b	2.98b
M_z/G_2	35.1b	1.52b	42.55b	3.43b
M_z/G_3	35.7b	1.53b	42.26b	3.03b
SE $\pm$	1.19	0.0157	0.59	0.43

NB: Means followed by the same letter(s) are not statistically different at 5% level of significance. Mean separation was by the use of DMRT.

Table 2: Means of soil physical properties as influenced by stylo cover.

	Infiltration rate ($mmhr^{-1}$)	Bulk density gcm^{-3}	Porosity %	Saturated K ($cms^{-1} \times 10^{-4}$).
Sole maize plots	37.2a	1.492b	43.68a	4.46a
Plots with maize and stylo	40.4a	1.446b	45.25a	5.49a
Grass fallowed plots	32.6b	1.548a	41.58b	2.73b
SE ±	1.19	0.0157	0.59	0.43

NB: Means followed by the same letter(s) are not statistically different at 5% level of significance.

Mean separation was by the use of DMRT.

4.2 Water use

Data on water use by maize are presented in Table 3. The crop had the highest water use during the season on plot that had treatment M_z/F_1. This was not, however, statistically different from the water use by the crop on plots treated with M_z/F_2, M_z/F_3 and $M_z/S/F_2$. The maize crop had lower water use on plots with treatments M_z/F_o, $M_z/S/F_o$ and $M_z/S/F_3$. These were, however, not statiscally different from each other. The lowest value of water use was given by the crop on the plot with treatment $M_z/S/F_1$. This was, however, not statistically different from all the treatments on the grass fallowed plots except treatment M_z/G_o which gave higher value.

When the means of the maize water use was compared between the sole maize plots, maize with stylo plots and grass fallowed plots it was found that the maize water use on the sole maize plots was the highest. This was followed by the water use on the maize with stylo plots. The water use on the grass fallowed plots was the lowest but was not statistically different from the maize with stylo plots. (Table 4).

4.3 Grain yield

Mean grain yield is presented in Table 3. Generally maize cropped on the stylo fallowed plots had higher grain yield than the grass fallowed plots. On the stylo fallowed plots treatment M_z/F_3 produced the highest grain yield which was not statistically different

from treatments $M_z/S/F_3$ and M_z/F_1. Treatment $M_z/S/F_o$ produced the lowest grain yield but was not statistically different from treatments M_z/F_o, M_z/F_2, $M_z/S/F_1$ and $M_z/S/F_2$. It however produced grain yield much higher than treatment M_z/G_2 on the grass fallowed plots.

On the grass fallowed plots, treatment M_z/G_2 gave the highest dry grain yield which was not statistically different from treatment M_z/G_3. Treatment M_z/G_o produced the lowest dry grain weight in the whole experiment which was however not statistically different from treatment M_z/G_1.

When the means of the grain yield were compared, it was found that the grain yield on the sole maize plots was higher than on the maize with stylo plots although the difference was not statistically significant. The grass fallowed plots produced the lowest mean grain yield (1728 $Kgha^{-1}$) (Table 4).

4.4 Plant growth

4.4.1 Number of leaves/plant

The effect of the treatments on the number of leaves/plant at 28 DAE (Table 5) shows that treatments M_z/F_3 and $M_z/S/F_3$ on $M_z/S/F_3$ on the stylo fallowed plots produced the highest number of leaves per plant.

Table 3: Water use and grain yield of maize as influenced by stylo cover and N levels.

Treatments	Water use (mm)	Grain yield ($Kgha^{-1}$)
M_z/F_o	813.5b	2603cde
M_z/F_1	836.4a	3480ab
M_z/F_2	830.3a	3157bc
M_z/F_3	835.8a	4216a
$M_z/S/F_o$	810.1bd	2521cde
$M_z/S/F_1$	799.2d	3038bcd
$M_z/S/F_2$	827.2a	3231bc
$M_z/S/F_3$	810.6b	3561ab
S	801.4cd	
M_z/G_o	812.3bc	883g
M_z/G_1	804.9bcd	1500fg
M_z/G_2	805.8bcd	2347de
M_z/G_3	799.9d	2182ef
SE ±	3.7	267.46

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NB: Means followed by the same letter(s) are not statistically different at 5% level of significance.

Mean separation was by the use of DMRT.

Table 4: Means of water use and Grain yield of maize as influenced by stylo cover and N levels.

	Water use (mm)	Grain yield ($Kgha^{-1}$)
Sole maize plots	829.0a	3364a
Plots with maize and stylo	811.8b	3087a
Grass fallowed plots	805.7b	1728b
SE ±	3.7	267.46

NB: Means followed by the same letter(s) are not statistically different at 5% level of significance.

Mean separation was by the use of DMRT.

Maize plant on the grass fallowed plot with treatment M_z/G_o had the lowest number of leaves/plant. At 42 DAE (Table 6) the effect of the treatments on the number of leaves/plant followed the same trend.

At 66 DAE (Table 7) treatments $M_z/S/F_o$ and $M_z/S/F_2$ on the stylo fallowed plots produced the lowest number of leaves/plant which were however not statistically different from treatments M_z/G_1 and M_z/G_3 on the grass fallowed plots. All the other treatments on the stylo fallowed plots produced statistically the same number of leaves/plant. Treatment M_z/G_o on the grass fallowed plots had the lowest number of leaves/plant in the whole experiment.

4.4.2 Leaf area/plant

Data on leaf area/plant is presented in Table 5. On the stylo fallowed plots, treatment $M_z/S/F_o$ produced lower leaf area/plant at 28 days after emergence than all the other treatments which were in turn, statistically the same. On the grass fallowed plots treatments M_z/G_1, M_z/G_2 and M_z/G_3 gave statistically same results. Treatment M_z/G_o produced the lowest leaf area per plant.

At 42 DAE (Table 6) all the treatments on the stylo fallowed plots produced leaf area/plant which were not statistically different. On the grass fallowed plots all treatments produced leaf area/plant which were lower than the treatments on the stylo fallowed plots.

Treatments M_z/G_1, M_z/G_2 and M_z/G_3 on the grass fallowed plots gave higher leaf area/plant than treatment M_z/G_o which was, however, not statistically different from treatment M_z/G_1 (Table 6).

At 66 DAE (Table 7) on the stylo fallowed plots treatments M_z/F_2 and $M_z/S/F_3$ gave the highest leaf area/plant which were not statistically different from all the other treatments except $M_z/S/F_o$, which gave lower leaf area/plant. Treatments $M_z/S/F_1$, $M_z/S/F_2$, M_z/F_1 and M_z/F_o were, however, not statistically different from treatment $M_z/S/F_o$. All the treatments on the grass fallowed plots produced leaf area/plant which were not statistically different. They were however statistically lower than the leaf area/plant produced by all the treatments on the stylo fallowed plots.

4.4.3 Plant height

Mean plant height at 28 DAE is presented in Table 5. On the stylo fallowed plots treatment $M_z/S/F_3$ produced the highest plant height which was not statistically different from treatment M_z/F_3. Treatments M_z/F_1, M_z/F_2, M_z/F_o, $M_z/S/F_1$ and $M_z/S/F_2$ produced plant heights which were not statistically different from treatment M_z/F_3. Treatments on the grass fallowed plots gave plant heights which were lower than those produced by treatments on the stylo fallowed plots. Treatment M_z/G_o gave the lowest mean plant height. Treatments

M_z/G_2 and M_z/G_3 gave plant heights which were not statistically different. They were, however, higher than plant height produced by treatment M_z/G_1.

Data on plant height at 42 DAE are presented in Table 6. Treatment $M_z/S/F_3$ gave the highest plant height but was not statistically different from treatments M_z/F_2, $_z/F_1$, M_z/F_2, M_z/F_3, $M_z/S/F_1$, and $M_z/S/F_2$ which, except treatment M_z/F_3, were in turn not different from treatment $M_z/S/F_o$. Treatment M_z/F_o produced lower plant height but was not statistically different from treatments M_z/F_1, M_z/F_2, $M_z/S/F_o$, $M_z/S/F_1$ and $M_z/S/F_2$. On the grass fallowed the result followed the same trend with plant height at 28 days after emergence with all treatments giving lower plant heights than the stylo fallowed plots. Treatment M_z/G_o gave the lowest plant height in the whole experiment. Treatments M_z/G_1, M_z/G_2 and M_z/G_3 gave plant heights which were not statistically different from each other.

At 66 DAE (Table 7) on the stylo fallowed plots, treatment $M_z/S/F_3$ produced the highest plant height but was not statistically different from the other treatments except M_z/F_o which gave the lowest mean plant height.

Table 5: Number of leaves/plant, Mean leaf area/plant, Mean plant height at 28 days after emergence as influenced by stylo cover and N levels.

Treatments	No. of leaves/ plant	Mean leaf area/ plant (cm^2)	Mean plant height (cm)
M_z/F_o	8b	2186.32a	58.55cd
M_z/F_1	8b	2178.79a	68.75bc
M_z/F_2	8b	2222.03a	67.67bc
M_z/F_3	9a	2382.54a	83.69ab
$M_z/S/F_o$	8b	2026.96b	61.89c
$M_z/S/F_1$	8b	2276.78a	72.12bc
$M_z/S/F_2$	8b	2333.03a	73.00bc
$M_z/S/F_3$	9a	2527.96a	92.37a
S	-	-	-
M_z/G_o	7c	977.80d	24.35f
M_z/G_1	8b	1462.62c	41.30e
M_z/G_2	8b	1676.59bc	48.31de
M_z/G_3	8b	1529.53c	42.17de
SE ±	0.15	134.57	5.60

Treatment means followed by unlike letters are significantly different at 5%.

Mean separation was by the use of DMRT.

Table 6: Number of leaves/plant, Mean leaf area/plant, Mean plant height at 42 days after emergence as influenced by stylo cover and N levels.

Treatments	No. of leaves/ plant	Mean leaf area/plant (cm^2)	Mean plant height (cm)
M_z/F_o	12b	5184.36a	167.74cd
M_z/F_1	12b	5174.81a	171.11abc
M_z/F_2	12b	5220.33a	169.65abc
M_z/F_3	13a	5378.50a	186.57ab
$M_z/S/F_o$	12b	5023.61a	164.25bc
$M_z/S/F_1$	12b	5271.70a	175.47abc
$M_z/S/F_2$	12b	5330.47a	177.12abc
$M_z/S/F_3$	13a	5524.54a	193.94a
S	-	-	-
M_z/G_o	11c	2792.44c	89.42f
M_z/G_1	12b	3515.16bc	124.77e
M_z/G_2	12b	3779.20b	137.43e
M_z/G_3	12b	3543.71b	127.98e
SE ±	0.15	274.06	8.81

Treatment means followed by unlike letters are significantly different at 5%.

Mean separation was by the use of DMRT.

Table 7: Number of leaves/plant, Mean leaf area/plant, Mean plant height at 66 days after emergence as influenced by stylo cover and N levels.

Treatments	No. of leaves/ plant	Mean leaf area/ plant (cm^2)	Mean plant height (cm)
M_z/F_o	15a	7323.62ab	219.01bc
M_z/F_1	15a	7365.52ab	231.70ab
M_z/F_2	15a	7210.77ab	231.25ab
M_z/F_3	15a	7873.99a	247.73ab
$M_z/S/F_o$	14b	6466.31b	225.74ab
$M_z/S/F_1$	15a	7417.99ab	236.83ab
$M_z/S/F_2$	14b	7501.14ab	238.63ab
$M_z/S/F_3$	15a	8096.61a	255.19a
S	-	-	-
M_z/G_o	13c	4498.28c	121.19e
M_z/G_1	14b	5220.03c	174.62d
M_z/G_2	15a	5486.54bc	185.86cd
M_z/G_3	14b	5282.39c	176.26d
SE ±	0.25	350.87	11.38

Treatment means followed by unlike letters are significantly different at 5%.

Mean separation was by the use of DMRT.

Difference between treatment M_z/F_o and all the others except $M_z/S/F_3$ was not not statistically significant. On the grass fallowed plots, however, treatment M_z/G_o gave the lowest plant height in the whole experiment. Treatments M_z/G_1, M_z/G_2 and M_z/G_3 gave plant heights which were not statistically different but were lower than all the plants produced by the treatments on the stylo fallowed plots.

4.5 Correlation studies

Correlation studies between grain weight, water use, saturated K, total porosity, bulk density and infiltration rate are presented in Table 8.

There was a very strong positive correlation at 1% level between total porosity and saturated K and between bulk density and saturated K. A very strong positive correlation at 1% level also existed between total porosity and bulk density.

Table 8: Matrix of correlation co-efficient between grain weight, water use, saturated K, total porosity, bulk density and infiltration rate.

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1.00					
C_2	0.622NS	1.00				
C_3	0.366NS	0.167NS	1.00			
C_4	0.311NS	0.79NS	0.987**	1.00		
C_5	0.298NS	0.078NS	0.987**	0.999**	1.00	
C_6	0.038NS	0.257NS	0.108NS	0.169NS	0.186NS	1.00

C_1 = Grain weight (Kg/ha)

C_2 = Water use (mm)

C_3 = Saturated K (cm^{5-1}) x 10^{-4}

C_4 = Porosity (%)

C_5 = Bulk density (gcm^{-3})

C_6 = Infiltration rate ($mmhr^{-1}$)

NS = Not significant

* = Significant at 5% level of significance

** = Significant at 1% level of significance.

CHAPTER FIVE

DISCUSSION

Soil total porosity was significantly affected by the stylosanthes cover crop. The stylo fallowed plots had significantly higher total porosity than the grass fallowed plots. This is attributed to higher pores created by the legume roots and possible improvement of soil structure due to higher organic matter content. Even on the stylo fallowed plots, the plots that had stylosanthes as a treatment had significantly higher total porosity than those that had no stylo. Addition of N up to 80KgNha^{-1} had no significant effect on total porosity. 120 KgNha^{-1}, however, produced a significantly higher total porosity than the other N levels. This was lower than the total porosity on the sole stylo plots, although the difference was not statistically significant. The N could therefore not be said to affect the total porosity of the soil. Result of this experiment shows that the stylo cover crop had improved the porosity of the soil. This is similar to the findings of Wilson et al. (1982).

Soil bulk density was also significantly affected by the stylo cover crop. The two years of stylo fallowed had improved the bulk density of the soil with the stylo fallowed plots having significantly lower bulk densities than the grass fallowed. This is similar to

to the findings of many authors (Wilson et al. 1982; Mohammed-Saleem and Otsyina, 1986; Obi and Nnabule, 1988). Significant differences in bulk density were also observed within the stylo fallowed plots. The plots that had stylo cover as a treatment had lower bulk densities. This is probably due to higher root growth on these plots than those without the stylo cover. Improvement of soil structure could also have caused the difference in bulk densities. But this is more likely to have caused the difference between the stylo fallowed and the grass fallowed plots. This is because of the two years of stylo fallow. As with total porosity, soil bulk density was not affected by the N levels. This is because the highest level of N produced soil bulk density which was not statistically different from the no N treatment i.e. sole stylo.

Result of the infiltration rate test reveals that steady state infiltration was attained after about 90 and 75 minutes on the stylo fallowed and grass fallowed plots respectively. On the average, the stylo fallowed plots had higher mean steady state infiltration rate ($39.07 mmhr^{-1}$) than the grass fallowed plots ($32.58 mmhr^{-1}$). This is due to the higher porosity and lower bulk densities on the stylo fallowed than the grass fallowed plots. The stylo cover had a significant effect in increasing the infiltration capacity of the soil.

This is confirmed by the findings of many authors (Bridge et al., 1983; Mohammed-Saleem and Otsyina, 1986; Mohammed-Saleem et al., 1986). Addition of N produced statistically the same infiltration rate except 120KgNha^{-1} which was statistically higher than the other levels. This was, however, lower but statistically the same with the plot planted with sole stylo. The infiltration rate was therefore not affected by the levels of N.

Saturated hydraulic conductivity values followed the same trend with total porosity and infiltration rate. The two years of stylo cover had a significant effect in increasing the hydraulic conductivity. This is similar with the reports of many authors. (Pereira et al., 1967). The stylo fallowed plots had significantly higher hydraulic conductivity (5.12cms^{-1}) than the grass fallowed plots (2.73cms^{-1}). This is attributed mainly to the higher total porosity on the stylo fallowed plots. Another factor could have been better soil structure on the stylo fallowed plots due to higher organic matter content. The saturated K was not affected by addition of N as can be observed from table 1. Addition of N up to 80KgNha^{-1} produced statistically the same K 120 KgNha^{-1}, however, produced statistically higher saturated K but this was not statistically different from the saturated K on the sole stylo plot.

Generally the two years of stylo pasture had a considerable effect on water use by maize. The maize plants used 93.1mm more water on the stylo fallowed than the grass fallowed plots. This was due to better physical conditions of the plots which resulted in higher infiltration rate. More water was able to penetrate the soil and stored for crop use. A close look at the result, however, reveals that the maize plants used less water when intercropped with the legume covers. The intercropped maize used 2% less water than the sole crop. This was probably due to competition between the crop and the stylo cover or reduced evaporation due to the presence of cover crops. Addition of N significantly increased the crop water use over the no N treatment although the three levels of N produced statistically the same water use. This is due to increased vegetative growth of the maize crop. When intercropped with stylo, however, the water use was statistically lower than the sole maize except treatment $M_z/S/F_2$ which gave statistically the same water use. On the grass fallowed plot addition of N did not affect the water use with all levels giving statistically the same water use.

When the water use efficiency (mean weight of dry grain/water use) was compared it was observed that the intercropped maize had higher water use efficiency (26.29%) than the sole maize (24.64%). The stylo cover

crop therefore increased the water use efficiency of the maize crops by increasing the yield. On the average the maize crop used 814.4mm of water during the season.

The stylo cover crop had a significant effect on the yield of the maize crop. The stylo fallowed plots produced significantly higher grain yield than the grass fallowed plots. This is attributed to the better physical condition of the stylo fallowed plots which was brought about by the ameleorative effect of the stylo cover. The lower bulk density and higher total porosity produced by the cover crop are favourable soil conditions for good root growth and ramification. The stylo fallowed plots also had higher infiltration rate and hydraulic conductivity. More water was therefore able to penetrate the soil and stored for crop use.

A closer look at the grain yield data reveals an interesting trend on the stylo plots. (Table 3). Addition of fertilizer increased the grain yield but the result was highly variable on the plots cropped with sole maize. Addition of $40KgNha^{-1}$ increased the yield significantly over the no N treatment. Further addition of fertilizer to $80KgNha^{-1}$, however, produced lower grain yield than the $40KgNha^{-1}$. $120KgNha^{-1}$ produced significantly higher yield than the $80KgNha^{-1}$.

This variability in trend could be attributed to the inherent variability in soil property. This is supported by the fact that intercropping maize with the stylo cover produced a gradual increase in yield with the addition of fertilizer. The stylo cover had a smoothing effect on the soil properties.

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CHAPTER SIX

SUMMARY AND CONCLUSION

This experiment was conducted to determine the effect of a stylo cover crop (Stylosanthes hamata) and N levels on soil physical properties, water use and yield of maize at Samaru. The field work was carried out at the Institute for Agricultural Research Farm in Samaru, Zaria, during the 1992 rainy season. The field on which the trial was conducted was divided into two parts: one part (Stylo fallowed) had been under stylo pasture for two years before the treatment of four levels of N - 0, 40, 80 and 120KgNha^{-1} was imposed. The stylo pasture was also planted as a treatment cover crop. The second part of the field had been under grass fallow for two years before the treatment of only four levels of N was imposed. Laboratory tests were carried out at the soil physics laboratory of the Soil Science Department, Ahmadu Bello University, Zaria.

The stylo cover was observed to improve infiltration rate, total porosity, saturated hydraulic conductivity and lower the bulk density of the soil N levels did not, however, affect these soil properties.

Maize cropped on the stylo fallowed plots used more water than on the grass fallowed plots, but the intercropped maize used less water than the sole cropped maize. The intercropped maize was, however, found to

have higher water use efficiency than the sole cropped maize. Addition of N significantly increased the crop water use over the no N treatment although the three levels of N produced statistically the same water use. Grain yield was found to be higher on the stylo fallowed than the grass fallowed plots. This is due to better physical condition of the stylo fallowed plots which was brought about by the ameleorative effect of the stylo cover. Addition of N increased the grain yield but the result was highly variable.

Simple correlation studies revealed that there was a very strong positive correlation between total porosity and saturated K and between bulk density and saturated K. A very strong positive correlation also existed between total porosity and bulk density.

The use of Stylosanthes hamata, a leguminous crops, as a soil cover has a significant effect in improving the physical conditions of the soil. Yield variation as a result of inherent soil conditions is considerably smoothened. Its use either as an intercrop or as fallow crop increases the yield of the companion or the subsequent crop through N fixation in the soil. Supplementary application of a N fertilizer must however, be done with caution as higher rates tend to diminish the beneficial effect of the cover crop.

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Appendix I: Physico-chemical properties of the top (0 - 15cm) Soil of the experimental plots.

STYLO FALLOWED PLOTS

TREATMENTS	PARTICLE SIZE ANALYSIS				pH					Exchangeable Bases (cmol/kg^{-1})				Micro Nutrients (ppm)				
	% SAND	% SILT	% CLAY	TEXT CLASS	H_2O	$CaCl_2$	%C	P (PPM)	% N	Ca	Mg	Na	K	Zn	Mn	Fe	Cu	CEC
Mz/F_o	49.12	40.00	10.88	Loam	6.1	5.8	0.56	5.376	0.045	3.2655	0.637	0.07348	0.34615	1.08	19.44	13.60	0.312	4.322
Mz/F_1	49.12	40.00	10.88	Loam	5.9	5.7	0.64	4.480	0.052	2.5830	0.701	0.07348	0.31154	1.60	21.20	17.40	0.280	3.669
Mz/F_2	47.12	44.00	8.88	Loam	5.9	5.7	0.44	5.376	0.053	1.7640	0.592	0.07913	0.28385	1.48	21.60	14.40	0.320	2.719
Mz/F_3	45.12	44.00	10.88	Loam	6.0	5.6	0.68	2.688	0.053	3.8640	1.004	0.09043	0.36692	1.40	24.80	17.80	0.180	5.325
$Mz/B/F_o$	51.12	36.00	10.88	Loam	5.7	5.3	0.58	5.376	0.056	2.9925	0.861	0.06783	0.31154	1.52	25.60	20.00	0.140	4.233
$Mz/S/F_1$	47.12	42.00	10.88	Loam	5.7	5.5	0.42	4.480	0.049	1.0290	0.660	0.07913	0.32538	1.20	26.00	21.00	0.356	2.094
$Mz/S/F_2$	39.12	50.00	10.88	Loam	5.9	5.6	0.70	1.792	0;059	2.5095	0.748	0.08478	0.41538	1.60	33.20	22.40	0.312	3.758
$Mz/S/F_3$	47.12	42.00	10.88	Loam	5.8	5.5	0.58	2.688	0.049	2.436	0.650	0.07348	0.29769	5.00	38.00	24.92	0.356	3.457
S	47.12	40.00	12.88	Loam	5.9	5.6	0.54	6.272	0.048	2.2680	0.697	0.08478	0.31154	1.12	29.20	20.40	0.220	3.361
Grass fallowed plots																		
M_z/G_o	51.12	36.00	12.88	Loam	5.8	5.4	0.26	5.376	0.048	2.0160	0.710	0.07913	0.26308	1.36	16.96	16.00	0.280	3.068
M_z/G_1	49.12	40.00	10.88	Loam	5.9	5.6	0.56	6.272	0.064	3.5385	1.151	0.08478	0.48462	1.40	31.12	26.32	0.280	5.259
M_z/G_2	47.12	40.00	12.88	Loam	5.7	5.4	0.38	5.376	0.042	1.7220	0.688	0.07348	0.24923	1.08	17.20	16.40	0.216	2.733
M_z/G_3	49.12	40.00	10.88	Loam	5.8	5.6	0.40	7.168	0.050	2.0055	0.681	0.07913	0.45000	1.28	18.72	15.12	0.180	3.216

APPENDIX II: Physico-chemical properties of the sub (15-50cm) Soil of the experimental plots.

STYLO FALLOWED PLOTS

TREAT-MENTS	PARTICLE - SIZE ANALYSIS				pH					EXCHANGEABLE BASES (cms /kg^{-1}				Micro - nutrients				
	SAND	SILT	CLAY	CLASS	H_2O	$CaCl_2$	% C	(ppm)	% N	Ca	Mg	K	Na	Zn	Mn	Fe	Cu	C.E.C.
Mz/F_o	41.12	32.00	26.88	Loam	5.5	5.2	0.20	1.792	0.025	2.7300	1.224	0.21462	0.07913	1.12	11.60	11.40	0.320	4.248
Mz/F_1	43.12	38.00	18.88	Loam	5.1	4.8	0.26	1.792	0.043	2.2785	0.820	0.19385	0.07913	1.20	24.80	17.16	0.272	3.371
Mz/F_2	43.13	36.00	20.88	Loam	6.1	5.6	0.58	3.584	0.062	4.6200	1.174	0.20769	0.09043	1.20	17.20	14.28	0.232	6.092
Mz/F_3	43.12	36.00	20.88	Loam	5.8	5.2	0.30	3.584	0.030	4.5465	1.363	0.33923	0.09043	0.88	22.80	15.80	0.360	6.339
$Mz/S/F_o$	51.12	30.00	13.88	Loam	5.8	5.4	0.36	2.688	0.050	1.7115	1.231	0.25615	0.07913	2.00	16.00	19.00	0.288	3.278
$Mz/S/F_1$	43.12	36.00	20.88	Loam	5.4	5.0	0.24	2.688	0.044	2.4780	0.921	0.21462	0.07348	1.52	22.80	17.56	0.260	3.687
$Mz/S/F_2$	39.12	44.00	16.88	Loam	5.9	5.7	0.26	1.792	0.028	1.4805	0.921	0.15923	0.07348	1.32	16.80	12.80	0.296	2.634
$Mz/S/F_3$	41.12	42.00	16.88	Loam	5.7	5.1	0.36	3.584	0.044	3.6540	0.949	0.18692	0.07913	1.20	22.80	24.00	0.152	4.869
S	47.12	30.00	22.88	Loam	5.7	5.2	0.36	4.480	0.033	2.6670	1.060	0.27692	0.07913	1.88	18.80	16.40	0.172	4.083
Grass fallowed plots																		
Mz/G_o	39.12	34.00	26.88	Loam	5.2	4.7	0.26	1.792	0.053	1.7325	1.172	0.24231	0.07913	1.00	6.40	10.00	0.140	3.226
Mz/G_1	39.12	36.00	24.88	Loam	5.8	5.4	0.28	1.792	0.045	2.7720	1.183	0.31846	0.08478	1.56	8.16	11.60	0.200	4.358
Mz/G_2	39.12	34.00	26.88	Loam	5.8	5.3	0.32	1.792	0.056	3.4020	1.402	0.24923	0.09043	1.20	9.44	13.08	0.260	5.144
Mz/G_3	41.12	32.00	26.88	Loam	5.4	4.9	0.34	3.584	0.045	2.4150	11026	0.27000	0.07913	1.00	6.80	11.00	0.200	3.790

Appendix iii. Data for determination of pore-size distribution using the Water Desorption Method.

Maximum Diameter of saturated pore (um)	Volume fraction of total pore space (Ov/St) on:			
	Sole maize plots	Plots with maize and stylo	Sole stylo plots	Grass fallowed plots.
468	0.79	0.75	0.69	0.82
295	0.78	0.74	0.68	0.81
93	0.76	0.72	0.66	0.79
47	0.70	0.66	0.59	0.71
29	0.63	0.60	0.53	0.64
15	0.57	0.54	0.49	0.63
6	0.40	0.38	0.28	0.39

Temperature: $24^{o}C$

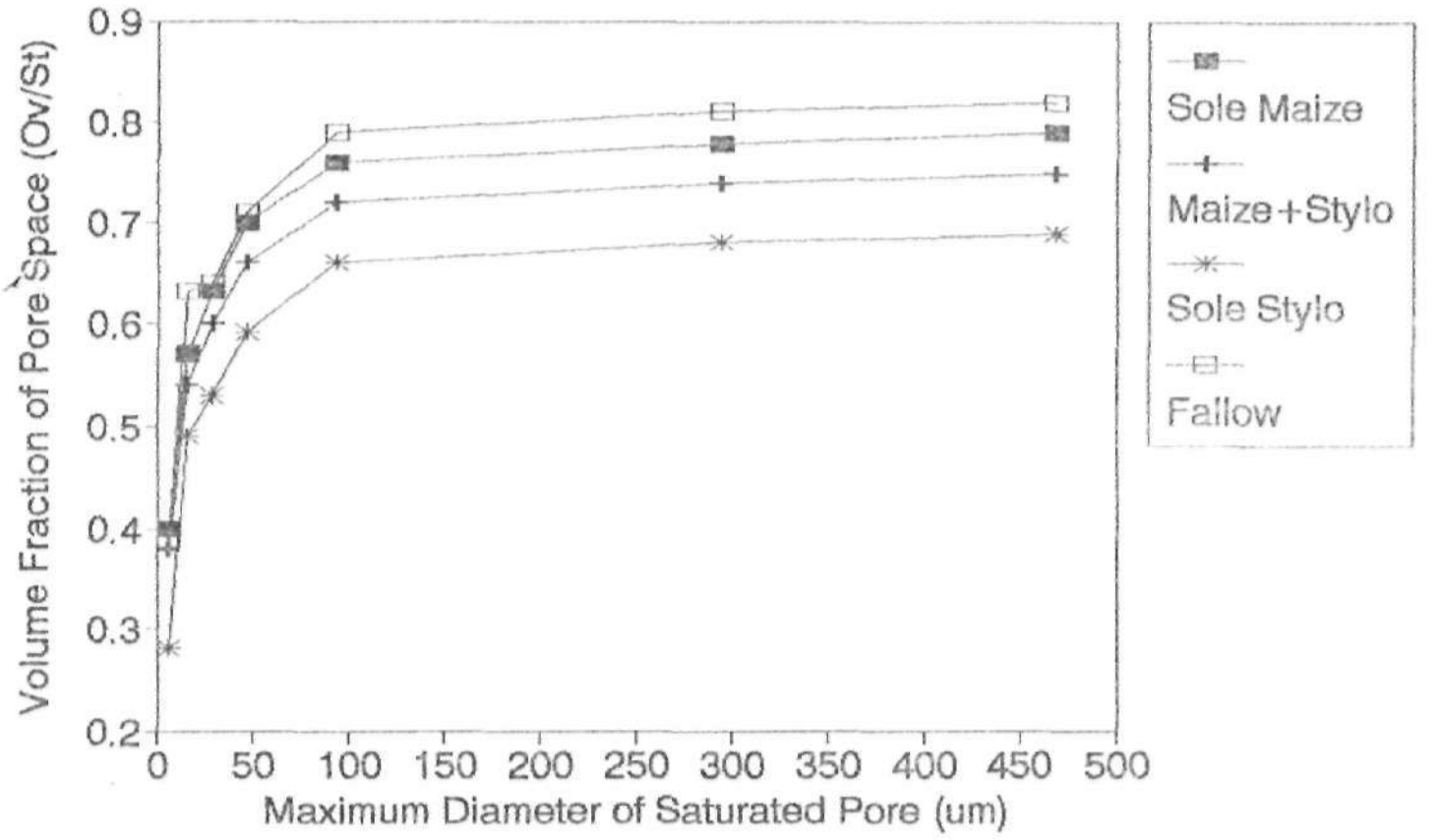
Surface tension: 0.07218 JM^{-2}

Particle density: 2.65Mgm^{-3}

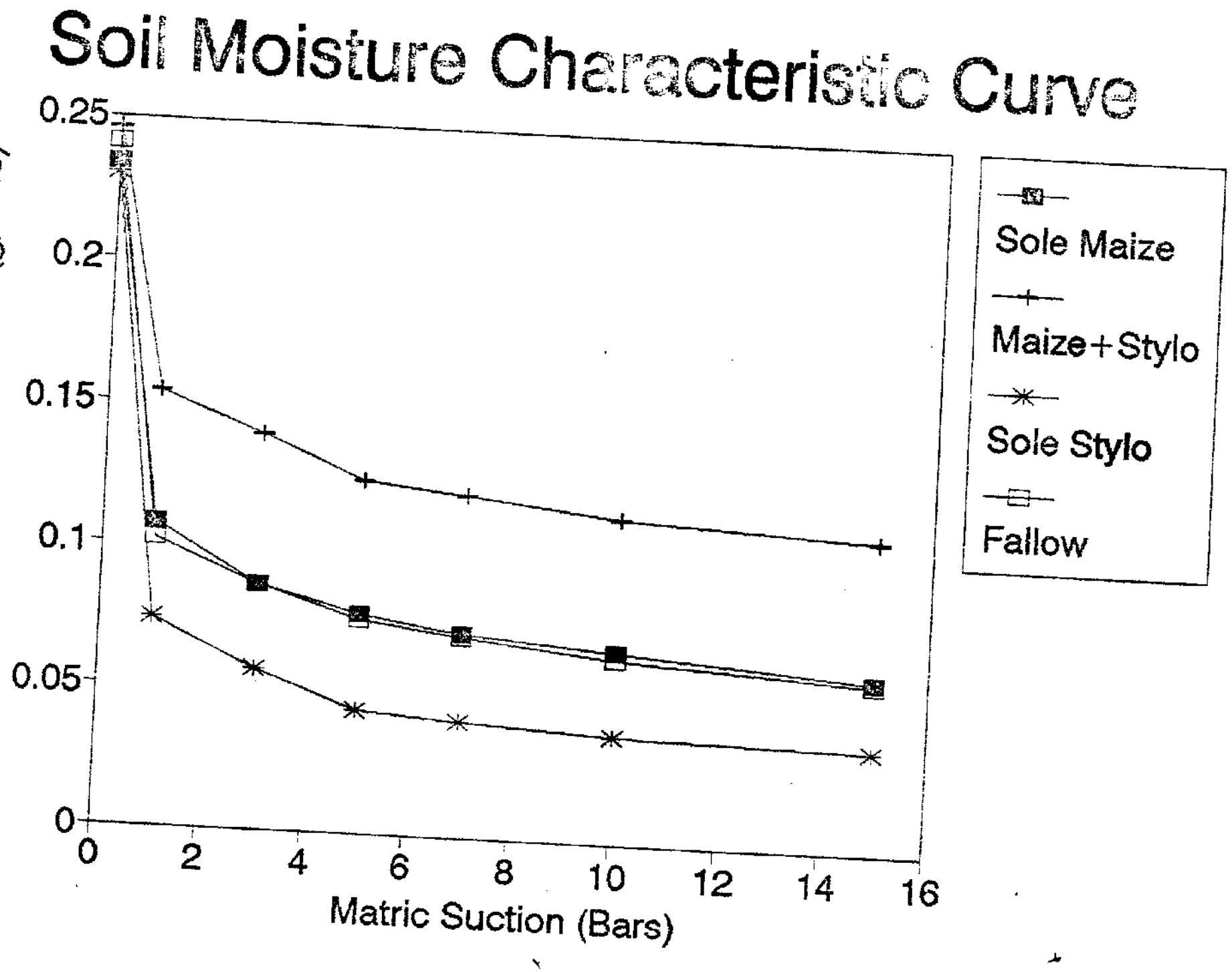
Appendix iv. Data for determination of soil moisture characteristic curve.

Matric Suction (Bars)	Gravimetric Moisture on: Sole maize plots	Plots with maize and styloe	Sole stylo plots	Grass fallowed plots.
0	0.234	0.246	0.230	0.241
1	0.108	0.154	0.074	0.102
3	0.087	0.140	0.057	0.087
5	0.078	0.125	0.044	0.076
7	0.072	0.121	0.041	0.071
10	0.068	0.115	0.038	0.065
15	0.061	0.110	0.036	0.060

Appendix v. Pore Size Distribution
Using Water Desorption Method



Appendix vi. Gravimetric Moisture Characteristic Curve



Appendix Profile moisture (% v/v) distribution for stylo fallowed plot planted with M_2/F_0.

Depth	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	14.29	13.11	22.49	22.08	23.57	25.45	21.01	24.11	22.13	19.18	25.02	24.67	26.66	24.26	24.24	25.84	25.58	5.50
15 - 30	21.57	21.11	24.81	23.37	25.04	27.67	23.92	24.88	25.85	24.89	25.43	25.58	26.72	25.32	26.01	26.43	26.63	23.04
30 - 45	24.48	24.20	26.77	25.94	26.57	28.96	26.05	26.34	27.36	26.73	27.01	27.22	27.67	26.77	27.54	27.63	27.63	24.31
45 - 60	23.34	23.14	25.14	24.95	25.21	27.43	25.32	25.65	26.62	26.20	26.66	26.21	27.29	26.01	26.64	26.79	26.80	25.17
60 - 75	19.39	19.14	20.39	21.15	20.98	23.81	23.09	23.18	24.18	24.01	24.32	24.13	24.82	24.03	24.72	24.15	24.99	25.40
75 - 90	19.87	19.98	20.53	20.71	20.74	24.34	23.88	23.97	25.05	25.41	25.77	25.25	25.80	25.48	25.91	25.55	26.47	26.31
90 - 105	21.20	20.99	21.87	21.59	21.79	25.45	24.65	24.82	26.03	26.87	27.35	27.00	27.42	27.15	27.58	27.02	28.02	27.33
105-120	23.49	23.20	23.66	23.43	23.72	26.41	25.71	25.92	27.65	28.46	28.99	28.52	28.85	28.74	29.17	28.86	29.62	28.44

Appendix ix: Profile moisture (% v/v) distribution for stylo fallowed plot planted with M_2/F_1

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	12.77	13.55	21.15	22.13	22.85	25.65	20.60	24.28	24.67	18.45	27.85	24.36	26.62	24.56	26.17	26.34	27.76	6.89
15 - 30	19.64	20.03	23.80	22.64	25.81	26.90	23.36	24.58	25.92	24.56	25.43	25.64	26.89	25.17	26.26	26.84	27.92	21.58
30 -45	22.42	22.65	24.54	25.00	27.84	27.86	26.14	26.49	27.56	27.16	27.14	27.37	28.32	27.17	27.92	28.06	29.02	26.65
45 - 60	22.21	22.42	23.86	23.61	27.02	27.26	26.41	26.82	27.60	27.82	27.46	27.79	28.73	27.84	28.45	28.34	29.22	27.65
60 - 75	21.73	21.59	23.58	23.04	25.09	25.21	25.19	25.10	26.23	27.44	27.26	27.47	27.97	27.50	28.02	28.10	29.00	28.41
75 - 90	21.20	21.01	23.52	22.73	23.74	23.40	23.56	23.41	24.59	27.52	27.07	27.28	27.89	27.57	27.79	27.74	29.06	28.72
90 - 105	21.10	20.86	23.41	22.98	23.60	23.36	23.00	23.58	23.97	27.50	27.30	27.56	28.06	27.75	28.13	27.82	29.27	29.09
105- 120	21.32	21.15	23.60	23.12	23.58	23.79	24.05	23.96	23.85	26.70	27.43	27.87	28.25	28.07	28.49	28.43	29.56	29.65

Appendix x: Profile moisture (% v/v) distribution for stylo fallowed plot planted with M_2/F_2.

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	10.30	9.89	18.44	19.21	22.14	24.01	18.15	20.84	21.41	14.31	25.06	22.53	25.14	18.26	22.35	23.61	24.79	5.53
15 - 30	16.86	16.79	19.46	19.97	21.41	23.01	21.42	22.09	23.87	23.18	23.24	24.36	25.35	23.74	24.43	24.24	25.69	18.24
30 - 45	17.93	18.17	18.72	19.74	19.74	22.11	23.39	23.47	25.56	25.50	25.17	26.04	26.76	25.78	26.27	25.85	26.71	21.63
45 - 60	19.06	19.16	19.31	19.34	19.47	19.76	21.97	22.51	24.12	26.70	26.31	26.93	27.65	27.06	27.20	27.10	27.30	24.42
60 - 75	18.70	18.90	18.79	18.67	18.92	18.82	19.29	19.41	20.56	25.90	25.42	25.77	26.90	26.21	26.79	26.46	27.00	24.55
75 - 90	18.65	18.67	18.95	18.77	18.80	18.68	18.85	18.87	19.12	25.12	24.93	25.31	26.29	26.34	26.52	26.48	26.89	25.54
90-105	19.29	19.21	19.47	19.57	19.55	20.95	19.53	19.44	19.55	23.17	24.46	24.15	26.12	26.41	26.57	26.66	27.20	26.19
105-120	21.06	20.96	20.87	20.87	21.08	20.99	20.98	20.87	21.14	23.73	23.99	24.16	25.80	26.99	27.78	27.50	28.44	27.12

KASHIM IBRAHI

Appendix xi. Profile moisture (% v/v) distribution for stylo fallowed plot planted with M_z/F_3.

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	11.61	9.23	20.58	21.90	20.75	24.34	17.50	20.27	23.79	15.78	25.07	22.80	24.88	22.00	23.02	21.95	23.30	6.95
15 - 30	17.67	17.11	20.19	19.67	21.74	23.16	20.53	21.23	23.01	22.59	22.31	23.32	24.94	22.76	24.14	23.29	24.83	22.21
30 - 45	19.92	19.75	20.88	22.16	23.19	24.11	23.45	23.63	24.49	25.16	24.41	25.29	26.31	25.34	26.05	25.37	26.33	23.93
45 - 60	20.23	20.03	20.77	21.05	21.69	22.88	23.74	23.99	24.32	26.37	25.41	25.77	27.04	26.00	26.73	26.03	27.07	25.31
60 - 75	20.70	20.17	20.36	20.24	20.53	21.00	22.73	23.10	23.74	26.26	26.12	26.11	27.07	26.59	26.85	26.48	27.32	26.51
75 - 90	20.61	20.25	20.28	20.11	20.30	20.18	20.76	21.09	22.16	25.92	25.60	25.64	26.48	26.48	26.95	26.63	27.19	27.47
90 - 105	20.39	20.22	20.13	20.15	20.15	20.39	20.24	20.40	20.50	24.40	24.45	24.32	25.12	25.86	26.57	26.38	27.18	27.46
105-120	20.90	20.76	20.71	20.75	20.81	20.86	20.76	20.79	20.76	23.63	23.90	23.91	24.06	24.82	26.14	26.55	27.57	27.91

Appendix xii: Profile moisture (% v/v) distribution for stylo fallowed plot planted with $M_z/S/P_o$

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	11.65	12.40	19.45	21.54	23.83	27.74	18.90	21.54	22.20	15.96	26.27	24.09	25.30	23.99	23.67	25.68	25.37	5.60
15 - 30	21.32	20.72	24.18	23.33	25.36	26.93	23.56	25.18	25.96	24.36	25.60	25.87	26.72	25.06	26.11	26.48	27.37	22.92
30 - 45	25.17	24.74	26.28	26.15	27.54	28.05	26.56	27.02	28.23	27.53	27.53	27.77	28.63	27.17	28.17	28.05	28.91	25.94
45 - 60	25.85	25.61	26.23	26.71	27.23	29.52	27.73	27.70	29.00	28.28	28.62	28.53	29.06	28.13	28.89	28.45	29.64	26.64
60 - 75	24.04	23.72	24.01	24.49	24.69	27.74	26.71	26.66	28.02	27.78	27.94	27.82	28.65	27.62	28.35	27.89	29.20	26.44
75 - 90	22.03	21.97	21.64	22.49	22.64	24.92	25.51	25.41	26.70	27.52	27.21	27.53	27.95	27.41	28.25	27.50	28.89	26.21
90 -105	21.58	21.38	21.40	21.63	21.85	23.32	23.50	23.52	24.29	27.54	27.31	27.62	27.77	27.68	28.07	27.67	28.98	26.96
105-120	21.62	21.42	21.32	21.23	21.21	23.46	23.07	22.84	23.10	27.88	27.95	28.35	28.62	28.30	28.78	28.53	29.94	27.77

Appendix xiii. Profile moisture (% v/v) distribution for stylo fallowed plot planted with $M_2/S/F_1$

Depth(cm)	18/6	1/7	8/7	13/7	15/7	29/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	6/10
0 - 15	13.59	13.73	21.58	22.17	23.46	28.35	20.28	23.34	24.34	16.05	23.73	24.86	25.73	24.97	23.59	24.51	26.32	8.52
15 - 30	19.82	20.45	24.07	22.68	24.53	27.66	22.66	23.76	25.26	23.13	24.74	25.01	26.15	23.78	25.05	25.35	26.57	17.93
30 - 45	23.61	23.68	26.00	25.10	26.28	28.50	25.05	25.45	26.70	25.12	25.92	26.16	26.66	24.83	26.28	25.56	27.26	21.30
45 - 60	25.25	25.64	26.94	26.88	27.58	29.47	26.94	26.98	28.49	27.09	27.36	27.90	28.38	27.14	28.07	27.18	28.86	23.85
60 - 75	23.75	24.32	25.92	26.43	26.69	29.13	26.92	27.32	28.18	27.33	27.36	28.15	28.33	27.34	27.96	26.96	28.80	24.95
75 - 90	22.59	22.58	22.83	25.04	25.53	29.05	27.26	27.33	28.14	27.99	27.70	28.21	28.55	27.75	27.86	28.01	28.88	26.20
90 -105	21.66	21.73	21.84	22.51	22.65	28.08	26.70	26.72	27.38	27.96	28.01	27.97	28.50	27.85	28.21	27.96	29.17	27.17
105-120	20.38	20.67	20.96	21.30	21.44	28.18	26.51	26.72	27.15	27.86	28.15	28.25	28.32	28.00	28.26	28.19	29.02	27.20

Appendix xiv: Profile moisture (% v/v) distribution for stylo fallowed plot planted with $M_2/S/F_2$.

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	12.71	8.94	20.94	21.80	22.67	23.79	20.89	22.35	25.12	18.49	24.44	24.87	24.79	23.50	23.75	24.55	24.87	5.64
15 - 30	19.16	19.20	23.11	22.53	24.13	25.78	22.30	23.84	25.23	23.64	24.56	25.30	26.27	24.16	25.66	25.68	26.53	22.24
30 - 45	22.48	22.86	24.90	25.36	26.61	27.66	25.96	26.57	28.06	27.05	27.16	27.92	28.67	27.12	28.20	27.83	28.62	25.53
45 - 60	23.00	23.24	24.14	24.70	25.33	27.35	26.76	27.20	27.93	27.68	27.94	28.33	28.76	27.84	28.61	28.34	28.91	26.03
60 - 75	22.39	22.50	22.83	23.47	23.49	25.83	26.06	26.57	27.41	27.90	28.06	27.93	28.48	27.88	28.60	28.36	29.18	26.55
75 - 90	21.62	21.75	21.88	22.54	22.75	24.71	24.47	24.70	26.65	27.85	28.10	28.06	28.26	28.02	28.37	28.62	29.00	27.41
90 - 105	20.31	20.57	20.54	21.36	21.44	24.57	23.80	24.20	25.03	27.91	28.00	28.51	28.37	28.17	28.56	28.51	29.32	28.14
105-120	19.76	20.03	20.33	20.37	20.33	25.38	25.27	24.92	20.21	28.73	28.24	29.43	29.05	28.93	29.55	29.59	30.25	28.75

Appendix xv: Profile moisture (% v/v) distribution for stylo fallowed plot planted with $M_2/S/_3$.

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	11.72	12.63	19.03	19.63	19.76	22.89	17.57	19.71	22.88	10.67	23.09	23.89	24.17	22.56	21.98	21.96	24.49	7.14
15 - 30	18.91	18.06	22.43	21.36	23.93	25.36	21.63	22.51	24.35	22.94	23.60	24.29	25.52	23.58	24.60	24.63	25.68	16.87
30 - 45	20.96	20.28	22.36	22.52	24.69	25.95	23.42	23.63	25.33	24.40	24.02	24.90	26.04	24.36	25.32	25.09	25.85	18.43
45 - 60	22.58	22.00	22.78	23.41	25.39	27.19	25.40	25.34	26.38	26.44	25.87	26.20	27.52	26.51	27.09	26.81	27.67	22.13
60 - 75	21.88	21.79	22.24	22.81	23.29	26.43	25.90	25.50	26.86	27.19	26.41	26.75	27.89	27.32	27.70	27.37	27.67	25.80
75 - 90	20.35	20.47	20.40	20.70	21.12	24.54	24.32	24.70	25.18	27.42	27.03	26.85	27.84	27.53	27.93	27.67	28.04	27.22
90 - 105	20.11	20.50	20.30	20.24	20.77	24.46	23.32	23.18	23.40	27.19	26.96	26.82	27.26	27.45	27.83	27.81	28.26	27.13
105- 120	20.22	20.31	20.38	20.23	21.68	23.91	22.85	22.83	22.74	25.82	25.81	25.88	26.19	26.52	27.58	27.52	28.35	27.58

Appendix xvi. Profile moisture (% v/v) distribution for stylo fallowed plot planted with sole stylo.

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	13.34	12.96	20.46	21.07	22.62	25.66	19.51	21.96	24.68	14.13	23.37	24.27	25.22	23.75	21.77	23.26	26.25	6.99
15 - 30	20.30	19.23	22.92	22.36	24.10	25.91	22.35	23.63	26.79	23.92	24.01	24.85	25.47	24.57	25.15	25.12	26.31	19.23
30 - 45	24.73	24.27	26.08	25.99	26.70	28.74	26.61	26.59	28.14	27.28	27.01	27.66	28.19	27.26	27.69	27.47	28.13	24.06
45 - 60	25.64	25.19	25.74	26.21	26.80	28.26	27.34	27.35	28.33	27.87	27.61	28.00	28.84	27.66	28.21	27.84	28.45	25.55
60 - 75	25.11	24.55	24.78	25.37	25.60	20.77	27.18	27.26	28.28	28.47	28.06	28.26	28.87	28.31	28.48	28.54	28.93	25.65
75 - 90	22.96	21.98	21.98	22.85	22.66	23.98	25.85	26.04	26.62	27.72	27.13	27.39	28.07	27.75	27.82	27.48	27.83	26.02
90 - 105	20.38	20.34	20.20	20.14	20.11	20.45	22.88	22.95	24.15	27.38	26.76	26.63	27.27	27.33	27.57	27.21	27.58	26.17
105-120	20.01	19.91	19.94	19.81	19.96	19.90	20.93	20.95	21.89	27.67	27.11	27.18	27.85	27.84	28.07	27.77	28.26	27.07

Appendix xvii. Profile moisture (% v/v) distribution for grass fallowed plot planted with M_z/G_o

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	9.13	10.24	19.41	20.46	19.33	23.61	17.48	22.58	24.17	14.93	23.08	24.14	24.90	23.49	22.95	23.81	24.36	5.16
15 - 30	19.35	18.57	21.03	21.03	21.68	25.32	22.63	22.66	24.77	23.77	23.73	24.48	25.66	24.19	24.71	24.30	25.28	19.09
30 - 45	22.86	22.59	22.98	23.72	23.68	26.66	25.58	25.29	26.84	26.59	26.50	26.94	27.74	26.92	27.03	26.71	27.41	23.13
45 - 60	23.87	23.89	23.75	24.01	23.91	25.51	25.61	25.53	26.76	28.39	28.11	28.32	28.99	28.48	28.55	28.34	28.45	26.78
60 - 75	23.22	23.32	23.15	23.31	23.31	23.97	23.80	23.82	24.13	28.51	28.16	28.23	29.15	28.91	28.81	28.74	28.77	27.80
75 - 90	22.78	22.55	22.53	22.56	22.61	23.26	22.93	22.83	23.12	27.05	27.00	27.03	27.99	28.04	28.09	28.10	28.01	27.35
90 - 105	22.34	22.04	22.01	22.05	22.13	22.68	22.31	22.31	22.30	24.69	24.96	24.78	25.91	26.42	26.39	26.43	26.45	26.27
105-120	23.04	22.99	22.77	22.84	22.80	23.77	23.21	23.16	23.03	25.18	25.92	25.19	25.89	26.67	26.91	27.29	27.73	27.95

Appendix xviii. Profile moisture (% v/v) distribution for grass fallowed plot planted with N_2/G_1.

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	19/9	23/9	8/10
0 - 15	11.25	9.01	17.80	20.47	21.07	23.47	17.55	20.05	22.99	12.38	21.42	22.57	25.06	22.82	23.05	22.85	23.77	5.25
15 - 30	19.85	19.38	22.53	21.75	23.56	25.05	22.31	23.19	24.16	23.15	23.29	24.04	25.14	22.97	24.05	23.85	25.67	18.51
30 - 45	22.93	22.57	24.59	24.07	25.21	26.44	24.81	24.96	25.99	25.74	25.58	25.71	26.43	25.38	25.89	25.40	26.51	21.97
45 -60	23.75	23.41	24.18	24.55	24.85	25.67	25.43	25.52	26.30	26.58	26.73	26.67	27.95	26.81	26.81	26.87	26.89	25.33
60 - 75	23.17	22.81	22.65	22.77	23.46	24.44	24.85	25.17	26.07	27.30	27.19	27.36	27.63	27.02	27.43	27.47	27.79	25.83
75 - 90	22.29	21.65	21.63	21.60	21.78	23.33	24.86	24.88	25.55	27.53	27.28	27.58	28.01	27.56	27.69	28.07	27.92	26.34
90 - 105	21.63	21.28	21.09	21.03	21.18	22.43	24.65	24.73	25.13	27.22	27.48	27.24	27.95	27.39	27.93	27.81	28.01	26.89
105- 120	21.04	21.12	20.81	20.68	20.91	21.82	24.34	24.41	24.99	27.40	27.22	27.38	27.92	27.73	27.81	27.91	28.41	26.80

Appendix xix: Profile moisture (% v/v) distribution for grass fallowed plot planted with M_z/C_2.

Depth(cm)	16/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
0 - 15	9.83	9.97	20.02	19.26	21.70	25.36	18.01	21.21	22.35	15.86	23.39	23.75	23.91	23.37	20.98	23.57	24.18	5.02
15 - 30	18.91	18.33	21.29	21.08	21.84	25.45	22.33	22.61	24.42	23.31	23.89	24.33	25.35	23.68	24.38	23.74	25.04	19.22
30 - 45	22.24	22.22	22.85	23.19	23.28	27.07	25.78	25.76	26.83	26.53	26.50	26.86	27.45	26.42	26.56	26.10	26.75	23.01
45 - 60	23.65	23.74	24.02	23.96	24.13	28.54	27.26	27.86	28.32	28.20	28.14	28.37	28.73	28.27	28.37	27.96	28.21	25.17
60 - 75	23.82	23.70	24.01	23.93	23.97	28.31	27.37	27.43	27.76	28.55	28.17	28.47	28.99	28.31	28.35	28.26	28.29	26.76
75 - 90	23.96	23.84	23.83	24.01	24.04	26.96	26.82	26.81	27.21	28.33	28.21	28.38	28.67	28.37	28.29	28.07	28.22	27.33
90 - 105	24.12	24.09	23.62	24.32	23.90	26.23	26.13	26.40	26.87	28.57	28.38	28.64	28.76	28.32	28.67	28.69	28.46	27.69
105 -120	24.24	24.26	24.22	24.39	24.20	26.46	26.25	26.38	26.97	29.32	28.96	29.12	29.30	29.09	29.15	29.05	28.98	28.34

Appendix xx: Profile moisture (% v/v) distribution for grass fallowed plot planted with M_2/G_3.

Depth(cm)	18/6	1/7	8/7	13/7	16/7	20/7	27/7	28/7	6/8	17/8	21/8	24/8	31/8	4/9	8/9	11/9	23/9	8/10
- 15	12.30	11.54	19.96	20.44	20.70	25.43	16.92	19.82	25.01	15.13	25.29	25.12	26.48	23.61	25.28	23.70	25.94	3.83
	21.14	21.00	24.57	23.35	25.05	27.23	23.83	24.41	25.87	24.56	26.00	25.71	26.75	24.13	25.52	25.50	26.75	19.72
30 - 45	24.55	24.26	26.22	26.04	26.65	28.58	26.53	26.33	27.62	27.05	27.28	27.31	27.90	26.70	27.28	27.12	28.18	24.21
45 - 60	24.14	24.16	25.17	25.74	26.02	29.13	27.28	27.25	28.39	27.93	28.16	28.33	28.75	27.92	28.27	27.78	28.64	25.79
60 - 75	23.61	23.54	23.03	24.45	24.67	28.29	27.28	27.35	28.18	27.65	27.84	28.17	28.27	27.76	27.95	27.64	28.32	26.42
75 - 90	23.00	22.95	23.25	23.76	23.82	28.30	27.70	27.50	28.61	28.30	28.48	28.76	28.66	28.50	28.51	28.31	29.05	27.39
90 - 105	23.16	23.21	23.20	23.40	23.37	27.54	27.68	27.38	28.49	28.52	28.36	28.77	29.23	28.43	28.56	28.42	28.98	27.54
105 -120	24.04	23.94	24.17	24.26	24.03	27.73	27.65	27.67	28.14	28.87	28.98	29.16	29.55	28.96	29.10	28.75	29.32	28.07

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