SOIL WATER BALANCE AND DEVELOPMENT OF MAIZE UNDER THREE DIFFERENT TILLAGE PRACTICES

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CERTIFICATION

This is to certify that this thesis has been read and approved as meeting the requirements of the Department of Agricultural Engineering, Federal University of Technology Akure for the Award of Master of Engineering in Soil and Water Resources Engineering.

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DEDICATION

To the Lord Almighty whose words has been the source of inspiration from my childhood, and for his immeasurable blessings and protection.

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LIST OF SYMBOLS

SYMBOL	UNIT	NOMENCLATURE
FUTA		Federal University of Technology, Akure
trt		Treatment
DAP	day	Days after planting
WAP	week	Week after planting
WUE	Kg/ha-cm	Water use efficiency
ΔW	mm	Change in soil water content
W_{in}	mm	Amount of water added
W_{out}	mm	Amount of water withdrawn
E	mm/day	Evaporation
E_o	mm/day	Potential evapotranspiration
ET	Kg/ha/mm	Evapotranspiration
PET	mm/day	Potential evapotranspiration
AET	mm/day	Actual evapotranspiration
MET	mm/day	Maximum evapotranspiration
RET	mm/day	Reference evapotranspiration
Δ_s	J/mm	Soil water potential
Δ_L	J/mm	Leaf water potential
R_{sL}	s/m	Resistance between the soil and the leaf
P	mm	Precipitation
R_o	mm	runoff

S_i	mm	initial amount of stored water
S_f	mm	Final amount of stored water
D	mm	Deep percolation or capillary rise
S	mm	Change in soil water storage
B		Bowen ratio
T_s	°C	Temperature of evaporating surface
e_s	mm/Hg	Vapour pressure at evaporating surface
e_a	mm/Hg	Vapour pressure of the air
T_a	°C	Air temperature
R_n	MJ/m²/day	Net radiation
G	MJ/m²/ day	Soil heat flux
H	MJ/m²/day	Sensible heat flux
LE	MJ/m²/day	Latent heat flux
LAI		Leaf Area Index
DM	g	Dry matter determination
L	m	Length
W	m	Maximum width
HI	%	Harvest - Index

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ABSTRACT

Soil water is a major limiting factor to the production of maize particularly under rainfed condition. Field experiments were conducted in the early and late season periods at the experimental farm of the Department of Agricultural Engineering, F.U.T. Akure. The aim was to quantify water use pattern, water balance and yield of maize (*Zea mays, L)* under three tillage methods. The tillage treatments are heaping (as practiced by traditional farmers), tied-ridging and untilled flat. The untilled flat and tied-ridge improved crop performance by increasing agronomic characters such as plant height leaf area biomass and maize grain yield.

The relative water use (ET/Eo) reflected the influence of precipitation and hence soils moisture availability on crop water use.

It is concluded that crop water use (ET) differed among the tillage treatments with decreasing order in untilled flat, tied-ridging and heaping.

The result obtained in this study would be useful in water stress studies, which can be used for scheduling irrigation and yield prediction.

CHAPTER ONE

INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

Maize is one of the main cereal staples in West Africa. David & Adams, (1988) stated that maize is one of the world's three most important cereal crops, others are rice and wheat. It is mainly grown in the tropical zone under rainfed agriculture. The fresh maize averagely contains about 10% protein, 67% carbohydrate, 5% lipids and 18% water. Maize has the same calorific value as wheat or rice but has lower level of essential amino acids, lysine and tryptophane. It also has lower level of niacin but it is higher in thiamines.

Maize is cultivated both in the southern and northern parts of Nigeria. It is used for both animal and human consumption. It is also widely utilized as the main constituent of several livestock feeds, serving as fattening food per excellence, high in energy, low in fibres and therefore highly digestible (Aladesanwa and Ademiluyi, 1996). The crop is also used industrially for starch and oil because of its ease of cultivation. When compared with other crops, it is very useful for a wide range of applications and possesses good storage characteristics.

Despite the increasing demand for maize in Nigeria; its production is grossly inadequate due to low grain yield of about 1.00 ton per hectare compared to the world average of 3.00 tons per hectare (Fajemisin, 1986).

Many factors are responsible for this poor grain yield. Yield decreases in maize have been attributed to weather factors, notably, potential evaporation and relative humidity (Fakorede and Opeke, 1985). Some (1989) and Nicou *et al* (1990) found out that most part of the zone where maize is grown under rainfed agriculture, is characterised by low and erratic precipitation that is partly responsible for poor yield. A rainfall of 600-1200 mm is needed by maize and this should be well distributed throughout the growing season for optimum yield. Good soil moisture is particularly important when the seed is setting and a dry period at this time will encourage disease, which will lead to a reduction in yield. This is because maize is very sensitive to drought.

Methods of seedbed preparation are an important factor responsible for poor yield. It is a general practice in traditional farming systems to make mounds or ridges before planting in both upland and lowland areas. Research results elsewhere have shown that the tillage type could alter the physical, chemical and thermal properties of soils through their effects on soil temperature, soil water infiltration and retention, and nutrient status (Lal; 1976; Black, 1970; Ojeniyi and Adekayode 1999). Under rainfed agricultural system, the extent of these alterations and the effects on crop yield would depend on the type of the tillage methods applied (Gumbs and summers 1985; Olufayo *et al* 1994; Ojeniyi *et al*, 1999).

In order for grain supplies to be any way near sustaining the livestock industry while still meeting the demand for its direct consumption as food, the yield per hectare needs to be improved. Such improvement could be achieved in part through efficient soil and water management.

1.1.1 State Of Art of Irrigation Scheduling in Nigeria

Irrigated agriculture plays a significant role in many parts of the world especially in the arid and semi-arid regions. In Nigeria for example, there has been upsurge of River Basins and Agricultural Development Projects within the last two decades particularly in the northern part of this country. The policy maker argues that irrigation is most relevant to the North because evapotranspiration exceed precipitation during the major part of the year. However, in recent times, many state governments in the southern part of the country have embarked on irrigation schemes especially during off-season.

Irrigation scheduling can simply be referred to as a decision making process of when to irrigate and the amount of water to apply. It is important to a successful irrigation management strategy since the cost of energy required to distribute water is high and hence this scarce resource must be judiciously utilised. It has been noted that most of our irrigation schemes lack adequate monitoring systems and it is therefore difficult to determine their viability and profitability (Olufayo, 1988).

Farmers in general are reluctant to deviate from the traditionally accepted methods of timing irrigations. Their methods are essentially based among other things on:

(I) irrigation by the calendar with disregard to variations weather;

(ii) fixed rotation schedules;

(iii) irrigation when the neighbour does it,

(iv) feel and soil appearances, which is quick and cheap way of estimating the amount of moisture for the purpose of irrigation.

These approaches are not based on the actual plant water status, which require a more scientific method for its determination. The state of art in irrigation scheduling in Nigeria is therefore rudimentary and lead to poor water management. The indiscriminate application of water with respect to both timing and amount, can lead to water logging which is unhealthy for plants since plants require adequate oxygen for respiration (Inuyama et al, 1976). On the other hand, insufficiency of water to plants will lead to reduction of plant metabolism, growth and development. The overall adverse effect of poor irrigation water management strategy is that it reduces the size of the fruit, quality and increase various fruit abnormalities. If irrigation must be practiced, there is therefore the need for scientific approach to schedule irrigation in order to have a better management of the water supply for the entire farm.

1.1.2 TILLAGE PRACTICES

In recent years a number of studies has shown an increasing trend toward adopting proper tillage practice as a way of improving crop yield. The major purposes for tillage are to prepare an adequate seedbed and to control weeds. To these are added several purposes such as improving aeration, increasing water infiltration, to make furrow for irrigation, and to bury crop residues. The importance of the various reasons for tillage varies with geographic location, soil differences, crop grown, and the climate.

In traditional farming system, extensive preplanting cultivation are not done except for root and tuber crops such as cassava and yam. Most planting is on the flat land. Where heaps, ridges, beds or mounds are required, they are constructed with hoe or other cultivating hand tools. These practices offer minimal disturbance to the fragile soil. When yam, cassava or sweet potato are harvested from the mounds, hollow spaces are left behind. These hollow spaces are first filled with water during the first few rains, thereby preventing run-off and reducing erosion. Furthermore, the crop residue from the yam vines and the left over stakes are left carelessly in the field. This practice also reduces the speed of run-off water. The various tillage systems practiced under the traditional farming system are a form of reduced tillage system where crop residue is left on the soil surface to minimise water run-off and soil erosion. Lal 1984) found out that zero tillage which involves planting crops in untilled soil create a favorable soil temperature regime and improve soil structure and can control run off and erosion on slopes up to 15%. With this system, it is often unnecessary to use other erosion control measures as long as there is adequate amount of crop residue mulch.

Another major tillage objective is to increase the amount of effective annual rainfall (Smith, *et al* 1972). Tied-ridging is envisaged to fulfil this requirement by harvesting rainwater (Hulugalle and Lal 1986). Yet, research elsewhere provides conflicting evidence about the performance of conventional tied-ridging on different soil types (Dagg and Macartney, 1968;). Research also suggests that compacted subsoil and/or poor topsoil water holding capacity, both typical features of sandy soils, make some primary cultivation necessary in order to create a sufficiently deep root proliferation zone and thus increase water availability (Wilcocks, *et al* 1993, Ojeniyi, 1986).

1.1.3 SOIL WATER BALANCE

The water balance is simply a statement of the law of conservation of matter, i.e matter can neither be created nor destroyed but can only change from one state or location to another. The water content of a given soil volume cannot increase without addition from the outside, nor it can diminish unless transported to the atmosphere by evaporation or to deeper zones by drainage (Hillel, 1971).

Soil water balane equation is expressed as

$$P= S + R + D + ET \qquad (1)$$

Where P is precipitation, S is change in soil water storage R is run-off, D represent net flux of water out of the soil and upward flow into the soil, ET is evapotranspiration. (Hillel, 1980)

In its simplest form, the water balance equation states that, changes in volumetric water content of soil over a period of time are equal to the difference between the amount of water added W_{in} and the amount of water withdrawn W_{out} during the same period:

$$\Delta W = W_{in} - W_{out} \qquad (2)$$

ΔW will be positive if gain exceeds losses, and conversely, ΔW will be negative when losses exceed gains. The term of the water balance is normally expressed in units of volume per unit area, e.g. mm.

For a given soil volume, gains and losses of water can be itemized as follows. The amount of water added W_{in} may be precipitation, P or irrigation I, or both:

$$W_{in} = p + I_r \qquad (3)$$

and the losses of water W_{out} may be due to the processes of run off R_O, drainage D and Soil evaporation, E and crop transpiration, T:

$$W_{out} = R_O + D + E + T \qquad (4)$$

In the above equaiton R_O is normally a loss of water, but it may also be a gain if water enters the field from an adjacent one. Drainage D refers to the water draining out of the root zone and may also be positive depending on whether the flow is upward or downward.

The integral form of the water balance equation is given by:

$$\Delta W = P + I_r - R_O - D - (E+T) \qquad (5)$$

With the various components summed over a time period. This equation can also be written in differential form, by expressing the time-rates of the simultaneous fluxes. In case, integral or differential form, the equation must obey the mass-conservation law.

Soil water balance approach is one of the several ways of estimating actual evapotranspiration. It involves periodic determination of root zone soil moisture and recording intervening rainfall, irrigation, or drainage. Soil tanks in which crops are grown, known as lysimeters, have been used to facilitate accurate water accounting. Weighing - type lysimeters, operated in a representative field environment, provide the most accurate ET information. In the Western areas of the US, the water balance method has also involved stream inflow - outflow measurements. Average ET for the land areas involved is equal to inflow, including ground water, surface water and rainfall, minus outflow after taking into account changes in moisture storage.

1.2 JUSTIFICATION

Studies of soil water balance are important to develop appropriate package of agronomic practices. Its use to engineers, farmers, irrigation planners, and soil and water researchers cannot be over-emphasized hence the need for appropriate information on the water use patterns and water use efficiencies of each crop.

Much work has been carried out on maize but not enough work has been done on the water use pattern and water use efficiency of maize as a sole crop under three different tillage systems. A study of this nature is necessary for maize in order to increase production. The need to increase maize production in the country has become inevitable as the demand for maize has more than doubled in recent years.

Effective soil water balance is a critical factor in increasing crop yield. It is necessary to develop package for effective soil water balance along with appropriate tillage practice for maize if yields are to be increased or maintained. Since much work is still needed to be carried out in this area, this research work will contribute to enhancing increased production.

1.3 OBJECTIVE OF THE STUDY

The main objectives of the study are:

(i) To compare the growth and development of maize under three different tillage practices,

(ii) To quantify the water use efficiency (WUE) of maize by monitoring the soil water content throughout the growing season.

CHAPTER TWO

2.0 LITERATURE REVIEW

Most parts of the tropical zone of Africa are characterised by low and erratic precipitation. High rate of evaporation in this zone makes it necessary for frequent upgrading of soil moisture for optimum plant growth. Water comprises more than 80% of the living and growing cells of most plants. Hillel, *et al* (1971) summarised the role of water: "life in plants takes place in an aqueous medium". Growth, especially of leaves, begins to decline before transpiration with decreasing soil water and increasing water stress (Hsiao and Acevedo, 1974). Under rainfed agriculture, the total amount and distribution of available water to crops, as well as the length of the growing season, constitute important climatic factors influencing yields. Extensive studies in the general pattern of water availability (including length of the growing season) have been reported (Kowal and Knabe 1972). Detailed water use and micro-climatic studies have also been reported for maize, sorghum, cowpea, cotton, rice and groundnuts (Kassam *et al*, 1975; Kowal and Andrews, 1973; Kowal and Kassam, 1973).

Higher water use efficiencies have been reported for maize/soya bean and maize/mung bean (De and Singh 1981). They revealed that intercrop productivity is increased due to phase differences in periods of peak demand for natural resources by the component crops. In another work carried out in Ghana by Haizel (1974), it was observed that period of peak demand for nutrients and light occurred 56 days after seeding for maize and from 56-120 days after seeding for cowpea in maize/cowpea inter crop. Ghosh et al (1975) reported that the highest wheat grain yield and water use efficiency can be obtained by maintaining -0.25 bar soil moisture potential in the root zone. Yield may decrease with decreasing soil moisture potential (below -0.25 bar). Increase in productivity cannot, however be attributed solely to better utilization of N and radiation, hypothesis has also centered on increase in water use efficiency (Haizel, 1974, Steiner, 1982).

2.1 SOIL AND WATER RELATION

The water need of plant is met through the phenomena: the capillary movement of the soil water to plant roots and the growth of the root into moist soil; although only a small portion of the soil water is adjacent to the absorptive plant root surfaces (Forbes and Watson, 1992).

Capillary movement of soil water

Evaporation from soil and plant surfaces is the driving force of water movement in the soil-plant-atmosphere continuum. Water is transported from the soil via the root to the plant tissue and finally evaporated to the atmosphere. When plant rootlets absorb water they reduce the moisture content, thus reducing the potential in the soil in the immediate surrounding of the plant. In response to this low potential, water tends to move towards the plant roots. The conductivity of the soil pores and the magnitude of the potential determine the rate of water movement. This rate is high and the flow appreciable in some sandy soils but in fine textured or poorly granulated clays, the movement will be sluggish and only meager amount of water will be delivered (Barden *et al*, 1987). Assuming a steady rate of flow, the water movement according to Jackson et al, (1977) can be represented by the following equation based on electric analogue:

$$E = \frac{\Delta_s - \Delta_l}{R} \quad (6)$$

Where: E = evaporation

Δ_s = soil water potential

Δ_l = leaf water potential

R = resistance between the soil and the leaf.

To satisfy the evaporative demand, the soil should be sufficiently wet, although not water logged from the surface downward. There should be a continuous air filled pore space, that is, the root zone should be sufficiently aerated.

The energy available for evaporation can be derived from the general form of the steady state of energy balance equation, which can be written as

$$Rn = G + H + LE + J + M \quad (7)$$

where Rn is net radiation flux, G is soil heat flux, H is sensible heat flux, LE is latent heat flux as L is heat of vaporisation and E is evaporation, J is the energy stored or retained by the surface, M is the net storage of energy during photosynthesis.

The ability of plant to absorb water is determined to a considerable extent by the distribution of roots within the soil profile. On a day to day basis, the total distance that water flows by capillary may not be more than a few centimeters. However, if the root have penetrated much of the soil volume, soil water movement over great distance may not be necessary. Soil water movement is of special significance during periods of low moisture content when plant root extension is minimised. Plant roots grow into pores of sufficient sizes to accommodate them so that contact between the outer cell of the root and the soil permit ready movement of water from the soil into the plant in response to differences in energy levels. When plant is under moisture stress the roots tend to shrink in size in response to this stress. The diameter of roots under these conditions may shrink by 30-50%. The shrinkage reduces considerably the direct root soil contact as well as the movement of liquid water and nutrients into the plant. Although water vapour can still be absorbed by plant, its rate of absorption is too low to do more than keep the most drought tolerant plant alive (Hsiao, 1982).

Rapid rate of root extension may complement the capillary movement of water in the soil because it assures a new root-soil contact.

This may be rapid enough to take care of most of the water needs of a plant growing in a soil at optimum moisture. The primary limitation of root extension is the small proportion of the soil with which roots are in contact at any time. This suggest that most of the water must move from the soil to the root even though the distance of movement may not be more than a few millimeters. It is also suggested that root extension is complimentary to capillarity as means of providing soil water for plant (Jordan, 1983).

2.2. BASIC CONCEPTS OF EVAPOTRANSPIRATION

Evapotranspiration {ET} is the combined process of evaporation and transpiration. Evaporation is the term used to describe water loss from water and bare-ground surfaces. It is a process by which moisture is converted into water vapour and removed and transported upward into the atmosphere. On vegetated surface where transpiration is an important component of water loss, the term "evapotranspiration" is used. Evaportranspiration is a complete process involving several sequential distinct processes enumerated by Ayoade, (1988).

If moisture is always available in sufficient quantities at the evaporating surface, evaporation will occur at the maximum rate possible. This is the basis for the concept of potential evapotranspiration outlined by Thornthwaite (1944). According to him, potential evapotranspiration (PET) is "the water loss which will occur at no time there is a deficiency of water in the soil for the use of the vegetation". Penman (1948) later defined PET as the ET rate of a "short green crop, completely shading the ground of uniform height and never short of water". This was modified by Doorenbos and Pruitt (1977) by specifying the size range of the short grass as 8 - 15cm tall.. Considering these various existing definitions, one can simply define PET as the total amount of water, which could be transferred from an area to the atmosphere under the existing meteorological condition.

The PET of crops differs since individual crops have different aerodynamic properties and growth characteristics, and hence, the ET should be calculated based on a particular reference crop. Doorenbos and Pruit (1977) used grass and defined the reference ET as "the rate of evapotranspiration from an extended surface of 8-15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water". Jensen (1973) and Hsiao (1982) also proposed alfalfa that is well watered and has 30-50 cm of top growth as the reference crop. Reference ET is essentially, equivalent to PET, with the exception that the leaf surface area typically not wet and a reference crop is specified. Inspite of the technical distinction, McKenney and Rosenberg (1993) viewed PET and reference ET as conceptually the same.

The fact that moisture is not always available sufficiently at the evaporating surface underlines the idea of actual evapotranspiration

(AET) - whose values are either equal to or below those of PET for any given environment.

AET is the amount of water given up to the atmosphere, which depends not only on the existing maximum ET condition, but alsoon the availability of water to meet the atmospheric demand and, the ability of the vegetation to extract moisture from the soil.

Maximum evapotranspiration (MET) is the highest value of AET and equal to AET of a crop under no water stress (Itier, 1996).

2.2.1 Estimation of Actual Evapotranspiration

Direct and indirect measurement of actual evapotranspiration are carried out in several ways (Itier, 1996) They include water balance approach and aerodynamics approach.

[a] Water balance approach

Evapotranspiration from vegetated surface can be estimated using the water balance equation as stated in chapter one and can be written as follows:.

$$ET = P - R - S - D \qquad (8)$$

where ET is evapotranspiration (mm), P is precipitation (mm), R_o is runoff and S = change in soil moisture storage in the root zone. D is deep percolation or capillary rise (mm). Difficulty in measuring seepage losses and the cumulative errors involved in the separate determination of the other terms of the equation limits the reliability of this method.

Lysimeter studies, for example, involve the growing of a crop in a large container and measuring water losses and gains. There are basically two types of lysimeters: weighing and non-weighing (drainage) lysimeters. The weighing lysimeter is an equipment consisting of a tank filled with soil and vegetation similar to that in the surrounding and supported by a weighing mechanism. ET values are obtained by calculating the changes in the weight of the soil-vegetation system within the week. Weighing lysimeters are often used to measure actual evaportranspiration and therefore not necessarily at field capacity, unlike the drainage lysimeter, which is used for measuring maximum evapotranspiration.

[b] **Energy balance and aerodynamic approach**

In view of the difficulties of measuring evaporation and evapotranspiration accurately on the field, attempt has been made to use indirect methods, which involve meteorological data.

Energy balance approach is based on the fact that evapotranspiration of water either directly at the soil level or transpired through plant stomata is associated with energy consumption through latent heat of vaporisation. This energy consumption corresponds to the latent heat flux over a surface covered with an active growing crop, it represents the major part of the use of available energy due to radiation balance. It is generally written as:

$$R_n - G = H + LE \qquad (9)$$

where

R_n net radiation G.' the soil heat flux H. sensible heat flux , and LE the latent heat flux. Bowen (1926), as cited by Jensen (1973), showed that the partitioning of the net radiation between sensible heat used for warming the air (H) and latent heat of evaporation (LE) is given

$$B = \frac{H}{LE} = 0.659 \frac{(K_h)}{(Ke)} \frac{(T_s + Ta)}{(e_s + e_a)} \qquad (10)$$

by

where

B is the bowen ratio, K_h and K_e are eddy diffusivities of heat and vapour, respectively.

T_s is the temperature or the evaporating surface, e_s is the vapour pressure at evaporating surface (M_b), T_a is air temperature (°C), e_a is the vapour pressure of the air (Mb), H and LE are as defined above.

By assuming that K_h = K_e , B can easily be solved from measurements of temperature and vapour pressure gradients. Thus the amount of evapotranspiration can be obtained using the equation of the form:

$$E = \frac{R_n + H}{1 + B} \qquad (11)$$

where E is evapotranspiration in mm of water.

Aerodynamic approach

If other factors remain constant, evaporation would be proportional to the wind speed and the vapour pressure deficit. This relationship provides the basic foundation of the several aerodynamic formulae for estimating values of evapotranspiration (Jensen, 1973, Itier, 1996).

2.3 Water Stress in Plants

Among the factors affecting water stress in plants are high rate of transpiration, impedance to water flow in parenchymatous and xylem cells, and root resistance. Others are soil temperature, soil matric forces and solute potential of soil solution that causes osmotic drought.

An increase in transpiration lowers the turgidity of the leaf cells, causing a fall in their water potential, which is made up by increased flow of water from the soil. At high rate of transpiration, however, this increased uptake is often inadequate to meet the increased demand, and even plant growth in well-watered soil tend to lose water faster than they can take it up. This is thought to account for the water stress that commonly appears about mid-day in many crops, causing temporary wilting.

Water in parenchymatous tissues or in the xylem does not move unimpeded. These resistances, retarding water flow, induces water stress in vigorously transpiring plants. The existence and environmental sensitivity of root resistance have profound implications. For example, at low soil temperature, the ability of plants to take up water is severely reduced. At 5°C the water uptake of many species may be only a fifth of the uptake at 25°C, even in moist soils, therefore the plant may be under water stress not because water is absent but because it is present but unavailable, this condition is known as physiological drought.

Despite the role of root resistance, water stress occurs most frequently in crops where neither soil temperature nor aeration are important contributory factors. The most frequent causes of water stress lies in the supply of moisture to the soil and in the nature of the forces tending to hold the moisture in the soil. Out of these forces the most important is the solute potential of the soil solution, which causes a condition called osmotic draught.

It is important to note that the widespread occurence of water stress in plants is due more to true drought, resulting from inadequate rainfall and the strong matric forces holding water in soils (Dyer *et al* 1984).

2.4 Managing Water Stress Through Tillage Practices

When plant water status falls below the optimum the yield is adversely affected. Owonubi, (1981) reported that irregular rainfall across semi-arid West Africa causes a decline in crop yield and makes agricultural planning difficult.

Drought is a major source of grain yield instability in maize in the lowland tropic. An estimated 80% of maize planted in the lowland tropical environments is reported to suffer periodic yield reductions ranging from 10-50% because of drought stress. These losses may increase in future if as projected, a large proportion of the crop is grown on drought - prone marginal lands (CIMMYT, 1981). Leave growth is a particularly sensitive indicator of when the plant water status falls below the optimum for growth. Photosynthetic processes stop when leaf water potential drops below -30 MP_a under severe stress (Johnson et al, 1974; Frank et al, 1973).

In the semi-arid West Africa, the zone is characterised by low and erratic precipitation. Aimed at finding the most efficient method of managing the erratic nature of rainfall, different tillage practices are often compared (Lal 1976, Adeoti and Olarenwaju, 1990). Groundwell (1966) showed, that in areas without an irrigation need, that the treatment of the soil in agriculture may significantly affect both the rate of entry of fresh supply of water into the soil and the capacity of the soil to store water. For instance, to conserve rainfall for annual crops in seasonal rainfall areas, agronomic measures such as tied-ridging is very important. Tied-ridging improves infiltration, prevent runoff and result in higher yield. The effect of ridging on yields may be influenced by the soil, topography, rainfall regime and distribution, crop grown and the date of planting. Groundwell (1966) noted that soil moisture in heavily trodden pastures fall and that grass growth becomes poor. Because the significant changes was in the soil surface structure, the water level in the soil could not be improved simply by increasing the water supply as this would lead to wastage. Instead, the condition of the soil would have to be improved.

Efficient tillage reduces runoff by conserving water in the soil due to its surface characteristics and porosity (Van Stavaren and Stoop, 1986; Nicou et al, 1990; Roose 1992) and would indirectly affect plant physiological behaviour. Olufayo et al (1993) in their study showed that physiological measurements such as canopy temperature and leaf water potential were useful indicators of water status in the case of grain sorghum planted under different tillage practices. In another development, Aina (1979) citing Baumer and Bakermans (1973) ascertained that apart from decrease in soil erosion, tillage improved available water, nutrient, and crop yield and saved labour.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

This study was conducted at the experimental farm of the Department of Agric. Engineering, Federal University of Technology Akure (FUTA) located in the lowland rainforest area of Nigeria. The annual rainfall ranges between 1000 - 1500mm. There are two growing seasons due to the bimodal character of rainfall distribution. The first starts from late March to late July ending in a dry spell of approximately two weeks and a shorter second season from late August to early November. The dry season lasts from November to March.

3.2 Maize Crop

The maize variety used was DMR-Y (Downy mildew resistance - yellow). - an early maturing variety resistant to downy mildew . It was sown manually at a spacing of 60 cm within row, and 75 cm between rows (*Ojeniyi and Adekayode*, 1999). Treatments were untilled flat, heap and tie ridging with maize seeds planted on top of heaps and ridges. Three seeds per hole were planted which were later thinned to two plants per stand two weeks after planting (Fig.1).

The first planting was done on 24th June 1998 while planting for the second trial was done on 27th August 1998 (late season period). The spacing of 60 x 75 cm at two plants per stand/hill, gave a plant population of 20833 stands per/ ha.

Fig. 1 : Photograph of maize growing in different plots on the field

3.3 Treatments and Experimental Design

Three tillage treatments were used in this study: untilled flat (UF), Heaping (HH) (as practiced by peasant farmers), and tied ridging (TR). The experimental design was randomised complete block (RCB) with three replications. Each plot measuring 6 x 4m containing five rows of maize. To minimize interference, there was a 2m wide guard strip of maize between blocks and plots. Weeds were controlled using manual weeding method starting from two weeks after planting and eight weeks after planting, i.e., two major weeding were carried out at each of the cropping seasons.

3.4 Measurements

Measurements taken can be grouped under three sub-titles:

(i) Meteorological variables

(ii) Soil measurements and

(iii) Plant/Agronomic measurements

3.4.1 Meteorological variables

The climatic data collected from FUTA meteorological station are presented in Table 3 while the corresponding instruments for the parameters are presented in Table1. The meteorological station is situated at Obakekere, which was close to the experimental site (Obanla). However, a rain gauge was also installed at the site for accurate records of rainfalls (Fig.2). The results of the rainfall monitored both at the meteorological station and experiment site are shown in Table .2

Fig. 2 : Rainguage mounted on the field during the experiment

Table 1 Climatic Parameter and their Instruments

S/No	Climatic Parameter	Instrument	Unit
1.	Air temperature	Thermometer	c
2.	Rainfall	Rainguage	mm
3.	Sunshine hour	Pyranometer	hr
4.	Wind speed	Anemometer	$m/_s$
5.	Relative humidity	Hygrometer	%

Table 2:Average monthly rainfall maintained at meteorological station Obanla and experimental site.

Months	**Met Station**	**Experiment Site**
June	9.11(mm)	10.57 (mm)
July	1.20	1.07
August	7.60	6.67
September	6.50	5.56
October	7.64	8.64
November	6.58	5.98

3.4.2 Soil Measurements

The soil measurements taken include:

[i] **Soil physical characteristics**

Soil physical characteristics i.e soil texture, field capacity and bulk density. Standard procedures were followed in their determination and the details of calculations are presented in the Appendix A

(ii) **Soil moisture Content**

Soil water content was measured, gravimetrically at weekly interval at depth 0, 20, 40, and 50 cm. A location was sampled in each plot at each time of measurement (Fig.3). Runoff could not be measured at the experimental site. It was however estimated from a previous work done by Hulugelle and Lal (1986) on similar topographical sequence as Akure (see detail in Appendix B).

3.4.3 Plant/Agronomic Measurements

The agronomic parameter measured include crop height, stem diameter, leaf area index, yield and yield components. In each plot, the 2nd and the 4th rows were used for the agronomic measurements. Sampling for crop height, stem diameter and leave number was carried out weekly on 10 plants from week one till tasseling and flowering stage.

Sampling for leaf area measurement was taken on 8 plants per treatment. The length (L) and maximum width (W) of each leaf blade in all plants sampled were measured. From these measurements. Leaf

Fig. 3 : Taking soil sample on a plot with a soil auger

surface area (cm^2) and leaf area index were estimated by the formula:

$$\text{Leaf surface Area} = 0.75\ LW \quad (12)$$

$$\text{Leaf Area Index (LAI)} = \frac{\text{Total Surface area of plant}}{\text{Soil surface area covered by the plant}} \quad (13)$$

Sampling for dry matter determination (DM) commenced 84 days after planting (DAP) corresponding to maturity stage (Fig.4). Three plants per treatments were used. The samples were partitioned into leaf, stem, tassel, root and ear (husks and cobs). These parts were bagged separately and oven-dried at 70-80°C until constant weight was obtained.

Grain yield was determined by harvesting maize from effective area within each plot. The ears harvested were weighed and shelled. The grain moisture content at harvest was determined by the oven method. Using the final weight of grain and total dry matter measurement, harvest - index (HI) was determined using the relation:

$$HI = \frac{\text{Grain weight at harvest}}{\text{Total dry matter yield}} \times \frac{100}{1} \quad (14)$$

Grain yield was converted to tones per hectare (t/ha) at 15% moisture content .

3.5 STATISTICAL ANALYSIS

Data were subjected to statistical analysis. Least significant difference (LSD o.o5) was used to determine the mean value of parameters produced by different tillage treatments.

Fig. 4 : Measurement being taking on a matured maize plant

CHAPTER FOUR

RESULT AND DISCUSSION

4.0 Prevailing weather during experiments

Table 3 Prevailing weather condition during the experiments

Climatic Parameter	June	July	August	Sept.	Oct.	Nov.
Average air temperature (°C)	25.3	27.6	23.7	24.5	24.1	26.3
Relative humidity (%)	81.1	84.9	94.0	84.0	82.4	76.7
Sunshine hours (hr)	3.6	4.4	5.4	6.7	7.3	7.8
Rainfall (mm)	291.1	182.3	392.3	476.0	292.7	27.7
Wind speed (m/s)	1.5	2.2	2.6	2.7	2.8	2.9

4.2 Water regime in the various treatments

The soil moisture content in the various treatments from zero to 80 DAP is presented in Tables 4 & 5. Figs 5&6 show the soil moisture content in the different treatments during the growing stages of the crop. It was observed that at the early stage of growth of maize, there was no significant difference in soil moisture contents between treatments.

Table 4. Effect of three different tillage treatment on soil moisture content %(early planting season)

Treatment	Soil Depth (cm)	DAP 0	13	28	36	42	49	56	63	70	77
UF	5	16.84	10.34	14.70	16.87	13.03	18.12	16.27	16.07	18.73	18.27
	20	13.82	12.92	15.39	15.61	13.86	15.21	18.54	14.25	17.44	13.50
	40	16.02	17.99	18.03	18.65	19.48	19.48	19.48	18.89	20.08	21.53
	50	17.91	19.98	21.73	22.17	20.10	21.34	22.30	22.58	22.99	23.40
HH	5	15.10	9.30	13.09	16.33	10.05	14.96	16.82	13.03	16.31	16.34
	20	13.15	15.39	14.33	14.31	12.33	15.50	15.45	13.93	12.78	11.70
	40	16.04	16.09	19.99	18.72	16.48	17.87	18.20	16.43	18.29	16.06
	50	16.28	18.19	18.19	18.88	21.44	17.67	19.08	21.60	19.01	18.00
TR	5	18.81	8.11	14.01	16.61	11.27	14.87	16.33	15.41	17.35	16.28
	20	15.60	15.05	17.39	18.13	17.49	18.09	16.24	14.22	18.10	13.33
	40	20.43	21.55	19.79	21.87	21.02	22.96	21.02	21.74	20.01	20.28
	50	20.20	22.17	21.79	22.13	21.69	19.20	22.93	22.63	24.49	22.76

Note: UF = Untilled flat; HH = heaped; TR = tied ridging; DAP = days after planting.

Table 5. Effect of three different tillage treatment on soil moisture content % (late growing season)

Treatment	Soil Depth cm	Days after planting 0	13	28	36	43	51	58	65	72	82
UF	5	16.24	8.24	10.57	18.10	7.81	13.16	13.16	10.42	13.48	13.07
	20	13.30	17.03	15.82	14.16	13.57	16.60	16.60	13.30	14.28	12.78
	40	18.30	20.25	20.93	19.40	19.55	20.36	20.36	18.92	21.38	19.58
	50	19.66	21.62	22.08	19.98	20.75	22.56	22.56	20.32	21.43	21.98
HH	5	14.83	6.57	12.56	13.69	9.96	14.57	12.59	13.45	15.80	16.54
	20	11.65	12.29	14.46	15.60	12.44	15.49	15.45	15.26	16.68	14.65
	40	15.82	18.35	16.47	17.88	16.01	18.09	17.14	16.14	20.39	15.55
	50	17.08	17.72	18.87	19.04	15.79	18.48	28.98	19.09	20.57	20.23
TR	5	15.33	6.14	11.85	11.56	9.06	10.96	13.46	10.89	12.53	13.88
	20	10.74	9.80	10.60	13.23	13.05	13.39	13.06	10.52	12.82	10.45
	40	18.22	15.15	13.52	17.69	17.82	18.30	17.51	16.72	26.61	15.26
	50	17.63	18.27	17.51	18.66	17.75	20.05	17.55	19.45	19.54	17.94

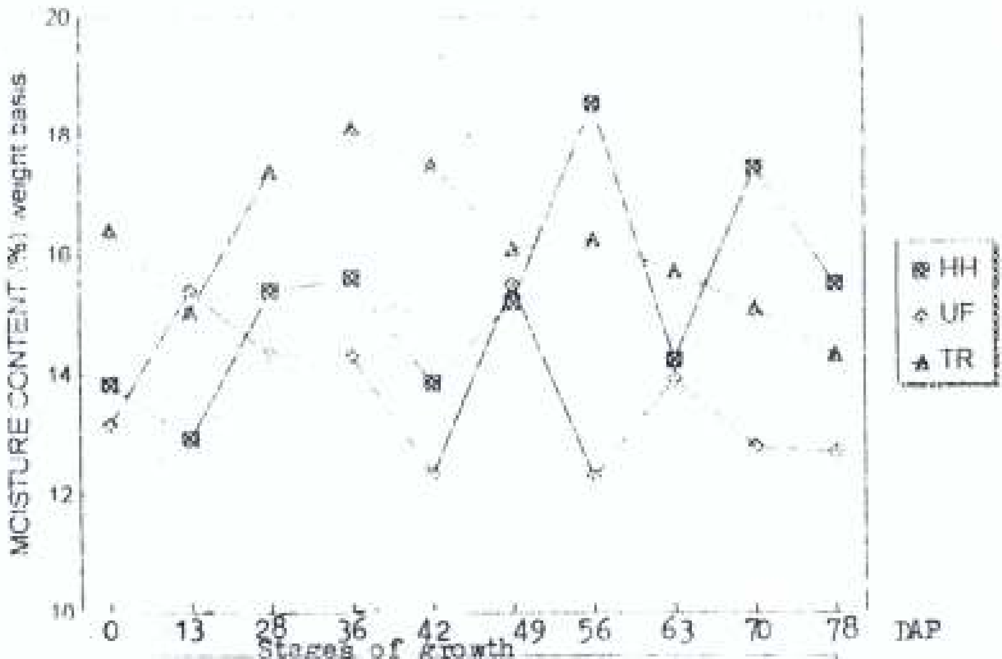

Fig 5 Soil moisture content changes at 20cm depth during the growth stages of crop (early growing season)

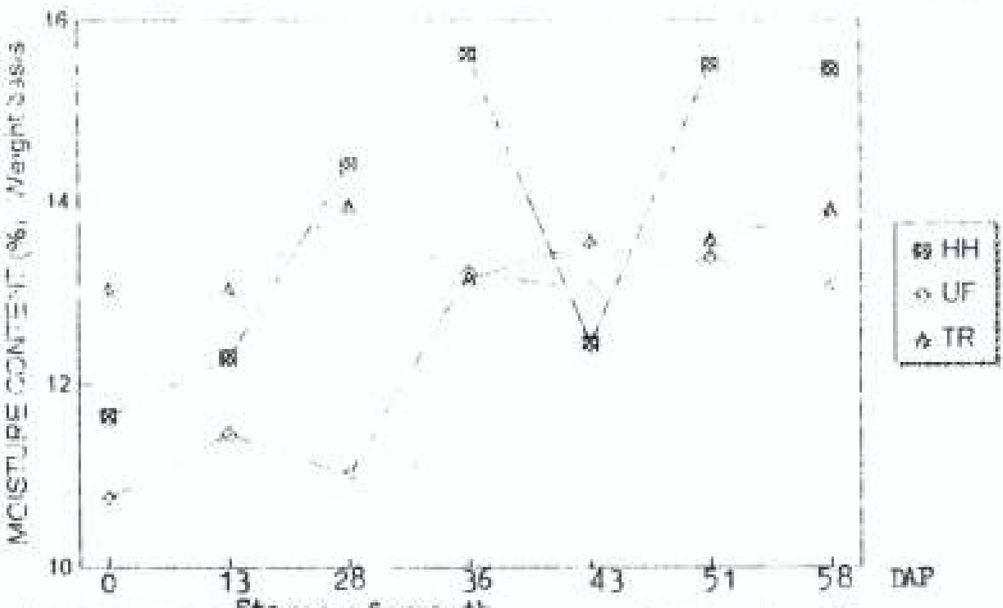

Fig. 6 Soil Moisture content changes at 20cm depth during the growth stages of crop (Late growing season)

However, from 30 to 65 DAP, there were significant differences in the soil moisture content in different tillage practices. At this stage of crop development, there is a high demand for soil moisture since maize, in particular, is known to have a high demand for water during the two weeks prior to and following tasseling (Waldren, 1983).

Throughout the growing season, the soil profiles in the untilled (UF) and tied-ridging plots (TR) were more humid than in the heap treatment. (HH). Untilled flat plots had higher moisture storage in the 0 - 15-cm depth compared to tie ridges and heaps Table 4. Moisture reserve, three weeks after planting in the first season was 22, 17 and 14% of the cumulative rainfall for untilled flat, tied ridges and heaps respectively. The result was the reverse in the second season with lower precipitation amount, than the first season. There was no significant difference in moisture reserve between tied-ridges and heaps.

Although measurement of infiltration capacity was not carried out in 1998, a previous study had shown that erosion, and hence soil loss was highly favoured in the heap treatment (HH) thereby reducing the infiltration capacity of the soil. Instability of apexes of heaps and ridges by stumping increased bulk density and infitration rate. This agrees with experimental results of Lawes (1961), Aina (1979) and that of Olufayo *et al* (1994). These authors noted that tied-ridging prevented runoff and increased soil.water content significantly up to a soil depth of 120cm. However, ponding was observed on the tied-ridging treatments during periods of frequent rainfall.

Table 6 shows the stages of development of maize crop, which comprises the vegetative, flowering and maturity stages.

Table 6. Stages of development of maize crop

Code	State of Development	Days	Week
0	Germination	0-4	1
1	Sprouting (Seedling growth)	4-11	2 .
2	Tillering	11-35	2-4
3	Stem elongation	35-42	5
4	Booting (Swelling of the flag leaf sheath)	43-50	6
5	Inflorescence emergency	51-57	7
6	Anthesis (flowering)	58-62	8
7	Milk development of the seed	63-70	9
8	Dough development	70-85	10,-11
9	Ripening of the seed	86-100	11-13

4.3 Soil Water Balance

The runoff component of the water balance equation (detail of the calculation are presented in the Appendix B1 for June - September and September - November 1998 for the three experimental treatments are presented in Tables 7 and 8. Table 9 is the seasonal sum of soil water balance for early and late planting seasons.

In Tables 7 and 8, runoff (R_o) and drainage (D) components did not differ significantly (at p =0.5 level) among treatments. Furthermore, when compared to precipitation (P), R and D values from the root zone were negligible. The ET values differed among treatments during the calendar period 1st - 14th October, when the crop depended on stored soil water for their water requirements during the period of absence of rains. The ET in untilled flat treatment was greater than those of heaped and tied-ridging by 27.8 and 36.5%, respectively. Prior to and subsequent to this period, evapotranspiration do not differ among treatments (Figures 7&8)

Relative water use, ET/Eo, the ratio of evapotranspiration calculated from water balance ET to potential evaporation or the evaporation from a free water surface (Eo) for the period 2nd September - 1st October was 1.86, 1.42 and 1.54 for UF, HH and TR respectively. Subsequent to 14th October the low availability of soil water resulted in little difference in ET among treatments. The ET/Eo values for 1st October - 12th November were 1.08, 1.08 and 1.07 for UF, HH, and TR respectively, indicating that all treatments were subjected to a high degree of water stress. The differences in ET observed for the different treatment during the period of 1st - 14th October may have been due to a combination of physical and physiological factors.

The patterns of R and D observed during early planting (Table 7 and 8) were similar to those of late planting. Mean seasonal R and D averaged among treatments were 1, 4 and 0.4% for UF, HH, and TR respectively of total precipitation. The ET value differed among treatments during the calendar period 7 - 21 July, and 27 July - 4th August. During 7 - 21 July, ET of UF exceeded that of HH by 15.8% and during 27 July - 4th August ET of UF exceed that of HH and TR by 21.7 and 18.9% respectively. The crops were therefore dependent to some extent on the stored soil water for their water requirements. During 24 June - 8 July and 8 July – 27 july this was of the order of 6.3, 13.2 and 17.4% of ET for HH, UF and TR respectively. During 27th July to 4th August, however, the contribution of the stored soil water to ET was greater; i.e. 25.3, 32.4, and 17.7% of ET were respectively coming from stored soil water for heap, untilled flat and tied ridging. The greater dependency of all treatments on stored soil water during 27th July - 4th August can be attributed primarily to the lower rainfall during the period.

During both seasons when precipitation greatly exceeded potential evaporation E_o (i.e., 3-17 September, 24 June - 7 July 1998 and 5 - 18th August, 1998), evapotranspiration was also found to exceed E_o. Such "Luxury" consumption of water has been reported by other workers (Taylor and Klepper, 1978).This may be mediated through changes in plant capacitance (Wenkert, 1983).

Total seasonal water use among treatments did not differ during early and late season planting (Table 9). This concurs with observations made by De and Singh (1981) for maize/soyabean and maize/mung bean intercrops.

Table 10 shows the summary of estimated ET from water balance at various stages of development of the maize crop. The water consumed in the untilled flat treatment is about twice that of the tied-ridge treatment. It can also be observed that significant proportion of total water was consumed in the vegetative period irrespective of the treatment.

Table 7. Soil water balance of maize during 1998 early growing Season

Calendar Period	Treatments	Days	P mm	E_o mm	S** mm	R mm	D* mm	ET
24th June - 7th July	HH	14	53.3	58.6	2.14	0.71	0.27	50.18
	UF				-0.93	0.78	0.07	53.38
	TR				0.60	0.65	-0.13	52.18
7th July - 21st July	HH	15	24.3	81.2	4.90	0.35	-0.04	19.09
	UF				1.60	0.30	-0.13	22.53
	TR				2.99	0.45	-0.22	11.08
22nd July - 4th August	HH	14	140.6	64.6	-8.43	4.82	0.10	144.11
	UF				-24.38	4.72	5.79	154.47
	TR				-18.38	5.31	2.03	151.64
5th August - 18th August	HH	14	67.8	75.6	8.26	2.55	0.00	56.99
	UF				8.67	2.13	0.14	78.74
	TR				8.40	3.08	0.07	56.25
18th August - 2 September	HH	16	32.9	73.6	1.49	0.50	0.02	30.89
	UF				2.74	0.50	0.02	36.16
	TR				1.34	0.33	0.02	31.18
3rd Sept. - 17th Sept.	HH	15	49.3	69.1	2.46	1.06	0.05	45.73
	UF				2.23	0.81	0.10	46.16
	TR				4.31	1.06	0.05	43.88

* A negative value for D indicates upward flow from below the root zone.
** A positive value for S indicates a gain in soil water storage.
P = Precipitation, Eo = Potential evaporation, S = Change in soil moisture storage
R = Runoff, D = deep percolation,ET = evapotranspiration.

Table 8. Soil Water balance of maize during 1998 late growing season

Calender Period	Treatments	Days	P mm	E_o mm	S mm	R mm	D mm	ET mm
17th Sept.- 30 Sept.								
	HH	14	80.4	110.4	3.56	2.98	0.07	73.97
	UF				3.56	2.14	0.07	74.63
	TR				4.38	2.02	0.07	73.93
1st - 14th Oct.	HH	14	133.6	168.3	-48.22	3.41	0.18	178.19
	UF				73.69	4.08	0.00	202.81
	TR				-49.5	3.92	-	178.78
15th - 28th Oct	HH	14	225.6	145.6	-17.05	1.06	-0.33	38.82
	UF				-23.12	1.0	0.49	44.13
	TR				-18.36	0.98	0.33	39.55
29th Oct - 12th Nov.	HH	15		175.8	-1.58	-	-0.16	1.74
	UF				-4.25	-	-016	4.41
	TR				-4.41	-	0.00	4.41

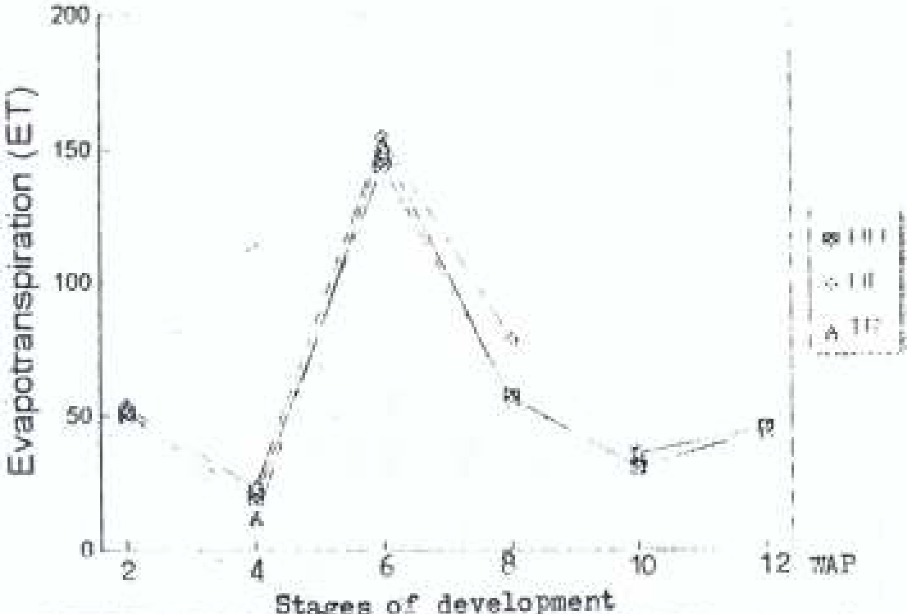

Fig.7 Relationship between the ET from water balance at various stages of development of the crop (early)

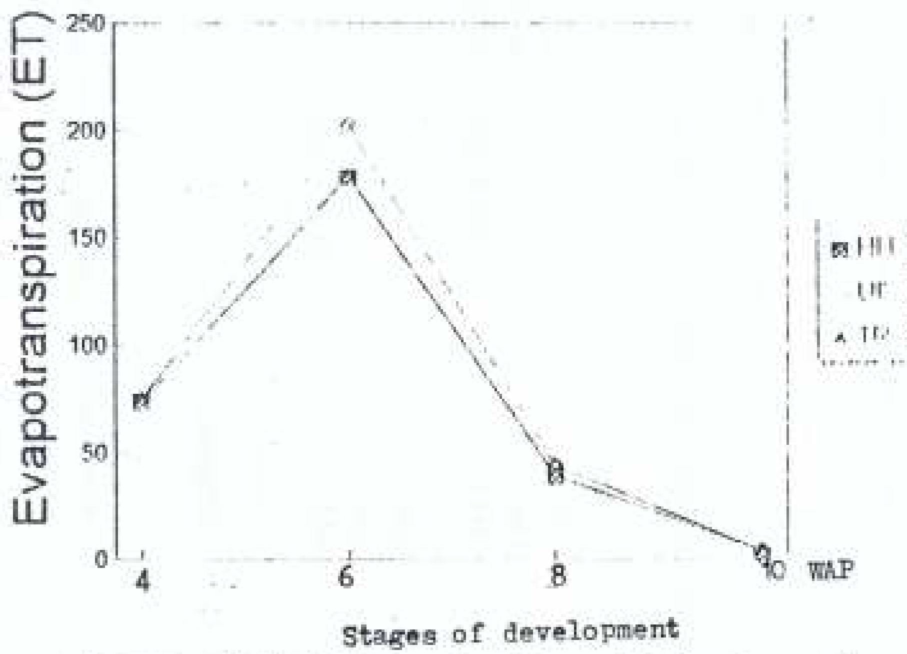

Fig.8 Relationship between the ET from water balance at various stages of development of the crop (late)

Table 9. Seasonal Sum of Soil water balance (mm) (early and late growing season)

Season	Treatments	P	E_o	S	R	D	ET
June - September (early)	HH	268.2	430.3	10.83	9.99	0.40	346.99
	UF			-10.07	9.24	6.99	391.44
	TR			-0.74	10.88	1.85	292.54
September - November (late)	HH	236.1	602.1	-63.29	7.45	-0.6	292.54
	UF			-97.50	7.22	0.4	325.98
	TR			-67.89	6.92	0.4	296.67

Table 10. Estimated evapotraspiration (ET) from water balance at various stages of.development (early growing season)

Stages of development	Evapotranspiration (mm)		
	HH	UF	TR
Vegetative 1-5 wks	69.3	73.9	63.3
Flowering 6- 9 wks	201.1	233.2	207.9
Maturity 10-13 wks	76.6	82.3	75.1

Table 11_ Estimated evapotraspiration (ET) from water balance at various stages of development (late growing season)

Stages of development	Evapotranspiration (mm)		
	HH	UF	TR
Vegetative 1-5 wks	252.0	277.4	252.7
Flowering 6- 9 wks	38.8	44.1	39.5
Maturity 10-13 wks	1.7	44.4	4.4

HH - Heap, UF - Untilled flat, TR - Tied-ridging, wks - Weeks

4.4 Agronomic Measurements

Leaf number and plant height

Table 12 and 13 present the result of the effect of the tillage treatments on plant height and leaf number during crop establishment, vegetative and reproductive stages of growth of the plant. It was observed that there was no significant difference in the number of leaves in the different tillage treatments.

Plant height

Figs 9 (a-b) show the plant height at t8th weeks as modified by the different tillage systems. Vegetative growth was more pronounced in the untilled flat treatment and least in the heaped treatment as shown by plant height (Table 12 & 13) Between untilled flat and tied - ridging tillage treatment, height difference at 40 DAP was not significant in the early and late season planting. Plants were significantly (P=0.05) taller under these two tillage treatments than in heaped technique in both seasons.

At seedling stage, plants in untilled flat plots were chlorotic and not as vigorous in growth as those in heaping and tied - ridge plots. More weeds emerged in untilled flat than in heaped and tied-ridged plots in both seasons. The higher weed emergence in the untilled flat plots suggests higher weed competition.

Table 12. Effect of three different tillage treatment on plant height and leaf number (early growing season)

Treatments		Weeks after Planing (WAP) 1	2	4	5	6	7	8	9
HH	LN	3.17	3.78	5.7	6.8	7.4	10.03	11.77	12,43
	PH(X)	12.22	39.38	82.49	104.44	138.09	175.30	204.46	213.90
UF	LN	3.16	3.67	5.73	5.8	6.80	9.13	11.80	10.37
	PH(X)	12.53	39.56	87.92	107.46	136.54	173.10	199.74	215.69
TR	LN	3.33	3.56	6.00	6.27	6.90	9.13	11.67	11.53
	PH(X)	12.52	39.46	84.19	107.22	136.36	169.15	197.89	216.25

Note: LN = Leaf number
PH(x) = Mean plant height (cm)
HH = Heaping
UF = Untilled flat
TR = Tied ridging

Table 13. Effect of three different tillage treatment on plant height and leaf number (late growing season)

Treatments		Weeks after Planing (WAP)							
		1	2	4	5	6	7	8	9
HH	LN	3.26	3.47	5.37	6.27	6.3	7.43	8.87	11.33
	PH(X)	10.16	30.95	64.92	82.91	103.40	127:22	145.65	145.63
UF	LN	3.00	3.50	5.33	5.7	6.73	8.73	11.83	10.16
	PH(X)	10.9	35.46	70.50	88.94	110.78	137.53	153.51	149.05
TR	LN	3.33	3.93	5.67	5.93	6.40	8.43	11.27	11.00
	PH(X)	12.28	34.78	70.08	84.8	107.71	133.21	157.60	171.11

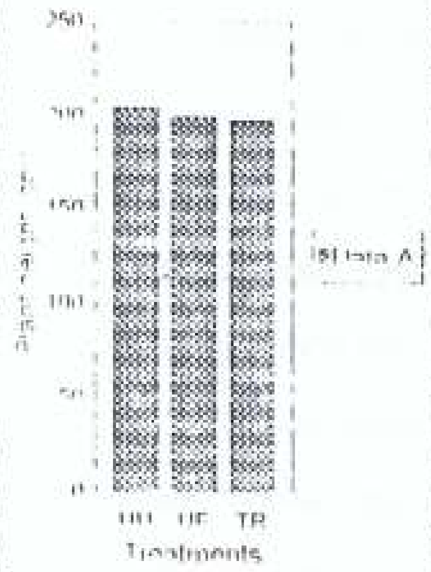

Fig 9 (a) Plant height at 8 wks (early growing season)

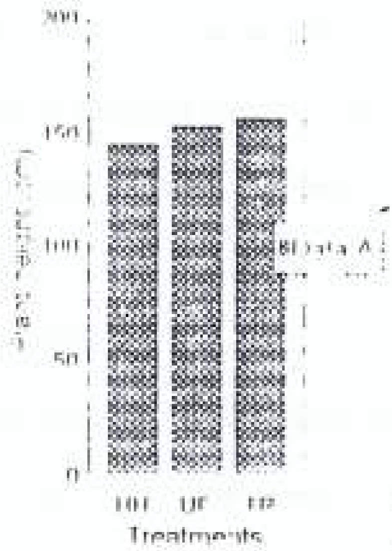

Fig 9 (b) Plant height at 8 wks (late growing season)

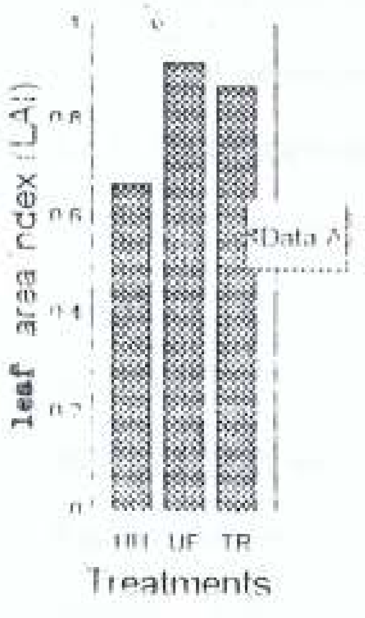

Fig 10 (a) Leaf area Index at six weeks (early growing season).

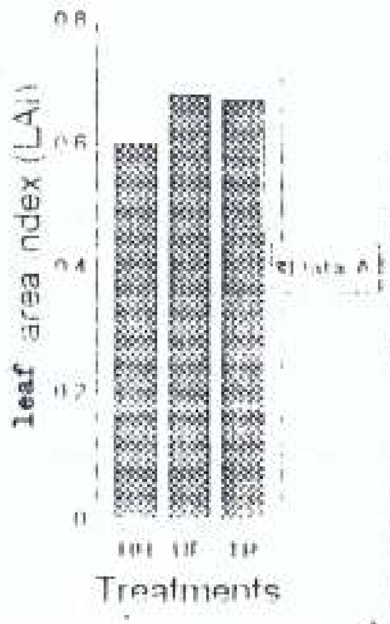

Fig 10 (b) Leaf area Index at six weeks (Late growing season).

Weed competition at this early growth stage could have significant adverse effects on seedling growth. This would explain in part the poor growth of maize seedlings in untilled flat plots if not timely checked. However, in this study, weeds were effectively checked early in the treatments.

Moisture stress also resulted in measurable differences in plant height. This is brought about by pressure placed in the soil moisture reserve due to plant growth. This pressure increases as the plant grows, resulting in different moisture stress in each of the treatments. Based on the level of soil water reserve, measurable differences in plant height will be expressed.

4.4.1 Leaf Area Index

The leaf area index was determined at 4th, 5th, 6th and 7th weeks. The values are presented in Tables 14 & 15. Fig 10(a) and (b) show the LAI in the different treatments taken at the 6th weeks during the early and late planting season. Untilled flat and tie-ridge treatments have greater vegetative growth (in that order) than heap treatment. It was observed that maize grown in untilled flat developed more leaves and produced more luxuriant growths when compared to other treatments. However, the variation within treatments was more pronounced in the reversed order i.e. heap followed by tied-ridging and untilled flat treatments. This observation agrees with those of other authors on crop water stress studies (Olufayo *et al*, (1993) and Kowal *et* al; (1943).

4.4.2 Biomass Yields

Tables 16 - 17show the shoot and root weights taken during the period for both early and late growing seasons.

The result of the biomass yield in all the treatments during the early and late planting season are presented in Tables 18 & 19. Table 20 & 21 shows the yield component of the crop, Figures 11 (a-d) express the biomass yield of maize under the different tillage treatments at both seasons. The untilled flat treatment gave the best result in terms of grain yield and its components. The plants benefited from accumulated water in the root zone. The same or even better results were expected from tied-ridging treatments but its yield was similar to the heaped treatments. This is as a result of ponding of free water at the soil surface allowed by tied ridging. The low yield in the heaped treatments is partly explained by relatively low numbers of racemes per panicle and low seed weight.

Table 14. Effect of three different tillage t treatments on leaf area and leaf area index (early growing season)

Treatment	4th Week Leaf Area	4th Week LAI	5th Week Leaf Area	5th Week LAI	6th Week Leaf Area	6th Week LAI	7th Week Leaf Area	7th Week LAI
HH	816.72	0.17	1778.31	0.37	3216.46	0.67	5424.17	1.13
UF	864.62	0.18	2498.52	0.52	4416.34	0.92	5472.75	1.16
TR	864.28	0.18	2304.93	0.48	4176.75	0.87	5472.75	1.14

Table 15. Effect of three different tillage t treatments on leaf area and leaf area index (late growing season)

Treatment	4th Week Leaf Area	4th Week LAI	5th Week Leaf Area	5th Week LAI	6th Week Leaf Area	6th Week LAI	7th Week Leaf Area	7th Week LAI
HH	720.48	0.15	1776.08	0.37	2880.30	0.60	2208.10	0.46
UF	912.83	0.19	2976.52	0.62	3264.72	0.68	4224.42	0.88
TR	816.09	0.17	2352.86	0.49	3216.24	0.67	4320.25	0.90

Note: LAI = Leaf area index

Table 16. Effect of different tillage treatments on maize shoot and root weights (early growing season)

Treatments	Fresh weights (g)		Dry weight (g)	
	Shoots	roots	Shoots	roots
HH	765.15	50.33	200.77	15.57
UF	780.85	56.86	208.67	20.11
TR	780.63	52.27	204.22	16.77

Table 17. Effect of different tillage treatments on maize shoot and root weights (late growing season)

Treatments	Fresh weights (g)		Dry weight (g)	
	Shoots	roots	Shoots	roots
HH	458.08	22.88	121.88	5.83
UF	576.40	32.66	161.90	10.70
TR	498.6	30.84	144.95	10.43

Table18 Effect of three different tillage treatments on the biomass yield (early growing season)

Treatments	Stem wt (g)		Leaves wt (g)		Root wt (g)		Tassel wt		Cob wt (g)		Biomass		Total Yield		WUE
	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	g/mm of H_2O
TR	250.03	47.0	201.83	46.57	55.67	15.57	8.57	4.03	314.73	109.33	775.16	206.93	830.83	222.5	0.57
UF	197.07	39.56	157.38	38.23	38.97	12.57	6.57	3.45	361.27	115.47	722.29	196.71	761.26	209.28	0.60
HH	194.33	24.7	154.93	36.70	46.83	15.2	8.47	3.93	188.32	97.5	546.05	172.83	592.88	188.03	0.54

Table 19. Effect of three different tillage treatments on the biomass yield (late growing season)

Treatments	Stem wt (g)		Leaves wt (g)		Root wt (g)		Tassle wt		Cob wt (g)		Biomass		Total Yield		WUE
	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	g/mm of H_2O
TR	155.03	32.93	152.7	29.6	36.0	11.47	8.2	3.17	260.06	83.67	584.99	149.37	620.99	160.84	0.54
UF	221.1	26.2	143.23	26.73	31.9	10.67	7.5	2.87	336.8	98.47	708.63	154.27	740.53	164.94	0.51
HH	165.7	24.0	139.5	24.9	30.23	7.23	7.8	3.3	264.4	80.87	577.4	134.07	607.63	141.3	0.48

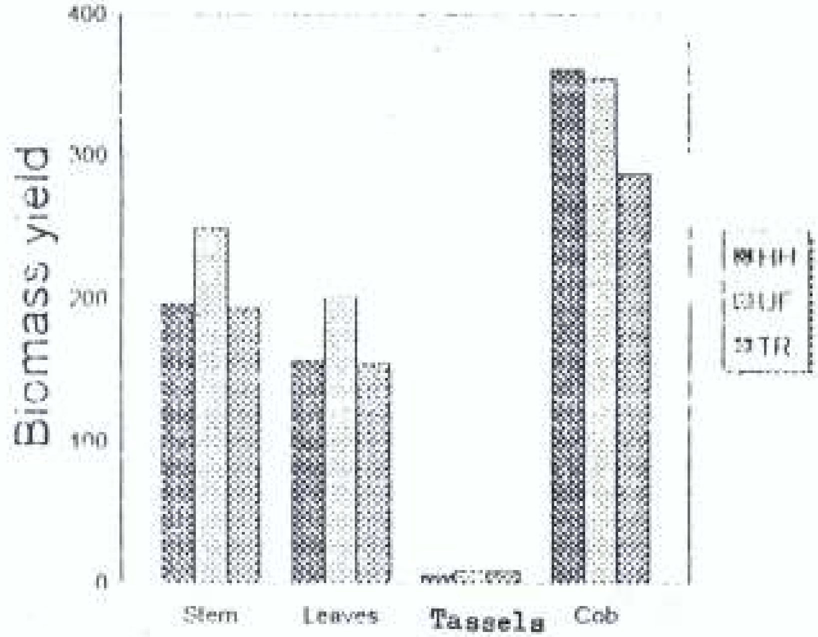

Fig 11 (a) Maize component yield under different tillage treatments (early growing season)

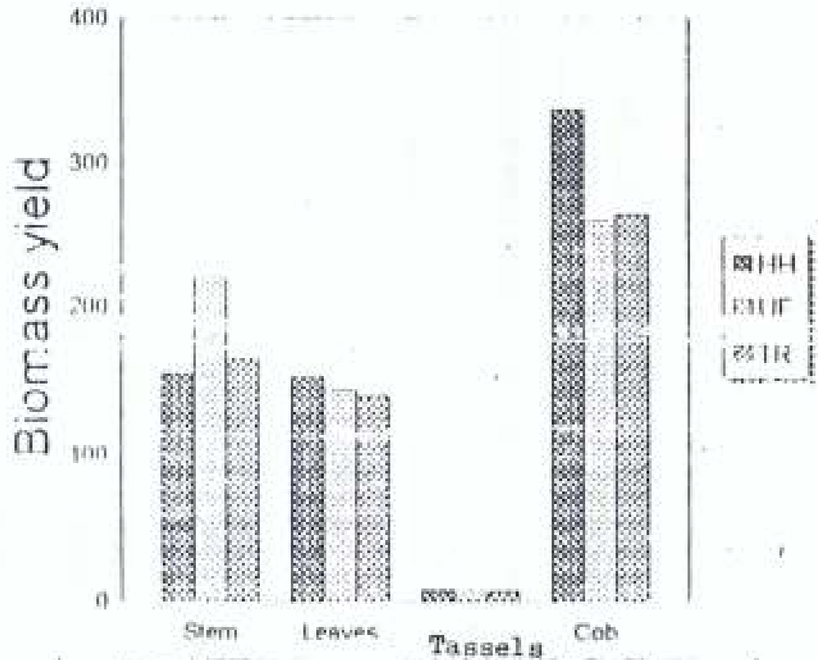

Fig 11 (b) Maize component yield under different tillage treatments (late growing season)

Table 20. Effect of different tillage on yield components [early growing season]

Treatment	Ear (fresh wt)	Husk (wt)	Cob (fresh wt)	Cob (dry wt)	Grain Yield (100 Seeds) (g)
HH	318.14	76.37	201.77	102.84	25.16
UF	480.49	270.33	260.17	135.78	26.77
TR	364.26	87.18	247.08	118.93	24.44

Table 21. Effect of different tillage on yield components (late growing season)

Treatment	Ear (fresh wt)	Husk (wt)	Cob (fresh wt)	Cob (dry wt)	Grain Yield (100 Seeds) (g)
HH	211.25	49.75	161.5	75.49	22.76
UF	272.44	80.47	191.99	107.52	23.91
TR	226.32	60.57	165.74	91.94	22.41

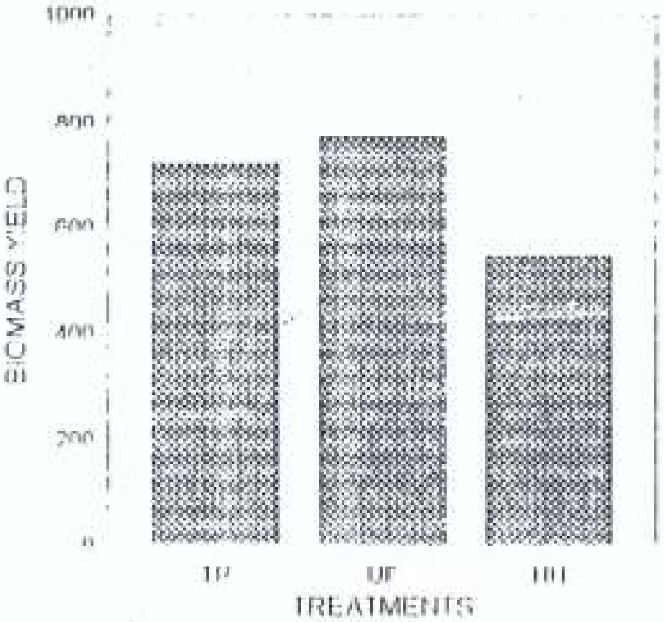

Fig 11 (c) Biomass yield of maize under different tillage treatments (early growing season)

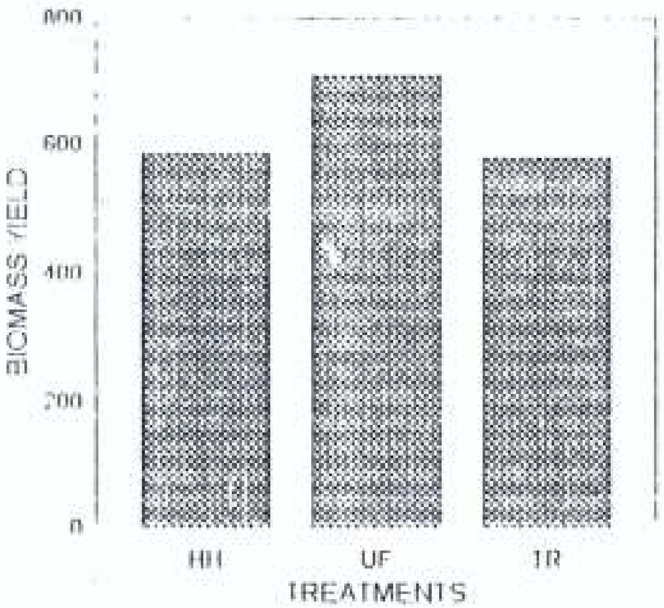

Fig 11 (d) Biomass yield of maize under different tillage treatments (late growing season)

The dry weight are in the order of 10% of the fresh weight of the biomass, indicating the plant contain over 80% of water. Considering the fresh weights, the stem weights were highest when compared to the weights of leaves and tassels. While in the dry weights, the leaves were about the same weights as in the stem, particularly in the heap and tied-ridging treatments. This shows that the ratio of dry matter to water is higher in leaves than in stem. From the tables (Tables 18 - 21) above it can be seen that UF has the greatest efficiency of water use in terms of dry matter per quantity of water use.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

This study evaluated the performance of maize under three different tillage practices - heaping, tied-ridging and untilled flat. The aim was to investigate the water balance, the growth, development and yield of the maize under the tillage treatments.

Soil water content was monitored to show the effects of the tillage treatments on soil water regime.

Tie-ridging produced highest value of soil moisture content of 8% while heaps produced the least.

Compared with heaping, untilled flat and tied-ridging increased soil water content and improved crop performance.

Grain yield was greatest under untilled flat (26.8g/100 seeds for early and 23.9g/100 seeds for late season planting). This was followed by heaping (25.2g/100 seeds for early and 22.7g/100 seeds for late season planting). The lowest yield was recorded with tied ridging (24.4g/100 seeds early and 22.4g/100 seeds for late season planting). Because of water logging, yield on tied-ridging was decreased. Maize appear to be very sensitive to soil water status, because the greater the soil water content during the crop cycle the greater the value of biomass yield observed, but the crop is also less tolerant to water logging. Hence the low yield observed in tie-ridging treatments (Figs 11c&d). As explained earlier, there were occational parches of ponded water observed between the ridges of tie-ridge treatments.

The biomass yield (fresh) vary from 775.2g in untilled flat to 546.1g in tied- ridging for early growing season and, from 708.6g in untilled flat to 577.4g in tied ridge for the late growing season.

Other agronomic measurements such as plant height, LAI responded to the different tillage practices. However, the number of leaves did not vary significantly among the treatments.

The value of water use efficiency (WUE) decreased in the order UF > TR > HH among treatments. It varies between 830.8g/ha-cm in UF to 592.9g in HH treatments. It was observed that soil water balance properly reflected soil water regime in the treatments and the biomass yield of the crop.

It is concluded that, compared with heaping and tied-ridging, grain yield is highest in untilled flat and lowest under heaping. Untilled flat was thus the most efficient tillage practice in the year studied. It produced 132.8 and 109.5% grain yield over heap and tied ridging. Since soil water content observed in the untilled flat and tied ridging treatments did not differ significantly, the low yield obtained in the case of tied-ridging can only be explained by the effects of ponded water observed during some days at the soil surface particularly at anthesis. Furthermore, 'water use efficiency of maize under untilled flat was significantly greater than those of tied-ridging and heaping.

It is highly recommended that this work be continued. Further studies are required to determine the degree of expression of yield reduction in maize under a wide range of defined tied ridging.

Secondly, the level of runoff and hence soil loss under heap tillage also require investigation. Finally, studies of this nature are necessary especially during dry season condition.

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APPENDICES

APPENDIX A

SOIL PARAMETERS DETERMINED

(i) **SOIL TEXTURE (Sieve analysis method)**

Wt. of empty can W_1 = 147g

Wt. of can W_1 t dry sample W_2 = 351g

Wt. of sample, W_3 = 351 - 147 = 204g

Table A-1: Soil texture at the Agricultural Engineering Experimental Site.

Sieve No.	Sieve diameter (mm)	Weight of soil retained (g)	% retained	% passing
1.	6.700	50.00	24.51	75.49
2.	1.700	7.00	3.43	96.57
3.	1.180	15.00	7.35	92.65
4.	0.850	15.00	7.35	92.65
5.	0.075	94.00	46.08	53.92
6.	Pan	5.00	2.45	-

$$\% \, retained = \frac{weight \ retained}{Total \ dried \ sample \ wt} \ x \ 100$$

% Passing = 100 - % Retained

Mechanical composition of the soil.

Sand (% retained in sieves 2, 3 and 4)
= 3.43 + 7.35 + 7.35
= 18.13%

Silt (soil retained in sieve 5 and 6)
= 46.08 + 2.45 = 48.53%

lay (soil particles washed away during sieving)
= 100 - (24.51 + 18.43 + 48.53)
= 100 - 91.17
= 8.83%

Table A-2. BULK DENSITY

Sample No.	wt. of tin (g)	wt. of tin + sample	wt. of sample	vol. of soil
1.	25.0	289.0	264.0	168
2.	24.5	268.1	243.6	168
3.	24.7	259.9	235.2	168

Analysis of data obtained.

$$Bulk\ density\ of\ soil\ sample = \frac{Weight\ of\ soil}{Vol\ of\ sand}$$

$$BD = \frac{264}{168} = 1.57$$

For Sample 1

$$BD = \frac{243}{168} = 1.45$$

Sample 2

$$BD = \frac{235}{108} = 1.40$$

Sample 3

$$Average\ BD = \frac{1.57 + 1.45 + 1.40}{3} = 1.47$$

(ii) FIELD CAPACITY

Table A-3: Calculated field capacity

Sample	W_1	W_2	W_3	W_4	**Field Capacity**
1.	197.22	172.2	136.5	35.7	20.73
2.	190.1	165.6	130.2	21.13	21.13
3.	197.5	172.8	137.0	35.8	20.71

$$Average\ field\ capacity = \frac{20.73 + 21.13 + 20.71}{3} = 20.85\%$$

Appendix B

Estimate of Soil Water Balance: Calculation of runoff

Runoff was extrapolated from N.R. Hulugalle and R. Lal's (1986) work on soil water balance of intercropped maize with cowpea at Ibadan. Akure and Ibadan lie on the same ecological zone.

Data from the maize monocrop treatment of the trial were taken and put in graph form. From here the Runoff of maize trial at Akure was extrapolated.

To ascertain the efficiency of the extrapolation, data of cowpea monocrop treatment of Hulugalle and Lal's work at Ibadan were compared with that of Afuye's similar work on cowpea at Akure. Their graphs were drawn and compared.

Table B-1: Precipitation and runoff of maize and cowpea at Ibadan, and cowpea at Akure.

Maize (Ibadan)		Cowpea (Ibadan)		Cowpea (Akure)		
Precipitation	Run off	Precipitation	Run off	Precipitation	Run off	Calendar Period
149.7	2.6	149.7	2.8	53.3	0.71	21 May - 4
52.5	0.4	52.5	0.4	24.3	0.45	June
82.5	1.2	82.5	1.3	140.6	4.31	4/6 - 18/6
58.6	0.6	58.6	0.9	67.8	2.55	18/6 - 3/7
39.6	0.7	39.6	0.8	32.9	0.50	3/7 - 16/7
175.9	2.0	175.9	2.1	49.3	1.06	16/7 - 30/7
79.3	1.3	79.3	1.5	80.4	2.98	6/9 - 15/9
131.3	3.3	131.3	3.7	133.2	3.41	15/9 - 4/10
11.6	-	11.6	-	22.5	0.98	4/10 - 17/10
3.0	-	3.0	-	-	-	17/10 - 31/10

Appendix C

Analysis for the different parameters

(i) Soil moisture

Table C-1: Soil Moisture grouped by Treatment and replications

	Block/Replications										Treatment	
Treatment	I	II	III	IV	V	VI	VII	VIII	IX	X	Total	Mean
UF	13,82	12,92	15,39	15,61	13,86	15,21	13,54	14,25	17,44	13,50	145,54	14,55
HH	13,15	15,39	14,33	14,31	12,33	15,50	15,45	13,93	12,78	11,70	138,87	13,89
TR	15,60	15,05	17,39	18,13	17,49	18,09	16,24	14,22	18,10	13,33	163,64	16,36
Block Total	42,57	43,36	47,11	48,05	43,68	48,80	45,23	42,40	48,32	38,53	448,05	44,81
Block mean	14,19	14,45	15,70	16,02	14,56	16,27	15,08	14,13	16,11	12,84	149,35	14,94

Table C-2 : Analysis of Variance (soil Moisture)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
UF	10	145,54	14,554	1,832804
HH	10	138,87	13,887	1,850734
TR	10	163,64	16,364	3,06218

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32,85506	2	16,42753	7,305756	0,002911	3,354131
Within Groups	60,71149	27	2,248574			
Total	93,56655	29				

Table C-3 : Biomass yield (dry) grouped by treatment and replications

	Block/Replications			Treatment	
Treatment	I	II	III	Total	Mean
UF	206,93	200,65	199,87	607,45	260,93
HH	172,83	170,23	185,43	528,49	229,10
TR	196,71	195,26	192,95	584,92	251,16
Block Total	576,47	566,14	578,25	1720,86	741,19
Block mean	192,16	188,71	192,75	573,62	247,06

Table C-4: Analysis of Variance (Biomass yield)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
UF	3	607,45	202,483	14,98173
HH	3	528,49	176,1633	66,09333
TR	3	584,92	194,9733	3,596033

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1102,959	2	551,4793	19,53958	0,002358	5,143249
Within Groups	169,3422	6	28,2237			
Total	1272,301	8				

Table C-5 : Total yield (dry) grouped by treatment and replications

	Block/Replications			Treatment	
Treatment	I	II	III	Total	Mean
UF	222,5	186,03	209,28	617,81	205,94
HH	172,83	170,23	185,43	528,49	191,05
TR	196,71	195,26	192,95	584,92	200,08
Block Total	592,04	551,52	587,66	1731,22	597,07
Block mean	197,35	183,84	195,89	577,07	199,02

Table C-6 : Analysis of Variance (Total yield)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
UF	3	669,04	223,0133	48,36123
HH	3	558,02	186,0067	37,76143
TR	3	616,49	205,4967	22,95023

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2056,187	2	1028,094	28,27724	0,000882	5,143249
Within Groups	218,1458	6	36,35763			
Total	2274,333	8				