EFFECT OF RAINFALL PATTERN ON RICE AND MAIZE YIELD IN BOSSO L.G.A OF NIGER STATE.

BY

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CERTIFICATION

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DEDICATION

This project is dedicated to the Almighty God," Who" has granted me life and favour, and Whose visitation has preserved my spirit"

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ABSTRACT

The study was carried out to determine the effect of rainfall pattern on rice and maize yield, in the Federal University of Technology, Minna, Niger State. Soil physical properties, that affect water movement in the soil like hydraulic conductivity, moisture content and infiltration rate were determined. The result of the soil analysis, showed that the soil was sandy loam. The result obtained from the study, revealed that annual (seasonal) rainfall has no direct effect on the yield of crops, but what affects the yield of crops is the monthly rainfall distribution. The study also compared the yield of the previous year (2000), with that obtained in this experiment, making reference to the amount of water used during the planting season of both years. The year 2000 had an average monthly rainfall of (249.5mm) during the growing season of maize, with a yield of 1.3 t/ha, while year 2001 had an average monthly rainfall of 272.4mm with a yield of 0.75 t/ha. Rice planted in year 2000 had an average monthly rainfall of 270mm with a yield of 0.63 t/ha, while at an average monthly rainfall of 206.9mm in 2001 there was a yield of 0.42 t/ ha. Variability of rainfall, poor drainage, disturbance from livestock were the major problems attributed to the change in yield. Possible solution to these problems were recommended.

CHAPTER ONE

INTRODUCTION

1.1 Background

The knowledge of soil – water – plant relationship has helped in understanding the factors and forces, which govern, water availability to plants.

In an environment known by low and high variable rainfall, air temperature and high evaporation demand, the soils are poorly structured, while scarce rainfall is one of the principal limitations. To increase productivity, the distribution of water within the soil profile and the proportion remains in the root zone for plant to utilize appears to be a more crucial limitation than the total rainfall. In such an environment, an understanding of the water uses and movement is particularly important to rotational management strategies and to be formulated to quantify the soil water movement.

The movement of water into and within the soil, moisture storage of the soil and the availability of soil moisture to plant are directly or indirectly related to the size and the distribution of soil pores and the attraction between the solid particles and moisture. (Ezedinma et. al, 1988)

The ability of plants to remove water from the soil is primarily a function of soil moisture tension and not just the water content. It is the soil moisture tension and not the water content that indicates when to irrigate. Soil moisture tension, is the measure of the tenacity with which water is held on to by the soil particles.

At any given point in time, only a little portion of soil water lies in the immediate neighborhood of absorptive surfaces of plant root systems. Moreover, a large amount of water is needed to offset transportation when growing crops. The capillary movement of soil water to plant root and the growth of roots into moist soils, are the two phenomena which account for the collection of water. Doovenbos,(1977).

The upward movement of ground water by capillarity from the water table into the root zone can be a major source of water for plant growth and maturity. To be most effective without serious restricting growth, ground water should be near but below the depth from which the major portion of the plant are extracted. If ground water is too near the surface, the land ability to economically produce most crops becomes almost nil. Anthony,(1986),

A number of crops are being grown under irrigation in the country at the moment, but what is of more importance is the availability of moisture content in the soil at the various growth stages of various crops in the country. This information is necessary for the supply of water at the appropriate time and amount, in order to avoid serious reduction in crop yield, especially under conditions of limited water supply. One of the practicable methods of measuring the available moisture content in the soil is by using a tensiometer. It is one of the many ways of determining the depletion of soil moisture content.

1.2 Objectives Of The Study.

To determine the effect of the pattern of rainfall on rice and maize yield

1.3 Scope and Limitation of Study

The study is limited to the amount of water available in the root zone of the plant.

Over the years the experimental plot has been used continuously for experiments, and the soil nutrient status has never been analyzed to determine the nutrient depletion.

CHAPTER TWO

LITERATURE REVIEW.

2.1 Geological Formation

The geology of Niger State is divided into two distinct geological zones. The basement complex and the Nupe sand stone. The dividing line runs in an approximately straight line N:W: - S : E orientation from south of Kontagora to north of Lapai. The other significant, but much smaller zone is the area alluvium, which is mainly found along the lower rivers of the Kaduna and Gboko rivers, as they flow over the Nupe sandstone zone along the river Niger.

Federal University of Technology, Minna, Niger State where this study was carried out, falls within the climate zone of the country generally referred to as the "middle belt". For purpose of clarity, the "middle belt" zone of Nigeria is an area in Nigeria, in which over a period of a year, 50% or more of all the year have dry season of 4 to 5 month duration (Pollen, 1962).

2.2 Soil Physical Properties

Soil which is a complex system must be in good physical condition to support plant growth. It must have the right proportion of air, water and solid particles.

Various physical forces interact in the development of the soil, and the result renders characteristics properties to soil which can be described in physical terms. These properties have considerable impact on anchorage, root penetration, aeration movement and retention of moisture, availability of plant nutrient, chemical and biological characteristic of the soil.

Soil that is expected to support plant life must; be will aerated, retain moisture to some certain degree and permit the right amount of rain water or irrigation water to get into the soil. These properties also determine the relative ease with which an agricultural implement moves in different soils.(Ezedinma et al,1988).

2.2.1 Soil Texture

Soil texture is the fineness or coarseness of the mineral particle of soil. It is the relative proportion of the various sizes of mineral particles present in a sample of soil. Depending on the basis of the combination of all the particles in the soil, texture can be described as sandy, clayey and loam. (Ona zi et al,1988).

Sandy soil includes soils in which the sand particles / aggregates make up 70% or more of the material by weight. It is generally coarse grained, loose, gritty and well aerated. It is well drained but capillarity is low due to large individual non – capillary pores. It heats up readily during a sunny day and cools down quickly during the night. Since heat destroys soil – micro – organisms, which play a great role in humus accumulation, it has low nutrient content and poor chemical properties.

Silt consist mainly of very small quartz. Each particle has a large surface area. It is smooth and powdery. When water is applied to silty soil, the air trapped in the pores will prevent it from moving freely into the sub soil, so moisture remains available in the topsoil. The higher the amount of silt in the soil, the greater the amount of water available to plants.

Clay particles have a large surface area and a high power of water holding capacity. Soil rich in clay are generally very sticky, and when they are wet, they are not easily permeable to water. They contain very little air due to the very narrow capillary pores, which reduce drainage and encourage capillary uptake and water retention. Clays have good chemical properties and bad physical properties. The higher the amount of clay in a soil, the less the amount of water available to plant soil texture can be determined by

i. Feel method

ii. Laboratory method

2.2.2 Soil Structure

The term soil structure refers to the arrangement of soil into natural aggregates. Structure comprises:

i. The shape and arrangement of the structural unit,

ii. Size

iii. Degree of development, distinctness and durability.

Sand, silt and clay particles are typically arranged into secondary particles called peds or aggregates. The shape and size of the peds determine the soil structure.

Soil organic matter plays a major role in soil aggeration. The best structure is that which increases soil aeration and water holding capacity. A loose, friable, freely draining soil is easier to cultivate than heavy compost soil. (Bradfield (1936)

2.2.3 Soil Bulk Density

The term bulk density is defined as the mass or weight of a unit volume of dry soil. The volume includes both "solids and pores". It is synonymous with particle density (mg/m^3 or g/cm^3). (Holmes et al , 1980). Bulk density is expressed as

$$\text{Bulk density} = \frac{\text{weight of oven dried soil (solids only)}}{\text{volume of soil (solid + pores)}} \quad \text{------ 2.1}$$

When expressed in terms of solid particle density

$$\text{Particle density} = \frac{\text{weight of soil solids}}{\text{volume of soil solids}} \quad \text{------2.2}$$

2.2.4 Porosity

Porosity is defined as the ratio of the pores to the total soil volume. It is an index of the relative volume pores, and is influenced by the textural and structural characteristics of the soil.

2.2.5 Infiltration

This is the process by which part of the precipitation enters the subsurface. During a rainstorm, water particles enter voids in the soil and fill them to saturation under sufficient rainy condition and water particles move freely to join the underground reservoir. The rate at which water percolates into the ground is known as Infiltration. (Manzumber ,1980)

2.2.6 Percolation

Percolation is the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation rate is synonymous with infiltration rate with the qualitative provision of saturated or nearly saturated conditions.

2.3 Moisture Content

The term "soil moisture" refers to that water that may be evaporated from soil by oven drying between 100^{o} C and 110^{0} C until there is no further weight loss (Gardner, 1958).

There are various methods of estimating soil moisture content and they include:

1. Gravimetric method.
2. Tensinelers
3. Pressure membrane and pressure plate method.
4. Neutron probe method.
5. Using electrical properties of porous block
6. Appearance and feel method.

For the purpose of this study, the gravimetric method would be used. Moisture content can be calculated by expressing it as a percentage of dry weight as given below (Marshal, 1980).

$$Md = \frac{Ww - Wd}{Wd} \times 100 \quad \text{--} 2.3$$

Md = Moisture content of the sample(%)

Ww = Mass of wet soil (g)

Wd = Mass of dry soil (g)

2.3.1 Field Capacity.

This is the moisture content after drainage or gravitational water has become slow, and the moisture content has become relatively stable. It is the moisture content beyond which water drain freely under the influence of gravity. This situation exists one to three days after the soil has been thoroughly wetted by rain or irrigation.

2.3.2 Permanent Wilting Point.

The permanent wilting point is the soil moisture content at which plant can no longer obtain enough moisture to meet transpiration requirements; and remains wilted until water is added to the soil. At wilting point the soil losts all of it's pore water and part of

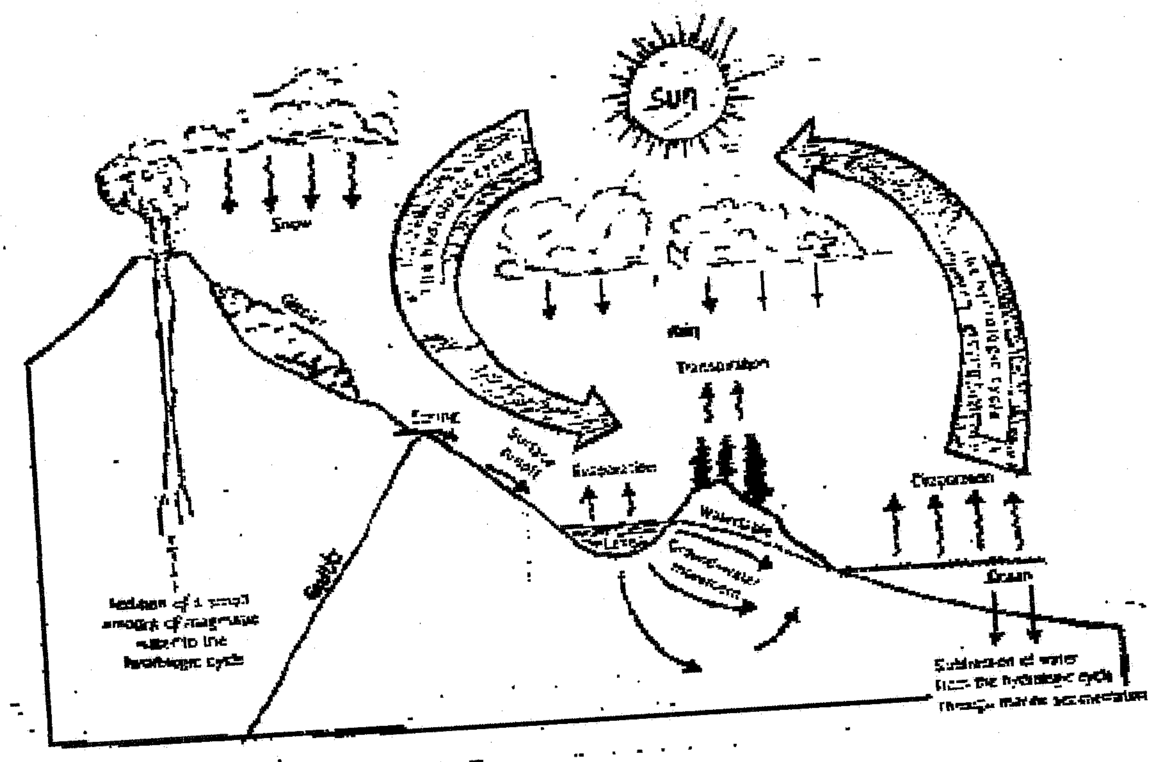
2.4 Hydrologic Cycle.

The total amount of water contained in the earth is constant and can neither be increased or decreased. The endless circulation of water between the earth and atmosphere, plays the most important role in the existence of the living being. However, the availability of water for the use of man is dependent on the earth's unending moisture cycle known as the Hydrologic Cycle. It comprises of gigantic distillation system operating in and on the land, and water bodies of the earth and in the atmosphere surrounding it with energy derived from the sun. Moisture is constantly circulating between land, ocean and atmosphere. The cycle has neither a beginning nor an end. The concept of the hydrological cycle begins with the water of the oceans, since it holds the bulk of water of the planet. Radiation from the sun evaporates water from the oceans to form water vapour. The water vapour rises and collects in the atmosphere to form clouds. The circulation of moisture from the oceans to the land is influenced by the wind atmospheric pressure difference, physiography of the continent, temperature difference and other factors. Under certain conditions, the clouds moisture condenses and falls back to the earth as precipitations.

Of the gross precipitation on land, nearly all is intercepted by the vegetation, with the remainder falling directly onto the soil. Water in excess, of that required to wet the leaves and branches, drips from the leaves or runs down the stem to the soil. Water retained by leaves is lost by evaporation and is referred to as interception loss.

Of the rain that reaches the soil, the difference between that soaking in and that running off comprises surface run off or overland flow. The movement of water into the soil from

Of the rain that reaches the soil, the difference between that soaking in and that running off comprises surface run off or overland flow. The movement of water into the soil from above is called infiltration. When the soil is thoroughly wet down to the water table, a steady rate of flow or percolation to the ground is maintained. Subsurface lateral flow or interflow also occurs through soils on slopes or when vertical flow through the subsoil is impeded. Interflow eventually contributes to stream flow from the catchment, as does the lateral flow of ground water, which is called base flow. Surface runoff makes a much less predictable contribution to stream flow and may be accompanied by soil erosion (White (1987)



Source : Hydrogeology by Stanley, Davies and Roger 1966.

Figure 2.0: Hydrologic Cycle

2.4.1 EFFECTIVE RAINFALL

In the simplest sense, effective rainfall means useful or utilizable rainfall. Rainfall is not necessarily useful or desirable at the time, rate or amount in which it is received. Some of it may be unavoidably wasted, while some may even be destructive. Just as total rainfall varies, so does the amount of effective rainfall. The useful portion of rainfall is stored and supplied to the user; the unwanted parts need to be conveyed or removed speedily.

The term effective rainfall has been interpreted differently not only by specialist in different fields, but also by different works in the same field. But our major concern is the interpretation of the Agriculturist. The Agriculturist considers effective rainfall, as the portion of total rainfall which directly satisfies crop water needs, and also the surface runoff which can be used for crop production on their farms being pumped from ponds or wells. He also considers that water which moves out of the field by runoff or deep percolation beyond the root zone of his crops is ineffective.

From the point of view of water requirement of crops, the Food and Agricultural organisation of the United Nations (Dastane,1974) defined the annual or seasonal effective rainfall, as the part of the total annual or seasonal rainfall which is useful, directly or indirectly for crop production at the site where it falls, but without pumping. It therefore includes water intercepted by living or dry vegetation, that, lost by evaporation from the soil surface, the precipitation lost by evaporatransporation during growth, that fraction which contributes to leaching, percolation or facilitates other cultural operation either before sowing or after sowing without any harm to yield and quality of the principal crops.

The above concept of effective rainfall is suggested for use in planning and operation of irrigation projects. The irrigation water supply in a given year should be planned to complement rainfall. Since annual rainfall varies from year to year, an irrigation project cannot be planned on one year's data, reports are needed over a long period to calculate effective rainfall on the basis of probability of occurrence.

The evaluation of effective rainfall involves measuring rainfall and the soil moisture uptake by the crop for evaporatranspiration. Information is also need on the rooting depth of crop plants. (Micheal, 1994)

2.4.2 Capillary Water

Capillary water, is that which rises above the water table in the soil and is held in the fine pores of soil particles by surface tension. Capillary water moves as a liquid in any direction, from more saturated to less saturated regions. The finer the pores, the greater the force binding the water (surface tension), and the higher the capillary tension (Chow, 1988)

2.4.3 Gravitational Water

This is the water which is drained from the soil under the influence of gravity. It is available to plants but it is often pulled down by gravity beyond the reach of plant roots.

2.4.4 PORE WATER PRESSURE

When the subsoil is fairly permeable, the pore water pressure can be determined readily by observing the prezometric level in an open stand pipe or observation well. Every change in hydrostatic pressure produces on almost simultaneous change of the water level in the well. If, for example, the pore water pressure increases in the surrounding open lower end of the observation well, a hydraulic gradient into the well is created. Consequently, the water flows rapidly into the well until equilibrium is reached. The water level in the well then corresponds to the pore water pressure that would exist in the soil, if there was not an observation. (For the 1990)

2.4.5 HYDRAULIC CONDUCTIVITY

The earliest quantitative description of water flow through a porous medium was that given by Henri Darcy (1956) who reported on the infiltration of water flowing through a sand bed for an improved supply.

Darcy 's experiment shows that the flow of water is the difference in hydraulic head at the ends of the column. This is known as Darcy's law expressed as

$$V = k\frac{[h_1 - h_2]}{L} \qquad \text{------ 2.4}$$

Where V = velocity of flow (m/day)

k = hydraulic conductivity depending on the properties of sand and liquid

$h_1 - h_2$ = difference in hydraulic head

L = distance along the flow between points h_1 and h_2. By defination, the quotient ($h_1 - h_2$) / L, along the flow path is the hydraulic gradient; thus

V = ki

The quantity of flow may be of greater interest than the velocity; hence in terms of quantity of flow, Darcy's law may be expressed as

Q = av = kia -- 2.5

Where ; Q = volume of water discharge in saturated length of time, usually expressed in m^3/ day.

a = cross – sectional area through which water moves in m^2

The value of k can be determined or obtained from laboratory test of sample formation of constant head parameter.

2.5 Maize

Maize is widely grown in Nigeria. It comes closest to being a staple food crop.

Maize does not grow well in areas with rainfall over 2000mm per year with soil pH below 5 and low sunlight. Deep permeable fertile sandy loam soils give the best with plenty of organic matter give best result. (N.C.R.I,1987)

Varieties

Medium / late maturing varieties

These includes:

1) White FARZ – 27 (TZPB). FARZ – 34 (TB), TZRS – W

They are suitable for human consumption.

2) Yellow : FARZ – 7, FARZ – 23 (096EP6), TZSR – W

Suitable for human and livestock consumption. These varieties are ready for harvest 110 – 130 days after planting.

Early Maturing Varieties

NE – Y and DMR – YE, TZESR – Y, TZER – Y

They are yellow – grained and are ready for harvest as dry grains 90 – 100 days after planting. They are suitable for human and livestock consumption.

Planting Pattern: planting patterns have direct effect on yield, solar energy capture and evaporation and thus an indirect effect on water use efficiency. Two important planting pattern practices, are plant density and row spacing. For maize production, the agronomical density and spacing is 75cm x 25cm or 90cm x 20cm at rate of 55000 plants per hectare. Widely spaced crop rows are avoided. A narrowing of rows generally means a uniform distribution of plants over a given area; thus making the plant canopy more effective in intercepting radiant energy and shading weeds. An added advantage is the reduction in raindrop impact on soil structure in the surface layer.

Planting Date: planting date is an extremely important in efficient water use. The main reason for choosing the optimum dates for sowing is to ensure good germination by placing the seed in the optimum moisture zone. After the seeds germinate, the moisture should be optimum for root growth and root penetration to envelope maximum soil volume for nutrient up take. The date also indicate right type of climate for the shoot growth and optimum utilization of moisture by the roots, under normal rainfall conditions, major yield can be obtained by making the best use of the interaction between plant breeding, agronomy and meteorology by sticking to the optimum planting time for particular crop and it's variety.(N.C.R.I, 1987).

Weed Control: one of the main management means of obtaining more efficient water use, is the elimination of weeds in crops. Weeds compete with crops for soil nutrient, water and light. Except in high rainfall areas, the primary concern is the water factor, because the water requirement of weed compared to nutrient requirement is greater than that of crop plants(Micheal, 1980). The competition for light is primarily operative when the weed species is as tall as or taller than the crop and density is high. Competition for water begins when the root systems of the weed and crop overlap. Suitable technology for efficient weed control, both mechanical and chemical have been developed which should be used in increasing water use efficiency of maize.

Fertilizer Application: fertilizers are applied to increase yield, and also increase water use efficiency. Some of the practices essential for the efficient use of fertilizer are

(i) Soil test to evaluate the nutrient deficiency in the soil and use of the proper quantity.

(ii) Placement fertilizers in the soil properly.

Harvesting: Harvest as soon as the grains are dry enough (90 – 130) days after planting depending on variety.

2.6 Rice

The plant rice (oryza sativa) is the major source of food for nearly one – half of the world's population. It is far more important than wheat as a source of carbohydrates. Cultivated rice are classified as upland and lowland. Upland types, which can be grown in high – rainfall areas without irrigation, produce relatively low yield. The lowland types, which are grown submerged in water for the greater part of the season, produce higher yields. In contrast to most plants, rice can thrive when submerged because oxygen is transported from the leaves to roots. Rice varieties are also classified as long – or short grain. Most long grain rice have high amylose content and are dry or fluffy when cooked, while most short grain rice has lower amylose content and are sticky when cooked.

Fertilizer Application: As with most crops, the chief nutrients required are Nitrogen, phosphorous and potassium. These are applied to increase yield and water use efficiency.

Harvesting: When rice is harvested depends partly on how it is to be used i.e. whether for consumption or for seed.

In the former case, which is of course the more usual ones, account must be taken of the "technological maturity", which corresponds to the highest yield from milling. It depends on the variety used, the season and the cultivation methods, that is why it is difficult to categorise the date of harvesting. However, "technological maturity" may be assessed according to the appearance of the panicle. Technological maturity is attained if the yellow colouration covers two – thirds of the length of the axis of the panicle.

A more precise method consists of measuring the humidity of the grains. Maturity is attained when the grains have a water content of around 22%.(Yayock,1988)

2.7 Evapotranspiration (ET)

In designating water use by crops, evaporation and transpiration are combined into one term evapotranspiration (ET), as it is difficult to separate these two losses in cropped field. The term consumptive use, is used to designate the losses due to evapotranspiration, and the water that is used by the plant. It thus includes all the water consumed by plants, plus water evaporated from bare land and water surfaces in the area occupied by crop. Factors, which influence evapotranspiration, are solar radiation, wind, temperature, humidity and also the stage of growth of the crop.

The total amount of water used in evaportranspiration by a cropped area during the entire growing season is called seasonal consumptive use. While the average daily water use rate during the few days of the highest consumptive use of the season is called the peak period use rate. (Micheal, 1992)

2.7.1 Estimating Evapotranspiration From Climatological Data

The need to be able to compute evaportaranspiration (ET) rapidly and accurately remains undisputed. In Nigeria, there is need to compute "ET" from those meteorological parameters which can be easily be measure. In other words, a model that is easy to apply and requires minimum of commonly available meteorological parameters, is preferred over a more complex and sophisticated model with comparable accuracy of prediction.(Duru 1984). A modified form of Blaney – Morin ET model termed Blaney – Morin – Nigeria (BMN) Et is proposed here as satisfying these requirements. The equation of this model is given thus:

$$Etp = rf\,(0.45\,T + 8)\,(520 - R^{1..31}) / 100 \quad \text{------------} 2.6$$

Where:

Etp = potential evaportranspiration (mm day $^{-1}$)

rf = ratio of maximum possible hours of sunshine to the annual maximum

T = Temperature (^{0}C)

R = Relative humidity

Therefore crop consumptive use can be calculated thus;

E_{tc} = crop consumptive use (mmday^{-1})

E_{tp} = potential evaporation (mm day $^{-1}$)

K_c = crop coefficient

2.8 **Soil Fertility**

Soil fertility may be defined as the availability of nutrients in a soil to the plants growing on it. This indicates the potential capacity of soil to produce crops at a satisfactory level over a period of time.

The fertility of tropical soil mainly depends on the availability of the major nutrients – Nitrogen, phosphorous and potassium. These nutrients can either be obtained from soil organic matter or from inorganic supplements (Youdeowei et al 1988)

2.9.0 **Rooting Characteristics And Moisture Use Of Crops**

The amount of soil moisture that is available to a plant is determined by the moisture characteristics of the soil, the depth to which the plant roots extend and the density of the roots.

Plants vary genetically in their rooting characteristics. Vegetable crops, such as onions and potatoes, have sparse rooting system and are unable to use all the soil water within the root zone. Forage grasses, sorghum, maize and such other crops have fibrous, dense roots. (Micheal,1992).

Plants may be limited in their rooting by factors other than genetics. High water table, shallow soils, and an impermeable formation near the ground surface restrict the depth of rooting.

2.9.1 **Effective Root Zone**

This is the depth from which the roots of an average mature plant are capable of reducing soil moisture to the extent that it should be replaced by irrigation. It is not necessarily the maximum root depth for any given plant, especially for plants that have a long tap root.

Root development of any crop varies widely with the type of soil and other factors. (Micheal 1992).

TABLE 2.0 : **EFFECTIVE ROOT ZONE DEPTH OF SOME COMMON CROPS**

(GROWN ON VERY DEEP, WELL DRAINED SOILS)

Rooting Characteristics			
Shallow rooted	*Moderately deep rooted*	*Deep rooted*	*Very deep rooted*
Depth of root zone			
60cm	90cm	120cm	180cm
Rice	Wheat	Maize	Sugar cane
Potato	Tobacco	Cotton	Citrus
Cauliflower	Castor	Sorghum	Coffee
Cabbage	Groundnut	Pearl millet	Apple
Lettuce	Muskmelon	Soyabean	Grapevine
Onion	Carrots	Sugarbeet	Safflower
	Pea	Tomato	Lucerne
	Bean		

Source :(Micheal, 1992)

2.9.2 MOISTURE EXTRACTION PATTERN WITHIN ROOT ZONE

The moisture extraction pattern shows the relative amount of moisture extracted from different depths within the crop root zone. Fig. 2D shows the moisture extraction pattern of average crop plants growing in deep uniform soils. It seen that about 40 percent of the total moisture used is extracted from the first quarter of the root zone, 30 percent from the second, 20 percent from the third and only 10 percent from the last quarter. This indicates the need for making soil moisture measurements at different depths (at least two) within the root zone in order to have a fair estimate of the soil moisture status.

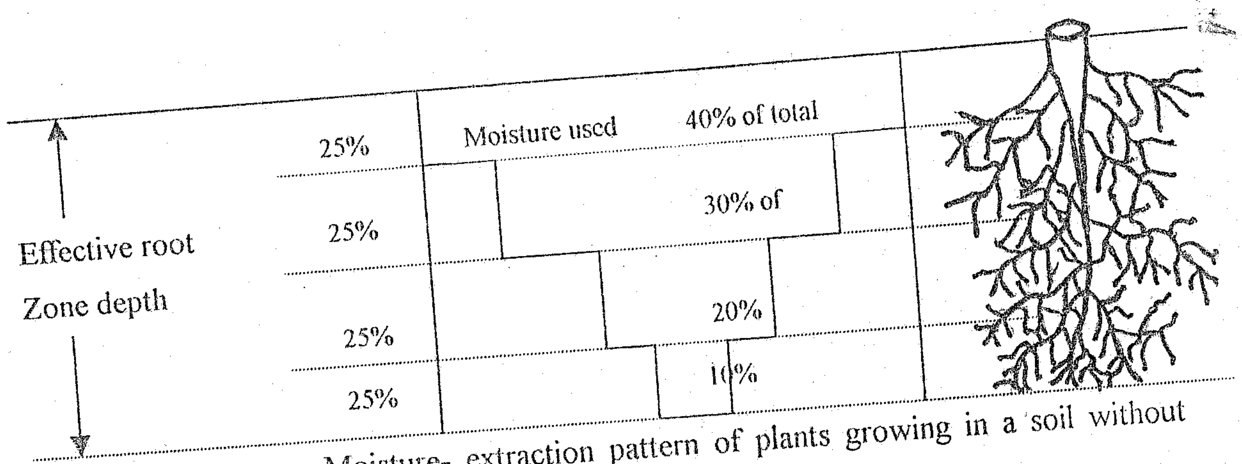


Figure 2.1 Average Moisture- extraction pattern of plants growing in a soil without restrictive layers and with an adequate supply of soil moisture (Micheal,1992)

CHAPTER 3

MATERIAL AND METHODS

3.1 EXPERIMENTAL LAYOUT

The study was conducted on the experimental farm of the Department of Soil Science of the Federal University of Technology, Minna, Niger State. The total land area cultivated was 75m by 25m. A total land area of 35 by 2.5m was used for maize (DMR –ESR – Y) while a total land area of 40 by 25m was used for the cultivation of upland rice WAB 33 –25 (oryza glabernma).

The maize seeds were sown on the 22nd of June 2001, with an intraspacing of 60 – 70cm and interspacing of 45cm. Basins of dimension 5m by 4m were constructed on the rice seeds sown on the 20th of July 2001.

3.2 METHOD OF INVESTIGATION.

The field experiment commenced on the day the seeds were planted. Readings of all parameters were taken twice in a week (piezometric level and soil tension). Readings were obtained from the tensiometer, piezometer. Experiments were conducted to determine moisture content of the soil, the hydraulic conductivity, the bulk density, and also the type and characteristics of soil available on the field.

The areas (rice and maize plot) were weeded on different occasions and fertilizer applied (check Appendix B for more information on date of planting, date of weeding, date of harvesting and fertilizer applied)

3.3 Determination Of Soil Properties.

3.3.1 Moisture Content.

An auger, which was about 1.5m in height was employed in the collection of soil samples at the depth of 0 – 20 and 30 –60cm. The soil samples were collected in cans indicating their depths. The cans and their contents were tied in polyethene bags to prevent loss or gain of moisture. The samples were taken to the laboratory and weighed using a weighing balance, the polyethene bags were then removed, and the tins were placed in the oven at the temperature of 105^0 C. After 24 hours, the oven was switched off and opened to allow the cans or tins to cool off. Later on, the cans and their contents were then re – weighed.

3.3.2 Infiltration Rate.

The double cylinder infiltrometer was used in determining the infiltration rate on the soil. The double cylinder consist of an outer cylinder of height 25cm and diameter 60cm, and an inner cylinder of height 25cm and diameter 60cm.

The outer cylinder was inserted into the soil by placing a plank across the ring and tapping it gently until it goes down to a depth of 10cm. The Inner cylinder was installed into the outer cylinder to the same depth. Care was taken to centralize the radial distance between the two cylinders.

The outer cylinder was filled up with water half way before filling the Inner cylinder to it's brim. The water level was monitored and readings were taken every five minutes using a metre rule and a stop watch. The outer cylinder served as buffer to maintain a constant average infiltration rate head.

3.3.3 Mechanical Composition Of Soil (Sieve Analysis)

The sieves were initially weighed and recorded. The sieves were of different diameter mesh and they were arranged in such a way that the sieve with the smallest mesh diameter came first and progressed to the sieve with the largest mesh diameter. Below, the smallest mesh diameter was a pan that collected the samples that passed through the sieves.

One kilogramme of soil was poured into the largest mesh diameter and covered. The whole content was placed on a sieve shaker and shaken or pulsated for five minutes, after which sample retained on each sieve was weighed. Thus the proportion of clay silt and sand were determined.

3.3.4 Hydraulic Conductivity (Unsaturated)

A plot of land 5m x 5m was marked out on the rice and maize plot, and ridges were constructed around the plots. The plots were then filled / saturated / flooded with water for two days to allow water reach or sink to a depth of 1m. The plots were covered with polyethene sheets to prevent evaporation.

Soil samples were collected at the required depth hourly for six hours on the first day, and daily for six days afterwards. The soil samples collected were placed in tins, covered with polyethene bags to prevent loss or gain of moisture and taken to the laboratory. The samples were weighed, and oven dried for 24hrs and the dried samples were weighed. The data obtained from the wet and dry samples were used in calculating volumetric water content, which in turn was used in calculating hydraulic conductivity.

3.3.5 **Bulk Density**

Points on the study site was cleared of vegetation, and then a core ring was pushed into the soil to obtain soil samples at different depths. The moist soils were transferred into a moisture can. The samples were taken into the laboratory and weighed. They were then oven dried for a day (24hrs) and after which the oven is switched off and it's content allowed to cool off. After cooling, the samples were re – weighed.

3.3.6 **Moisture Tension**

This was measured twice in a week with an instrument called the field tensionmeter, at depths of 0 – 30 and 40 – 60.

3.3.7 **Water Table**

Water was monitored by observing the piezometric level in the perforated standpipe. At every change in hydrostatic pressure there was a change in water level. The piezometric level was taken twice a week.

3.4 Field Equipment Employed

3.4.1 Tensiometer

Measures the tension with which water is held in soils. It consists of a porous cap filled with water and attached to a vacuum gauge or mercury manometer. A hole was dug in the soil, a handful of loose soil was placed into the hole and the cup pushed firmly into the soil. Additional soil was packed around the cup and around the tube wherever necessary to ensure firm contact with the soil. A temporary connection was established between the water inside the cup and the water in the soil. As water in the cup moved out because of suction or tension existing in the soil water, a vacuum was created in the cup and registered in the gauge.

3.4.2 The Piezometer

The piezometer consist of a P.V.C pipe of length of 2m and a diameter of 0.05mm. The pipe was perforated half way (1m) along it's length using a hot nail. The perforated end was completely buried into the ground leaving the un – perforated end above the ground level.

It measures the pore water pressure and the rise and fall of water table.

CHAPTER FOUR

RESULTS AND DISCUSSION

The results from the field and laboratory are given below:

4.1 Soil Physical Properties

The result of the particle size analysis as presented in table 4.1, indicates that the percentage of sand exceeds 60% at every depth. The percentage of silt and clay are below 30%. From the Textural Triangle (United States Department of Agriculture), the soil on the maize plot was shown to the sandy loam, while that of the rice plot was shown to be sandy clay loam.

Tables 4.2 and 4.2.1 show the level of water in the piezometer on both plots. The water in the tubes rose whenever there was an increase in water table and fell whenever there was a decrease in the water table.

The infiltration rate of both soils as shown in Tables 4.3 and 4.3.1, indicates that infiltration decreased with time. The infiltration on the rice plot was lower than that of the maize plot and this was due to the moisture content of the soils and the texture of the soils. Tables 4.4 and 4.4.1, shows the unsaturated hydraulic conductivity which decreases down the soil profile with respect to time.

From Table 4.5, it can be seen that bulk density increases down the soil profile and this is due to compaction. Moisture content increases down the soil as shown in Tables 4.6 and 4.6.1

Table 4.1 : Particle Size Analysis Of Soil Samples

Plot	*Depth*	*% Sand*	*% Clay*	*% Silt*	*Textural Class*
A	0-30	65.20	16.40	18.40	Sandy - loam
	40 – 60	68.10	12.80	19.10	
B	0 – 30	60.50	29.75	10.20	Sandy clay - loam
	40 – 60	66.90	21.50	11.60	

Plot A – Maize

Plot B – Rice

Textural class gotten from U.S. Department textural classification.

Table 4.2DEPTH OF WATER IN PIEZOMETERS (MAIZE PLOT)

WEEK AFTER PLANTING	TUBE 1 (mm)	TUBE 2 (mm)
1	318.2	447.2
2	237.0	351.5
3	516.7	411.7
4	182.0	254.0
5	215.0	370.0
6	319.0	382.0
7	398.0	426.0
8	461,5	209.0
9	640.0	335
10	558	
11	566	274
12	342	478
13	514.5	468

4.2.1: DEPTH OF WATER IN PIEZOMETERS (RICE PLOT)

WEEK AFTER PLANTING	TUBE 1 (mm)	TUBE 2 (mm)
1	398.3	391.7
2	185.9	140.7
3	253.3	146.0
4	390.0	409.0
5	132.5	12.0
6	377.0	396.0
7	37.0	132.0
8	75.0	145.0
9	419.0	328.0
10	761.0	764.0
11	7070	7440
12	594.1	6481
13	327.4	750.1
14	849.3	898.5

Table 4.3: Infiltration Rate (Rice Plot)

Time (mm)	*Initial Depth (cm)*	*Charge in Depth (cm)*	*Accumulated Infiltration (cm/mm)*	*Infiltration (cm/mm)*	*Infiltration Rate (cm/hr)*
0	13	-	-	-	-
5	11.5	0.9	0.9	0.18	10.8
10	10.1	0.7	1.6	0.14	8.4
15	8.9	0.6	2.2	0.12	7.2
25	6.5	1.1	3.3	0.11	6.6
35	5.7	0.8	4.1	0.08	4.8
45	5.1	0.6	4.7	0.06	3.6
60	4.2	0.9	5.6	0.06	3.6
75	3.3	0.9	6.5	0.06	3.6
90	2.7	0.6	7.1	0.04	2.4
100	2.3	0.4	7.5	0.04	2.4
105	2.1	0.2	7.7	0.04	2.4

Table 4.3.1: Infiltration Rate (Maize Plot)

Time (mm)	*Initial Depth (cm)*	*Charge in Depth (cm)*	*Accumulated Infiltration (cm/mm)*	*Infiltration (cm/mm)*	*Infiltration Rate (cm/hr)*
0	15	-	-	-	-
5	13.4	1.6	1.6	0.32	19.2
10	12.1	1.3	2.9	0.26	15.6
15	11	1.1	4	0.22	13.2
25	9.3	1.7	5.7	0.17	10.2
35	7.9	1.4	7.1	0.14	8.4
45	6.7	1.2	8.3	0.12	7.2
60	5.2	1.5	9.8	0.10	6
75	3.9	1.3	11.1	0.087	5.2
90	2.7	1.2	12.3	0.08	4.8
100	1.9	0.8	13.1	0.08	4.8
105	1.5	0.4	13.5	0.8	4.8

Table 4.4 : Unsaturated Hydraulic Conductivity of Maize Plot

Water stored (cm)	Time (hr)	L Δθ (cm)	Δt (h)	kθ (cm/h)
32.92	0	- 7.22	1	7.22
25.70	1	- 2.58	5	0.522
23.12	6	- 0.75	12	0.06
22.4	18	- 1.2	24	0.05
21.2	42	- 1.8	24	0.075
19.4	66	-	-	-

LΔθ - change in water stored

Δt - change in time

Kθ - hydraulic conductivity

$$K\theta = \frac{-L\Delta\theta}{\Delta t}$$

Table 4.41: Unsaturated Hydraulic Conductivity of Rice Plot

Water stored (cm)	Time (hr)	L Δθ (cm)	Δt (h)	kθ (cm/h)
36.6	0	- 4.1	1	4.1
32.5	1	- 6.6	5	1.32
25.9	6	-1.2	12	0.1
24.7	18	-1.5	24	0.06
23.2	42	-0.7	24	0.03
22.5	66	-	-	-

Table 4.5 : Matric Potential , Corresponding Moisture Content and Bulk Density

Depth (cm)	Matric Potential (CB)	Moisture Content (%)	Bulk Density (g/cm^3)
30	5	23.01	1.12
60	4	24.43	118
Maize plot			
30	4	25.99	1.21
60	2	34.35	1.24
Rice plot			

Table 4.5.1 : Number of Rains during the Growing Seasons of Rice and Maize

RICE			MAIZE		
Month	Number of Rains	Amount of Rainfall (mm)	Month	Number of Rains	Amount of Rainfall (mm)
1st Month	16	209.6	1st Month	14	352.9
2nd Month	16	262.5	2nd Month	15	195.9
3rd Month	15	148.7	3rd Month	15	268.4

4.2 Soil Moisture Status

The quantity of water available at the depth of 30cm and 60cm for both crops at different weeks with corresponding moisture content, and matrix potential is shown in Table 4.6 and 4.6.1.

From both Tables (4.6 and 4.6.1), it was observed that the higher the moisture content, the lower the tensiometer reading and vice-versa. This is also confirm in figure 4 through figure 4.3.

4.3 Soil Moisture Balance

The total amount of rainfall during the growing season of maize was 817.2mm and that of the rice was 620.8m as shown in Tables 4.7 and 4.7.1

The crop consumption use of both crops, during their three distinct stages of growth (germination, flowering and maturity) is shown on table 4.7. The total crop consumptive use for maize and rice is 198.32mm and 168.34mm respectively, as shown in Appendices D and E

4.4 Grain Yield

The maize was harvested on the 18th of September 2001 with a total yield of 0.75 t/ha.

While the rice was harvested on the 21st October 2001 with a total yield of 0.42 t/ha.

Table 4.6 : Quantity Of Water With Corresponding Matric Potential (Maize Plot)

	AT 30CM			*AT 60CM*		
WAP	*MATRIC POTENTIAL (CB)*	*MOISTURE CONTENT (%)*	*QUANTITY OF WATER (mm^3)*	*MATRIC POTENTIAL (CB)*	*MOISTURE CONTENT(%)*	*QUANTITY OF WATER (mm^3)*
1	7.4	21.12	2.36	4.8	23.23	2.74
2	4	24.43	2.73	2.5	28.76	3.39
3	5	22.99	2.57	3.3	25.96	3.06
4	5	22.45	2.51	3	26.04	3.07
5	8	20.85	2.3	5	22.99	2.71
6	5	22.99	2.57	4	24.43	2.88
7	4	225.03	2.80	3	26.84	3.16
8	5	23.01	2.57	3.5	25.46	3.64
9	6	22.03	2.46	5	23.00	2.71
10	8	21.02	2.35	7	21.34	2.51
11	6.5	21.66	2.42	4.5	23.63	2.78
12	4.5	23.63	2.64	3.5	25.40	2.99
13	7.5	21.07	2.35	6	23.03	2.71

WAP - Week After Planting

Quantity Of Water = Moisture Content x Bulk density

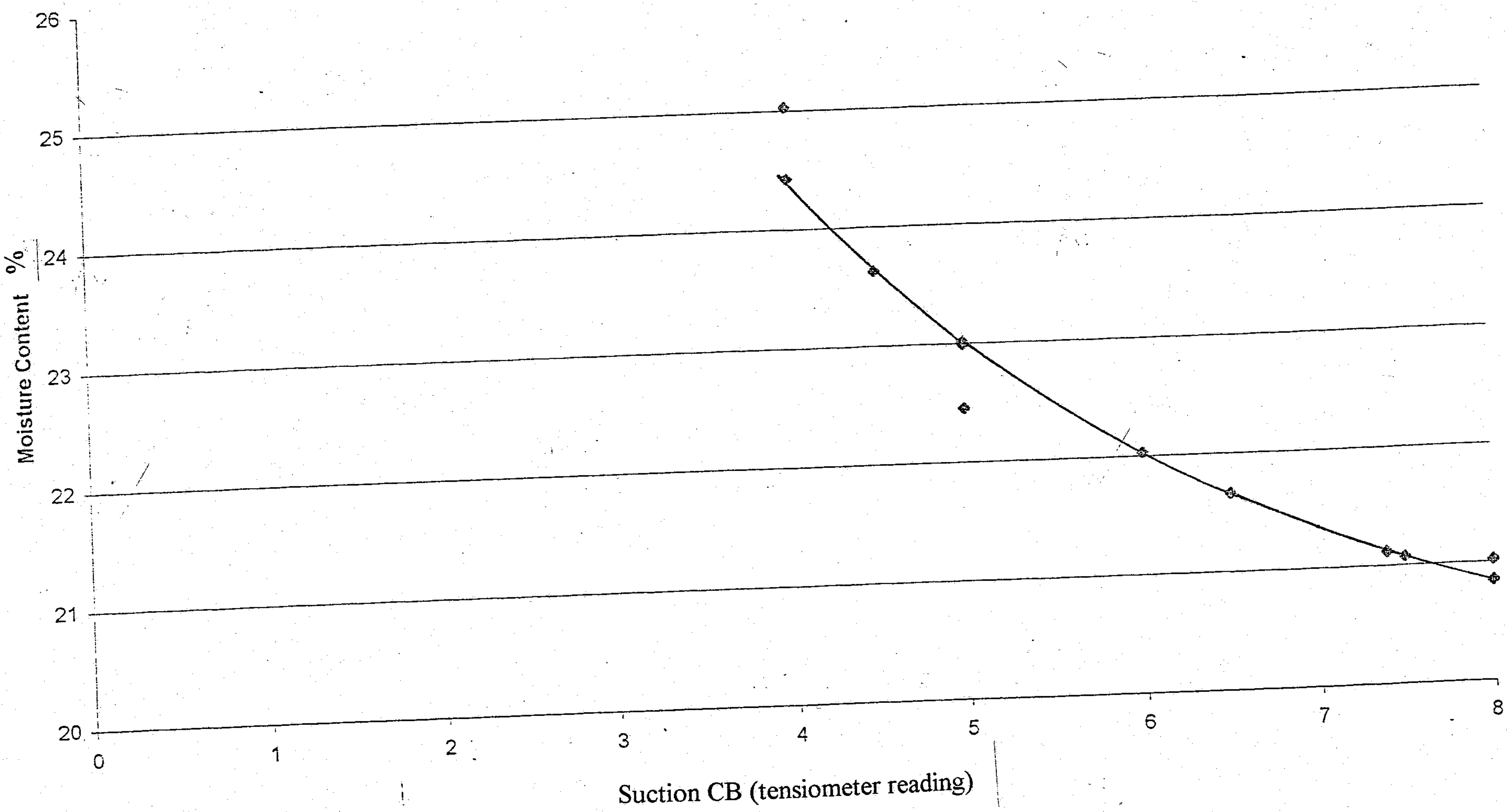


Fig4.0: Graph of Moisture Content Against Suction at 30cm (Maize)

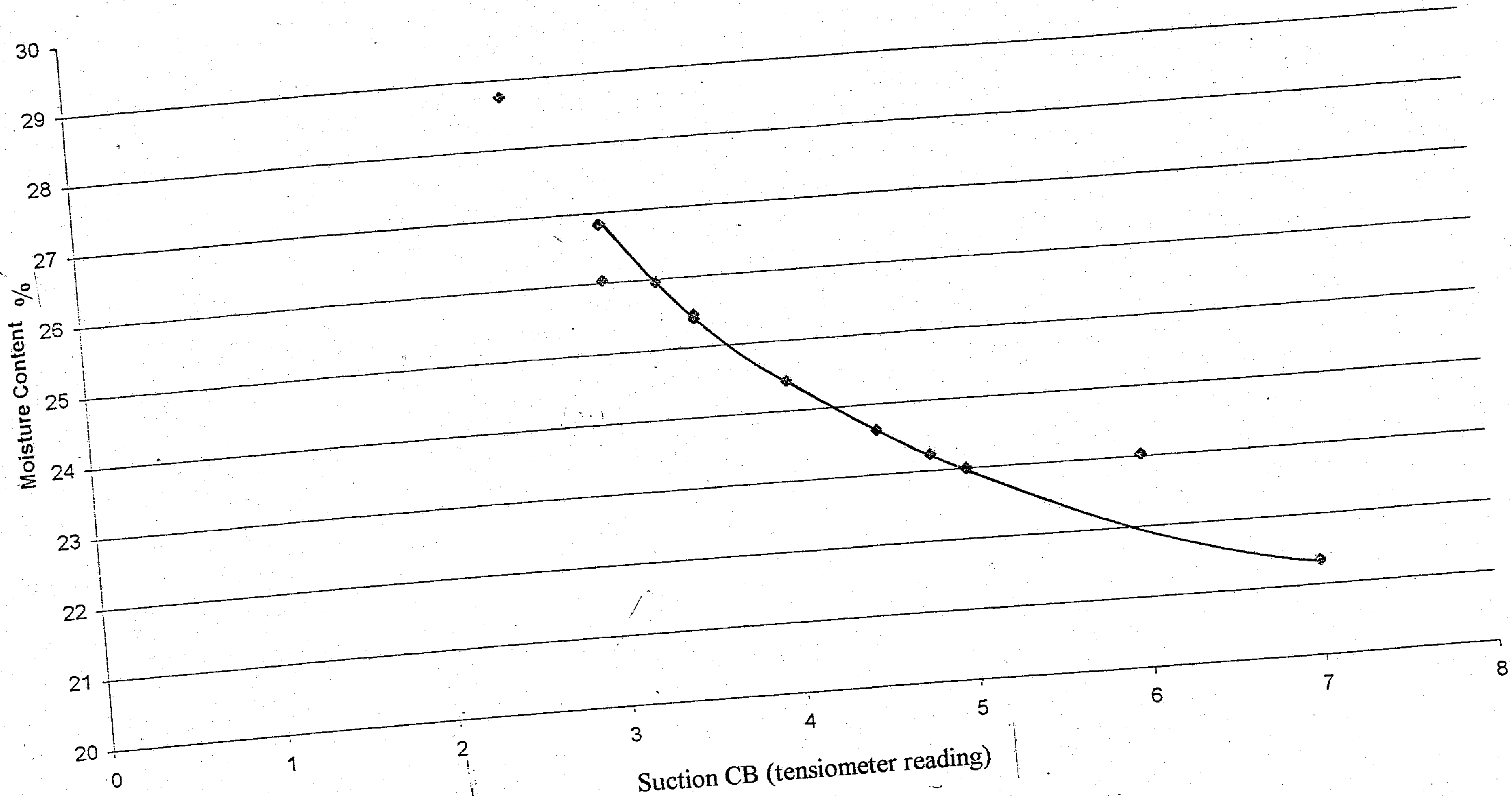


Fig.4.1: Graph of Moisture Content Against Suction at 60cm (maize)

Table 4.6.1 : Quantity Of Water With Corresponding Matric Potential (Rice Plot)

	AT 30CM			AT 60CM		
WAP	*MATRIC POTENTIAL (CB)*	*MOISTURE CONTENT (%)*	*QUANTITY OF WATER (mm^3)*	*MATRIC POTENTIAL (CB)*	*MOISTURE CONTENT(%)*	*QUANTITY OF WATER (mm^3)*
1	6	20.30	2.46	4	25.02	3.10
2	4.3	27.35	3.31	2.7	31.23	3.87
3	5	25.35	3.07	3.3	32.01	3.97
4	5	24.64	2.98	2	33.19	4.12
5	4	25.99	3.15	2	34.35	4.26
6	5	24.76	2.99	4	28.91	3.58
7	3	32.98	3.99	2	33.64	4.17
8	5	23.74	2.87	2	35.69	4.43
9	6	22.12	2.68	5	25.22	3.13
10	7	20.56	2.49	5.5	23.28	2.89
11	7	20.67	2.50	5	24.76	3.07
12	6	20.42	2.47	4	25.78	3.19
13	8	19.79	2.39	7	20.58	2.55
14	9	19.40	2.35	7	19.98	2.48

WAP - Week After Planting

Quantity Of Water = Moisture Content x Bulk density

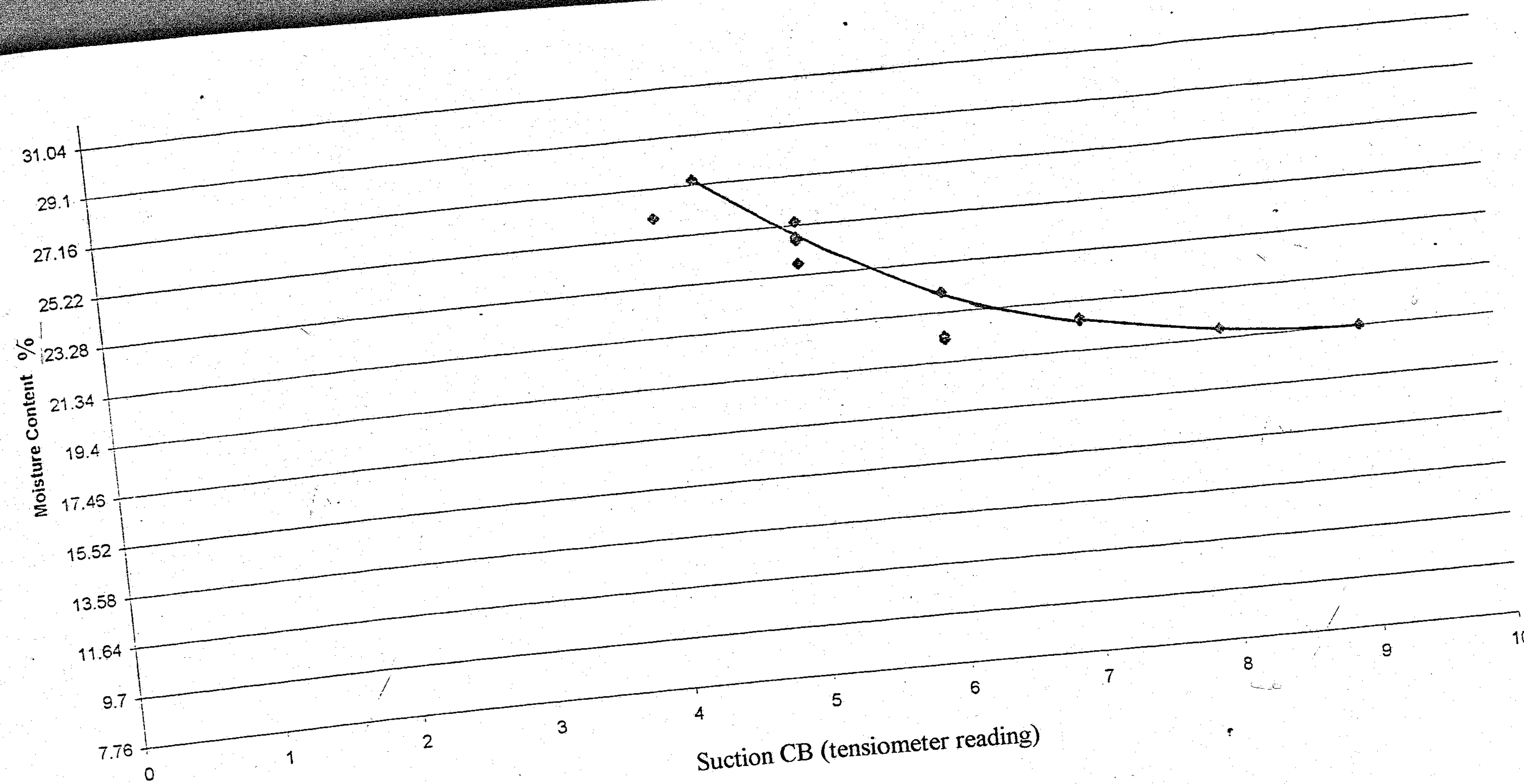


Fig 4.2: Graph of Moisture Content Against Suction at 30cm (Rice)

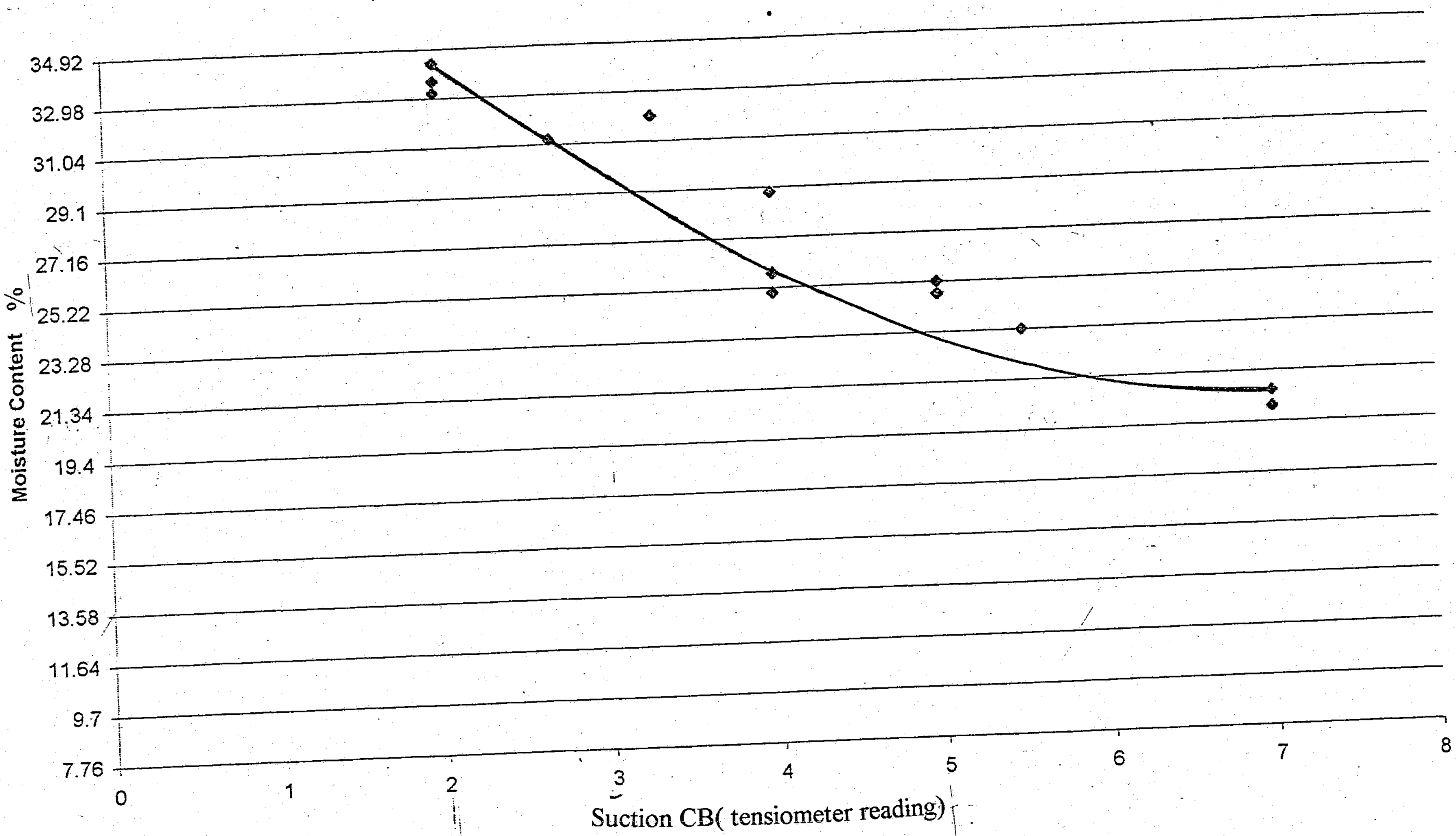


Fig. 4.3: Graph of Moisture Content against Suction at 60cm (Rice)

Table 4.7 : Distinct Growth Stages of Rice with Corresponding Amount of Rainfall, E_{tp} and E_{tc}

Stage of growth	**Decades*	*Amount of Rainfall (mm)*	*E_{tc} Crop (mm/day)*	**Difference (mm)*	*Etp B.MN calculated (mm / day)*	*Total Rainfall (mm)*	*Total E_{tc} (mm/day)*
Stage 1 (Initial)	1st	70.6	1.42	69.18	2.52	209.6	18.2
	2nd	58.4	5.66	52.74			
	3rd	80.6	11.07	69.53			
Stage 2 (Crop Development)	1st	74.6	18.04	56.56	2.81	262.5	74.56
	2nd	152.8	23.48	129.32			
	3rd	35.1	33.04	2.06			
Stage 3	1st	118.6	31.74	86.86	4.4	148.7	75.58
	2nd	14.5	25.74	-11.24			
	3rd	15.6	18.1	-2			

*Difference between Rainfall and E_{tc}

* Decades : Dividing each month into three parts made of ten days.

Table 4.7.1 : Distinct Growth Stages of Maize with Corresponding Amount of Rainfall, E_{tp} and E_{tc}

Stage of growth	**Decades*	*Amount of Rainfall (mm)*	*E_{tc} Crop (mm/day)*	**Difference (mm)*	*Etp B.MN calculated (mm / day)*	*Total Rainfall (mm)*	*Total E_{tc} (mm/day)*
Stage 1 (Initial)	1st	170.5	2.16	168.34	3.76	352.9	24.66
	2nd	46.8	7.72	39.08			
	3rd	135.6	14.78	120.82			
Stage 2 (Crop Development)	1st	82.5	22.44	60.06	3.28	195.9	88.92
	2nd	8.1	30.82	-22.72			
	3rd	105.3	35.66	69.64			
Stage 3	1st	88.6	34.06	54.54	3.31	268.4	84.74
	2nd	154.8	28.68	126.12			
	3rd	25	22	3			

*Difference between Rainfall and E_{tc}

Table 4.8 : Monthly Value of Temperature, Relative humidity and Radiation Ratio

Year 2001

Month	*Temperature (^0C)*	*Relative Humidity (2)*	*Radiation (mm/day)*	*Radiation Ratio (rf)*
January	27.7	31.1	7.3	0.091
February	29.9	30.1	7.7	0.096
March	31.6	44.9	6.8	0.085
April	30.4	57	7.3	0.091
May	28.9	61	7.1	0.88
June	26.4	70	6.8	0.085
July	25.6	76	4.4	0.066
August	25.0	79	4.6	0.058
September	25.2	73	5.5	0.069
October	27.1	52	6.4	0.080
November	26.6	43.7	8.9	0.111
December	27.5	35.6	7.1	0.088

Source :Department of Meteorological services Nigeria Airways Minna.

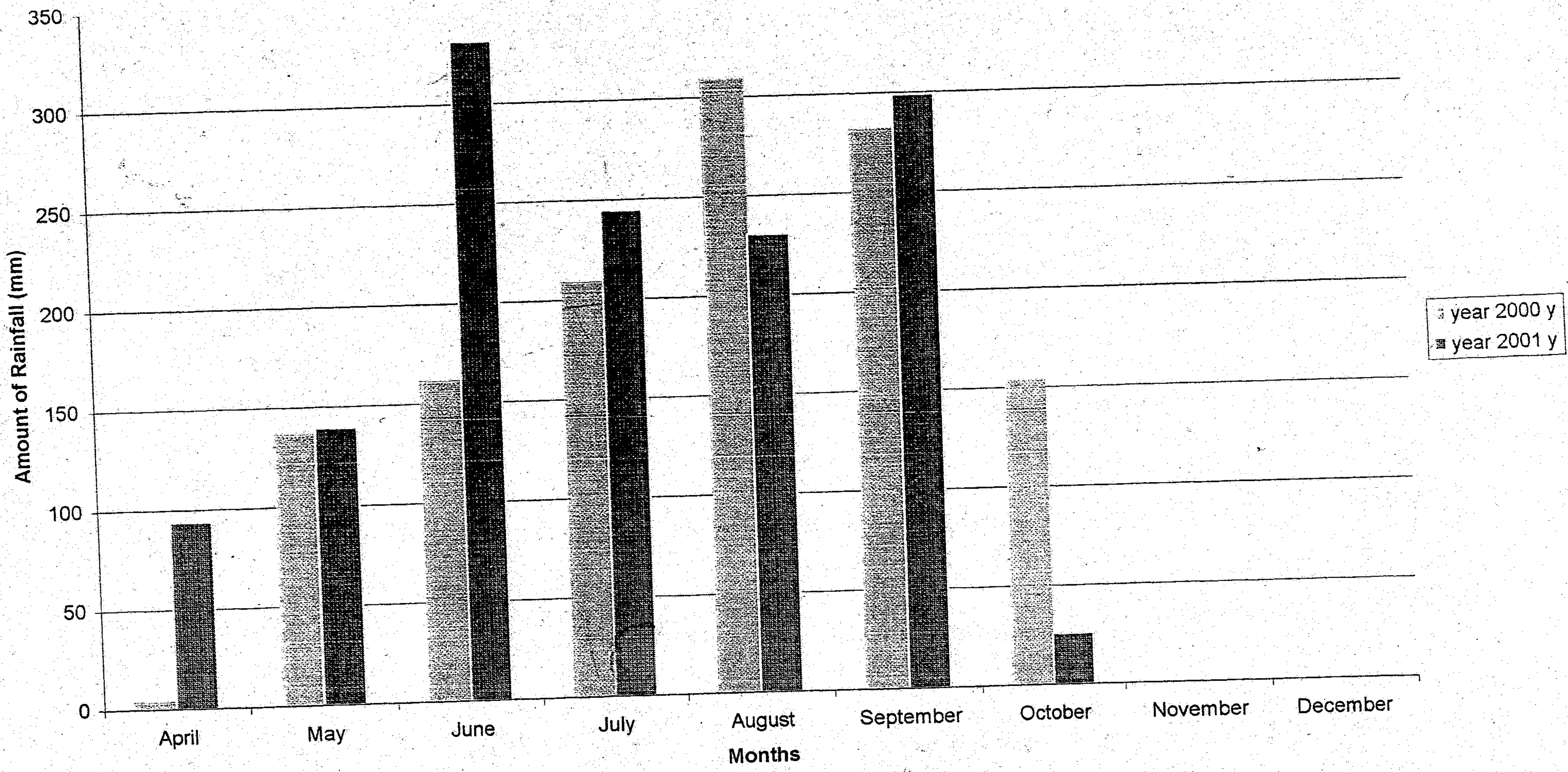


Figure 4.4: Monthly Rainfall Distribution For Year 2000 and 2001

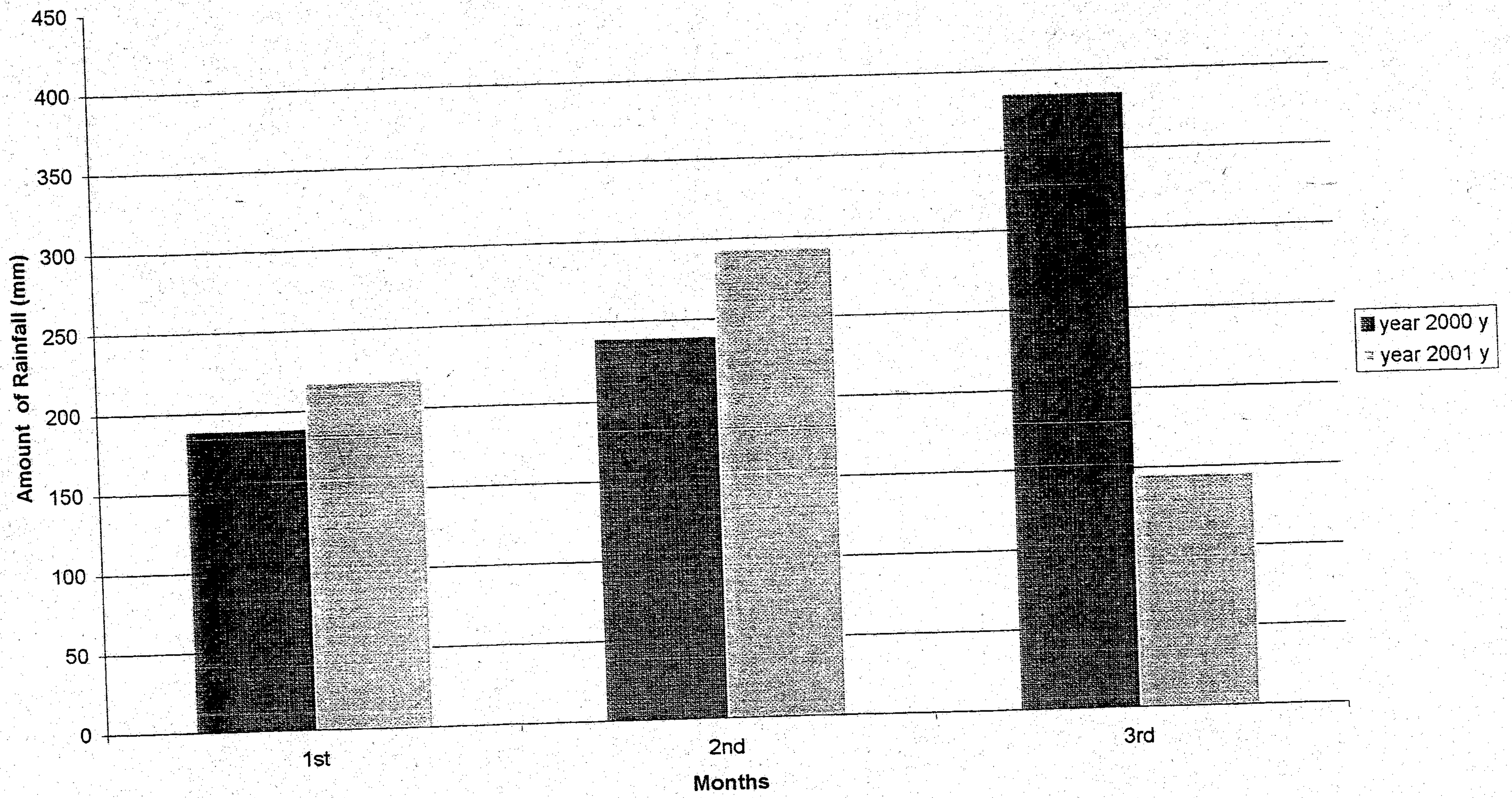


Fig4.5 : Amount of Rainfall During Growing Season Of Rice

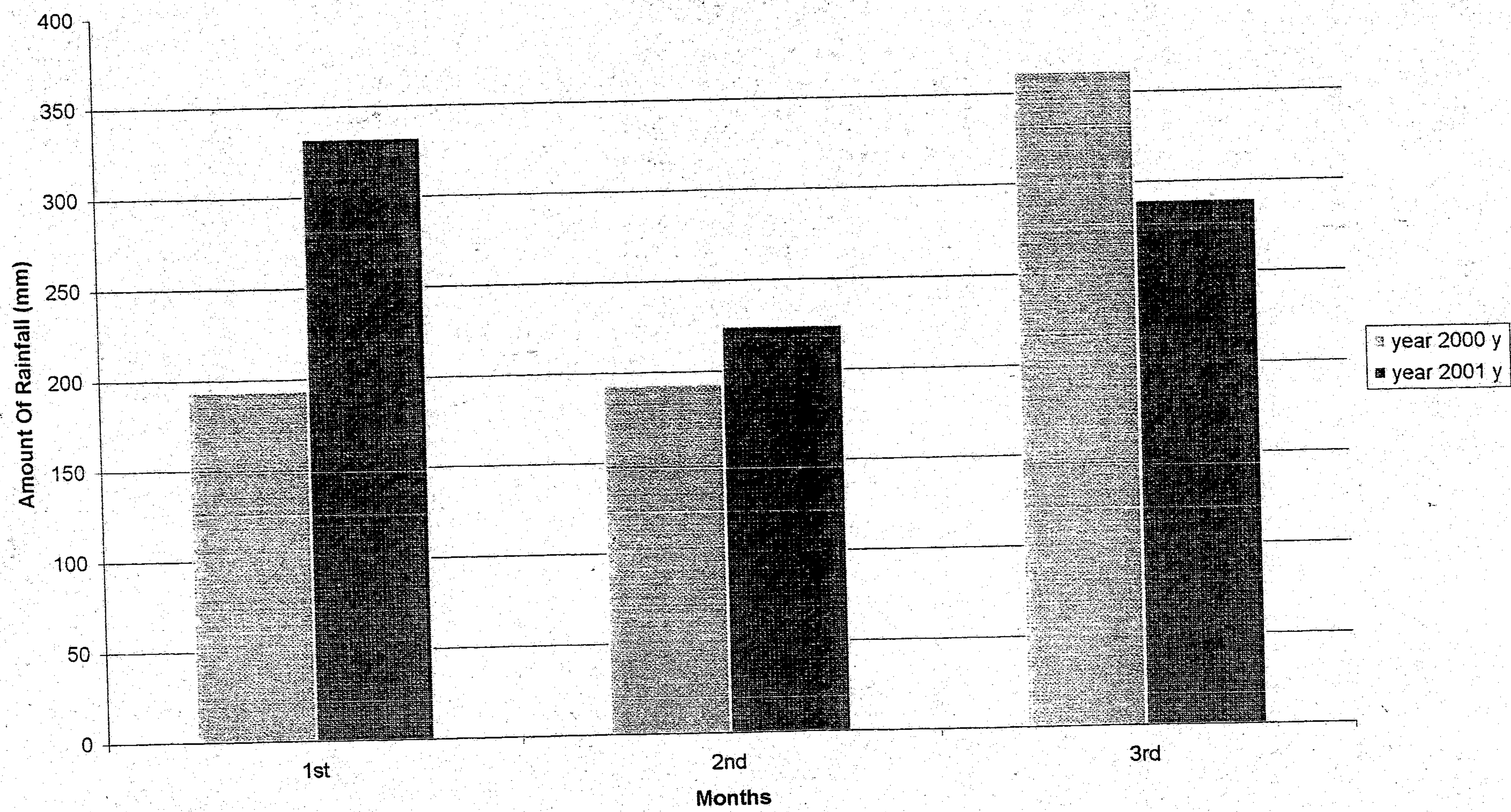


Fig.4.6: Amount of Rainfall During Growing Season of Maize (2000- 2001)

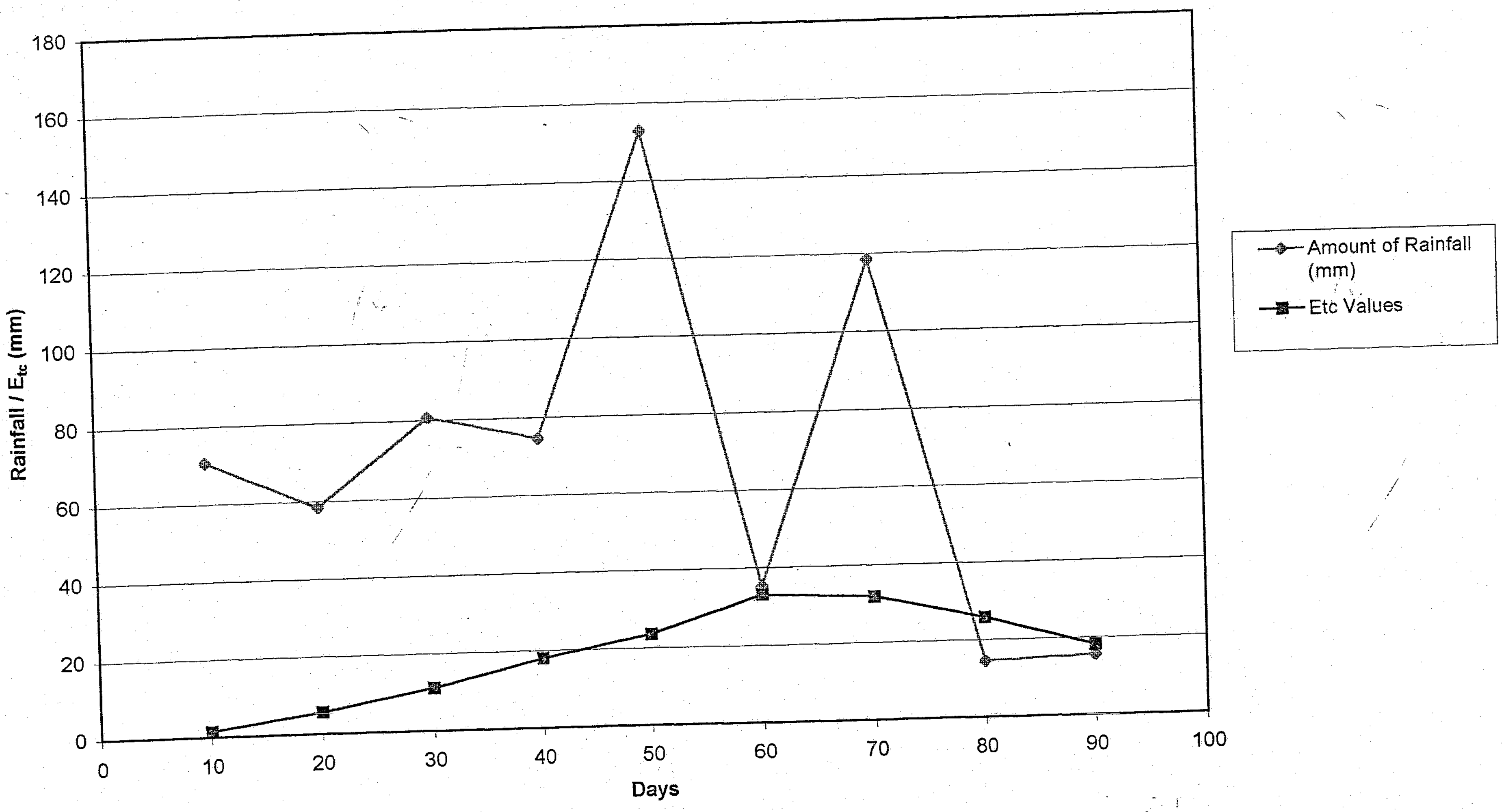


Fig.47 : Graph of Etc and Corresponding Rainfall (Rice)

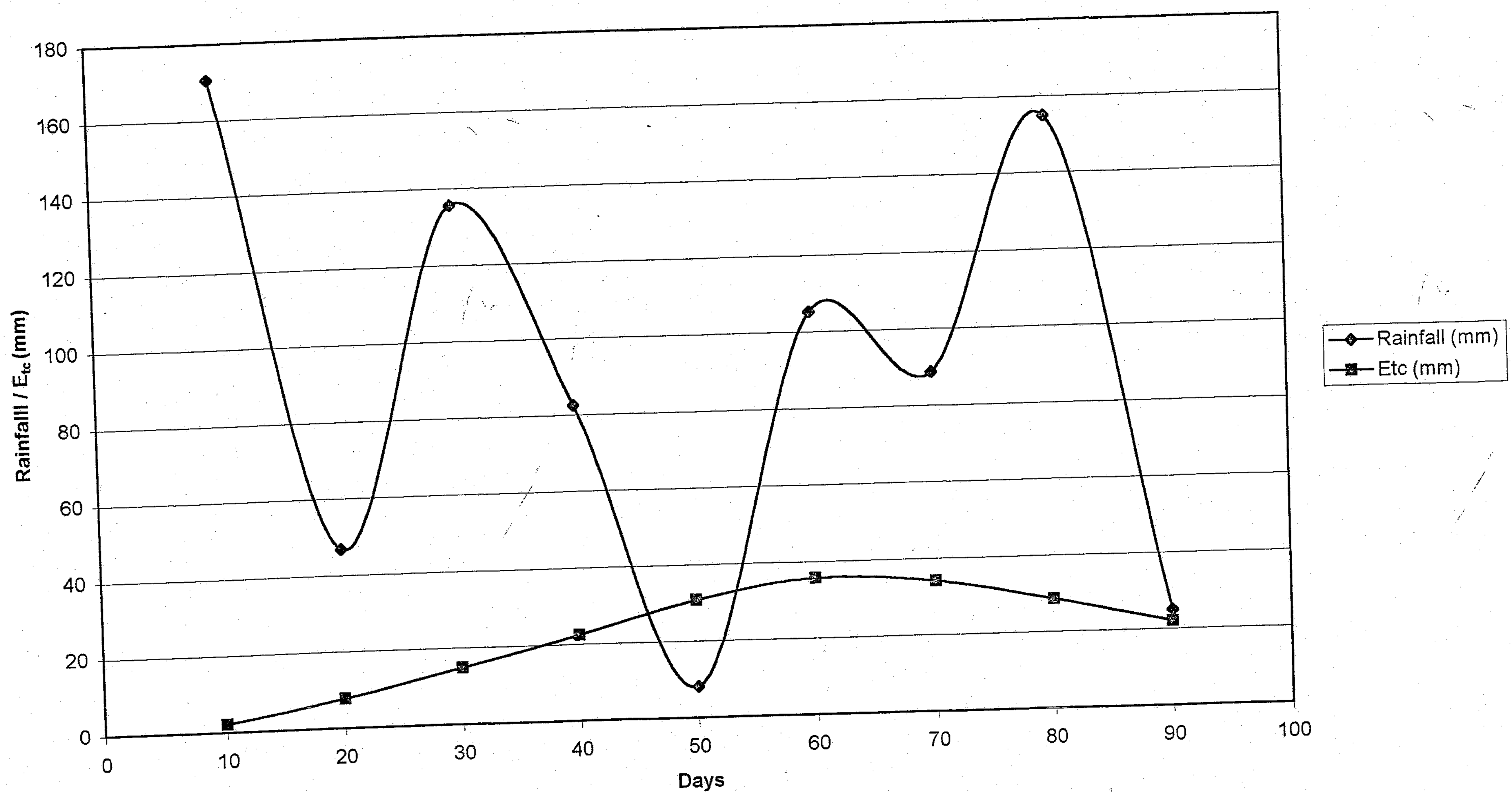


Fig.4.7.1: Graph of E_{tc} and Corresponding Rainfall (Maize)

4.5 Effect Of Rainfall On Yield

To ascertain the yield of crops, the most important factors to be considered are sunlight, rainfall and soil nutrient. While soil nutrient can be improved on, the others are natural except where irrigation is involved as in the case where there is shortage of rainfall. Rainfall plays an important role in the growth and development of crops, because nutrients have to be in solution form before it can be used by the crop. Therefore different crops require different amount of rainfall to be able to have optimum yield. When the amount of rainfall required by a crop, falls below or above that required by the crop, it's growth, development and yield are affected.

In Nigeria guinea savannah, with reference to Minna, the annual average rainfall is 1,214.8mm (Odofin, 2001) and this falls within the range required by both upland rice and maize for optimum yield. Maize requires rainfall within the range of 800 – 1200mm to attain a yield between 1.0 – 1.2 t/ha, while rice requires rainfall between 800 – 1500mm to attain a yield of 1.3 – 1.8t/ha.(Yayock, 1988). About 74% of the annual rainfall is precipitated from June to September, with August as peak. Although the annual rainfall is generally adequate for crops, growing in the agro-ecological zone, it does not have a direct effect on the yield of crops be cause of the variability of monthly rainfall distribution. (Owonubi and Olorunju, 1985).

Although the total rainfall during the growing season of Rice exceeds that required by the crop, the distribution during the growing season shows irregularities. At stage 1 (Initial) and stage 2 (crop development), the rainfall during these stages exceeds that required by the crops and this can be clearly seen from their difference in Table 4. 7. At stage 3 (late season) of growth, the rainfall exceeded that required by the crop in the first decade but at the 2nd and 3rd decades, there was deficiency of water, especially in the 2nd decade, (fruiting stage) and this is expected to have an adverse effect on the yield (0.42t/h). Which is obvious when compared with typical values (1.3 – 1.8 t/ha) within the rainfall range of (800 – 1500) by Yayock (1988). Taking a look at figure 4.7 , between the 80th and 90th day after planting, it can be clearly seen that there was deficient water and this is the period when the rice is sensitive to stress. Also when the total rainfall during the growing season of Rice (260.8mm) is compared with the above standard it can be clearly seen that there was insufficient water during the growing season of rice. The number of rains and the amount during the growing season of rice is shown on Table 4.5.1

From Table 4.7.1, and figure 4.7.1 showing distinct growth stages of maize crop, it would be seen that through the three stages of growth, the total rainfall exceeded that required by the crop. According to Micheal (1994), the yield of maize can be reduced considerably, especially during the period of seedling and flowering, due to it's sensitivity to excess water. Breaking the growth stages into decades, as in Table 4.7.1 and Figure 4.7.1, it would be seen that there was excess water throughout all the decades, except the second decade of the second stage, where rainfall was deficient by 22.72mm, which corresponds to the 50th day as seen of figure 4.7.1. At this period or stage, the crop is sensitive to stress, and this had an effect on the crop during it's development stage. Other factor which attributed to the decrease in yield were, poor drainage of excess water and disturbance from livestock. The yield obtained was 0.75 t/ha. The number of rains and the amount during the growing season of maize is shown on Table 4.5.1. The

Rainfall, Et_c and Et_p for an average of 14years (1987 – 2000), was also analyzed and the result obtained can be seen in Appendix H. It was also observed that the values of the Potential evapotranspiration and Crop evapotranspiration for the year of cropping were consistently lower than that for the 14years average (see Tables 4.7 and 4.7.1 and Appendix H)

Comparison Of Yield With Respect To Rainfall

The average monthly rainfall of 272.4mm in year 2001, yielded 0.75 t/ha of maize, which was 42% less than the yield obtained in year 2000 (1.3t/ha). Though, the average monthly rainfall for 2000 (249.5mm) was less than that of 2001 (278.5mm), the decrease in yield, is attributed to the poor drainage of the plot. Maize yield can be reduced considerably, especially during the period of seedling and flowering, due to it's sensitivity to excess water (Micheal, 1994). During the course of the experiment, it was observed that livestock was another source of disturbance which affected the yield of maize.

It was observed that the average monthly rainfall of 206.9mm in 2001, gave a yield of 0.42 t/ha, and this was 33% less than that obtained in 2000 (0.63 t/ha). Although, the average monthly rainfall for 2001 (218.4mm) was less than that of 2000 (270mm), it can also be clearly seen, that the total rainfall during the growth of rice (655mm) low and insufficient compared to the range (800 – 1500) as stated by Yayock, 1988 for optimum yields.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The following where established during the experiment.

(1) The total rainfall during the growing season of any crop may exceed that required by the crop, what is more important is the rainfall distribution, during it's growth stages. This can be achieved by dividing the growth stages into decades and obtaining the actual water used during those decades.

(2) From the comparison made, it was observed that the average monthly rainfall during the growing season of maize in year 2001 (272.4mm) was more than that of year 2000 (249.5mm), and knowing the maize requires low amount of rainfall, this led to a decrease in the year 2001 (0.75 t/ha). The yield in year 2000 was 1.3 t/ha.

(3) Water was insufficient during the growing season of rice (620.8mm) as compared with that of year 2000 (810.2mm) and that stated by Yayock, 1988 (800 – 1500mm). This led to decrease in yield because rice requires a considerable amount of water for optimum yield.

5.2 Recommendations

At the end of the experiment, the following were recommended:-

(1) To obtain a good comparison, the crops have to be grown in a secluded environment, from any form of environmental stress or disturbance e.g. disturbance from livestock

(2) Analysis should be carried out yearly before planting, to ascertain the soil nutrient status

(3) Drainage facilities should be constructed to drain excess water from the field.

(4) Rainfall should be supplemented by irrigation where it is insufficient.

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PLATE 1: Maize At A Month And Two Weeks After Planting

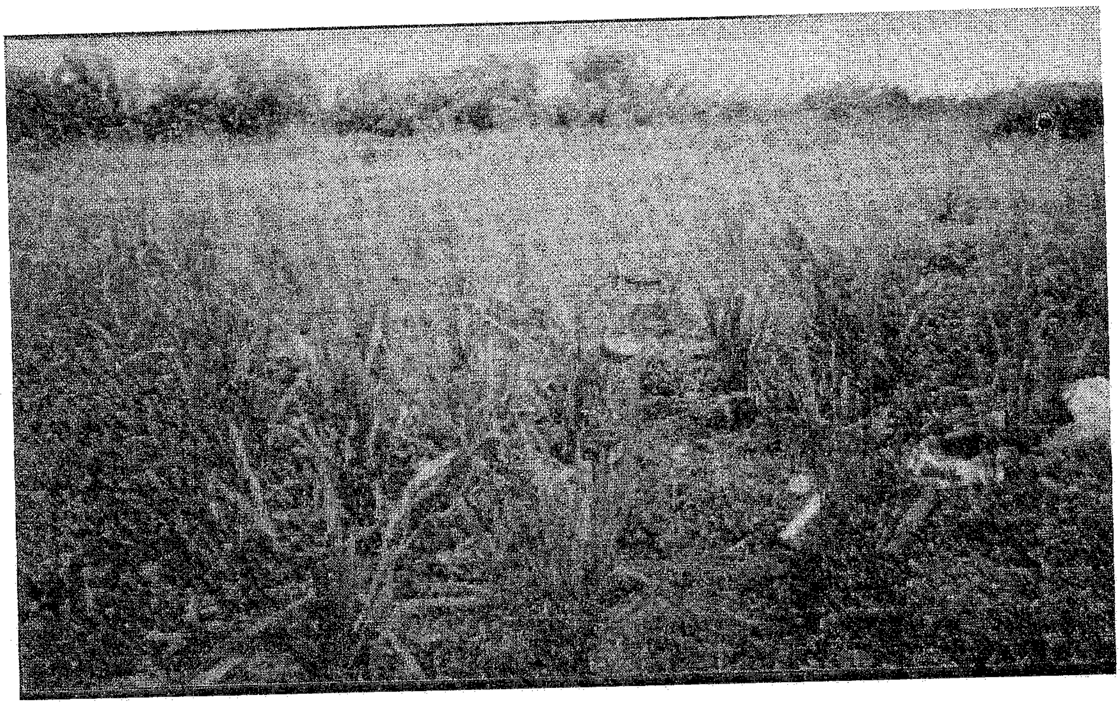


PLATE 2 : Rice At Two Months and Three Weeks after Planting.

APPENDIX A

Table A1: Rainfall Data (1981 – 2001)

Year	*Jan.*	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total(mm)*
1981	-	-	-	22.8	57.6	188.1	239.2	276.3	183.0	92.3	-	-	1059.3
1982	-	-	13.0	99.8	45.3	138.1	288.9	353.2	160.0	104.6	-	-	1202.9
1983	-	-	-	12.2	94.0	96.9	149.2	299.7	228.7	41.0	-	-	921.7
1984	-	-	3.0	54.6	81.2	116.9	188.4	163.6	170.1	73.3	-	-	851.1
1985	-	-	61.2	17.3	141.7	250.6	233.3	249.7	176.6	61.0	-	-	1191.4
1986	-	-	39.6	15.4	86.0	183.3	221.7	243.0	315.8	83.8	19.6	-	1208.2
1987	-	-	13.5	44.6	104.5	83.9	143.7	238.5	94.6	100.1	-	-	823.4
1988	10.5	-	0.1	57.9	94.6	135.5	175.0	309.5	382.1	36.9	-	-	1202.1
1989	-	-	7.3	48.9	215.1	250.8	188.2	206.4	179.6	85.2	-	-	1181.5
1990	-	-	-	107.4	199.5	94.9	198.6	181.0	187.0	141.4	-	-	1109.8
1991	-	-	-	114.5	336.0	180.1	192.9	268.5	190.8	33.9	-	-	1316.7
1992	-	-	1.3	158.2	176.8	162.9	196.4	231.5	230.3	46.6	37.9	-	1241.9
1993	-	-	13.5	8.6	174.4	170.5	189.7	271.1	178.3	63.3	-	-	1069.4
1994	-	-	7.3	72.5	114.4	239.0	142.5	367.2	261.3	208.1	-	-	1412.3
1995	-	-	-	100.5	123.2	144.5	153.7	40.9	189.1	135.7	23.6	-	911.2
1996	-	-	-	48.6	164.7	225.0	259.7	256.9	191.1	127.9	-	-	1273.9
1997	-	-	3.6	80.6	238.4	233.0	172.4	192.7	203.3	115.0	6.1	-	1245.1
1998	-	-	-	82.5	121.2	221.0	155.1	243.0	160.9	139.9	-	-	1123.6
1999	-	7.9	-	35.7	102.8	164.2	243.9	245.7	237.0	212.2	-	-	1159.5
2000	0.3	-	-	3.6	135.9	161.0	208.8	308.5	303.0	153.4	-	-	1274.5
2001	-	-	-	93.9	139	331.7	244.6	230.2	298.8	25.7	-	-	1363.9

Source : - Department of Meteorological Service, Nigeria Airways Authority, Minna

APPENDIX B

IMPORTANT DATES

Rice

Planted on the 20th July 2001

Height after a month = 42.4cm

Height after two months = 75.6cm

Height before harvesting = 96.3cm

Dates of Weeding: - 15th August 2001

5th September 2001

22nd September 2001

Fertilizer application: - 17th August 2001

25th September 2001

Fertilizer applied and quantity = urea (28kg/ha)

Harvested on the 21st October 2001

Total yield = 0.42t/ha

Maize

Planted on the 22nd June 2001

Height after Two weeks = 38.10cm

Height after a month = 71.10cm

Height before harvesting = 195.0cm

Maize started tasselling at approximately a month and two weeks after planting

Dates of Weeding : - 7th July 2001

21st July 2001

4th August 2001

18th August 2001

Fertilizer Application : - 7th July 2001

4th August 2001

Fertilizer applied and quantity = N.P.K 20 : 10: 10 (10kg/ha)

Harvested on the 18th September 2001

Total yield = 0.75t/ha

APPENDIX C

CALCULATION OF BULK DENSITY

$$\text{Bulk density } (P_b) = \frac{\text{weight of moisture can + oven dried soil – weight of moisture can}}{\text{Volume of soil}}$$

Volume of soil = volume of core ring

Volume of core ring = $\pi r^2 h$

Where π = 3.142

r = 3cm (radius of core ring)

h = 6cm (height of core ring)

volume of soil = $3.142 \times (3)^2 \times 6$

= $169.6cm^3$

At depth of 30cm

$$\text{Bulk density} = \frac{190}{169.6} = 1.12g/cm^3$$

At depth of 60cm

$$\text{Bulk density } \frac{200.5}{169.6} = 1.18g/cm^3$$

APPENDIX D

EVAPOTRANSPIRATION AND CROP CONSUMPTIVE USE (RICE)

$E_{tp} = rf\,(0.45\,T + 8)\;(520 - R^{1.31})\,/\,100$

$E_{tp} \times kc = E_{tc}$

E_{tp} = potential evapotranspiration (mm/day)

E_{tc} = crop evapotranspiration (mm/day)

k_c = crop coefficient

T = Temperature

R = Relative humidity

rf = ratio of maximum possible radiation to annual maximum

1st stage of growth (July – August)

$$E_{tp} = \frac{E_{tp}\ \text{July} + E_{tp}\ \text{August}}{2}$$

$$= \frac{2.66 + 2.37}{2} = 2.52\text{mm/day}$$

$$E_{tc} = 2.52 \times 0.55$$

$$= 1.39\text{mm/day}$$

2nd stage of growth (August – September)

$$E_{tp} = \frac{E_{tp}\ \text{August} + E_{tp}\ \text{September}}{2}$$

$$= \frac{2.37 + 3.24}{2} = \underline{\underline{2.81\text{mm/day}}}$$

$$E_{tc} = 2.81 \times 1.15$$

$$= \underline{\underline{3.23\text{mm/day}}}$$

3rd stage of growth (September – October)

$$E_{tp} = \frac{E_{tp}\ \text{September} + E_{tp}\ \text{October}}{2}$$

$$= 3.24 + 5.56 = \underline{4.4\text{mm/day}}$$

$$E_{tc} = 4.4 \times 0.3$$

$$= \underline{\underline{1.32\text{mm/day}}}$$

APPENDIX E

EVAPOTRANSPIRATION AND CROP CONSUMPTIVE USE (MAIZE)

1[st] stage of growth (June – July)

$$E_{tp} = \frac{E_{tp}\ June + E_{tp}\ July}{2}$$

$$= \frac{4.38 + 3.18}{2} = 3.76mm/day$$

$$E_{tc} = 3.76 \times 0.48$$

$$= 1.81mm/day$$

2[nd] stage of growth (July – August)

$$E_{tp} = \frac{E_{tp}\ July + E_{tp}\ August}{2}$$

$$= \frac{3.18 + 3.37}{2} = 3.28mm/day$$

$$E_{tc} = 3.28 \times 1.10$$

$$= 3.61mm/day$$

3[rd] stage of growth (August – September)

$$E_{tp} = \frac{E_{tp}\ August + E_{tp}\ September}{2}$$

$$= \frac{3.37 + 3.24}{2} = 3.31mm/day$$

$$E_{tc} = 3.31 \times 0.55$$

$$= 1.82mm/day$$

APPENDIX F

The daily rainfall from the day of planting to the day of harvesting is given below

For year 2000 (Rice)

1st month (12th June – 11th July) = 187.5mm

2nd month (12th July – 11th Aug.) = 238mm

3rd month (12 Aug. – 11th Sept.) = 384.7mm

Total yield = 0.63t/ha

For year 2000 (Maize)

1st month (10th June – 9th July) = 193.5mm

2nd month (10th July – 9th Aug.) = 192.6mm

3rd month (10th Aug. – 9th Sept.) = 361.6mm

Total yield = 1.3t/ha

For year 2001 (Rice)

1st month (20th July – 18th Aug) = 209.6mm

2nd month (19th Aug. – 17th Sept.) = 262.5mm

3rd month (18th Sept. – 21st Oct.) = 148.7mm

Total yield = 0.42t /ha

For year 2001 (Maize)

1st month (22nd June – 21st July) = 352.9mm

2nd month (22nd July – 21st Aug.) = 195.9mm

3rd month (22nd Aug. – 18th Sept.) = 268.4mm

Total yield = 0.75 t /ha

APPENDIX G

TableG1 :Rainfall Date For Year 2000

Month / Date	Amount (mm)	Month/Date	Amount(mm)	Month/Date	Amount(mm)
Jan 19	0.3	July 19	13.5	September 30	24.9
April 10	2.4	July 27	27.4	October 1	19.8
April 30	1.2	July 29	28.7	October 5	1.2
May 4	1.2	July 30	0.8	October 7	12.0
May 16	21.0	July 31	4.8	October 8	84.0
May 17	37.3	August 2	4.3	October 11	8.8
May 18	1.6	August 3	3.7	October 12	9.9
May 19	11.8	August 8	30.2	October 14	9.0
May 20	1.6	August 12	45.4	October 15	8.3
May 21	1.2	August 13	10.0	October 16	0.4
May 23	1.6	August 14	0.2		
May 24	2.3	August 15	34.2		
May 25	3.9	August 17	22.9		
May 26	1.5	August 18	8.6		
May 27	26.9	August 19	2.4		
May 30	6.3	August 21	26.4		
May 31	11.2	August 23	0.2		
June 1	16.5	August 24	63.0		
June 2	3.0	August 25	13.9		
June 4	4.8	August 26	1.9		
June 5	0.6	August 27	2.9		
June 6	0.1	August 29	19.9		
June 7	15.2	September 1	2.7		
June 10	6.0	September 5	1.8		
June 13	2.9	September 6	4.5		
June 14	45.6	September 9	30		
June 15	2.6	September 10	63.3		
June 17	2.0	September 11	5.8		
June 18	16.7	September 13	1.6		
June 20	28.4	September 14	9.6		
June 21	12.7	September 16	6.6		
June 22	3.8	September 19	17.1		
July 1	26.1	September 20	21.6		
July 2	4.0	September 21	11.2		
July 4	20.7	September 23	4.0		
July 5	15.6	September 24	8.5		
July 6	6.4	September 25	23.26		
July 16	21.7	September 26	45.2		
July 18	39.1	September 27	0.3		

TableG2 :Rainfall Date For Year 2001

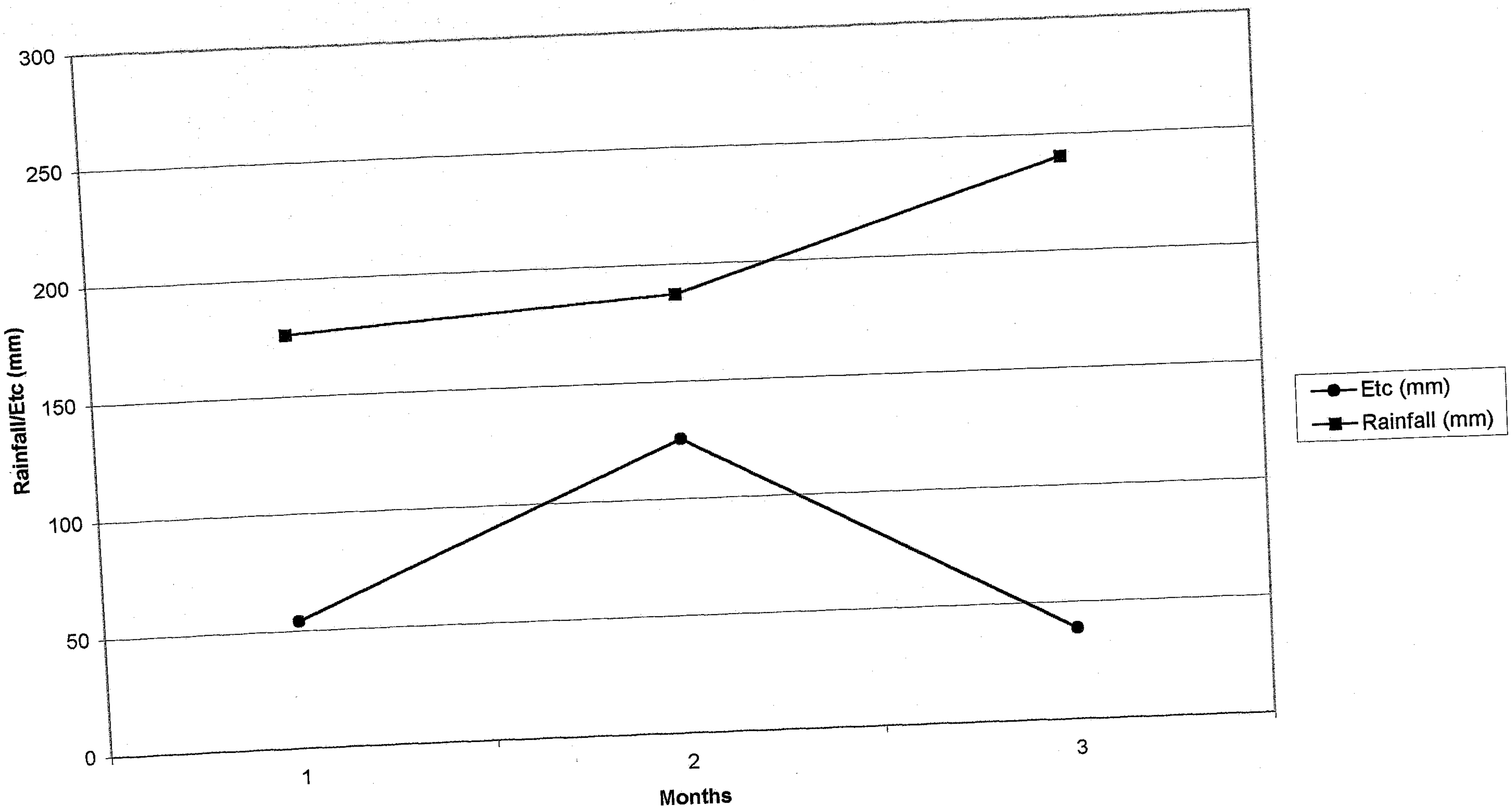
Month / Date	Amount (mm)	Month/Date	Amount(mm)	Month/Date	Amount(mm)
April 2	17.9	July 21	7.6	October 3	0.3
April 4	5.7	July 24	20.1	October 4	7.4
April 14	12.9	July 27	0.2	October 5	0.8
April 17	13.7	July 28	11.7	October 6	1.6
April 19	0.8	July 31	50.5	October 8	3.5
April 20	5.1	August 2	1.7	October 10	11.3
April 23	2.0	August 3	1.7	October 16	0.8
April 28	35.8	August 4	1.1		
May 5	5.9	August 5	1.6		
May 8	2.3	August 7	1.8		
May 12	63.3	August 9	0.2		
May 14	18.0	August 11	3.4		
May 15	22.3	August 12	1.4		
May 16	1.6	August 14	63.4		
May 28	1.7	August 15	12.2		
May 29	0.7	August 20	24.9		
June 1	13.4	August 22	5.2		
June 4	2.8	August 23	0.6		
June 7	30.2	August 26	43.9		
June 8	0.2	August 29	38.9		
June 10	23.7	August 31	0.2		
June 12	13.6	September 2	42.6		
June 13	13.0	September 3	0.4		
June 16	27.0	September 4	67.7		
June 20	3.1	September 5	30.0		
June 21	0.4	September 8	13.9		
June 22	26.8	September 11	3.1		
June 24	1.1	September 12	1.9		
June 26	18.1	September 14	3.1		
June 28	80.3	September 16	4.8		
June 29	17.6	September 17	8.3		
June 30	26.6	September 19	3.8		
July 4	20.5	September 21	42.8		
July 9	3.0	September 22	6.3		
July 11	23.3	September 23	3.9		
July 15	30.1	September 24	20.8		
July 16	35.9	September 25	30.0		
July 19	31.0	September 27	11.0		
July 20	31.0	September 30	4.4		

APPENDIX H

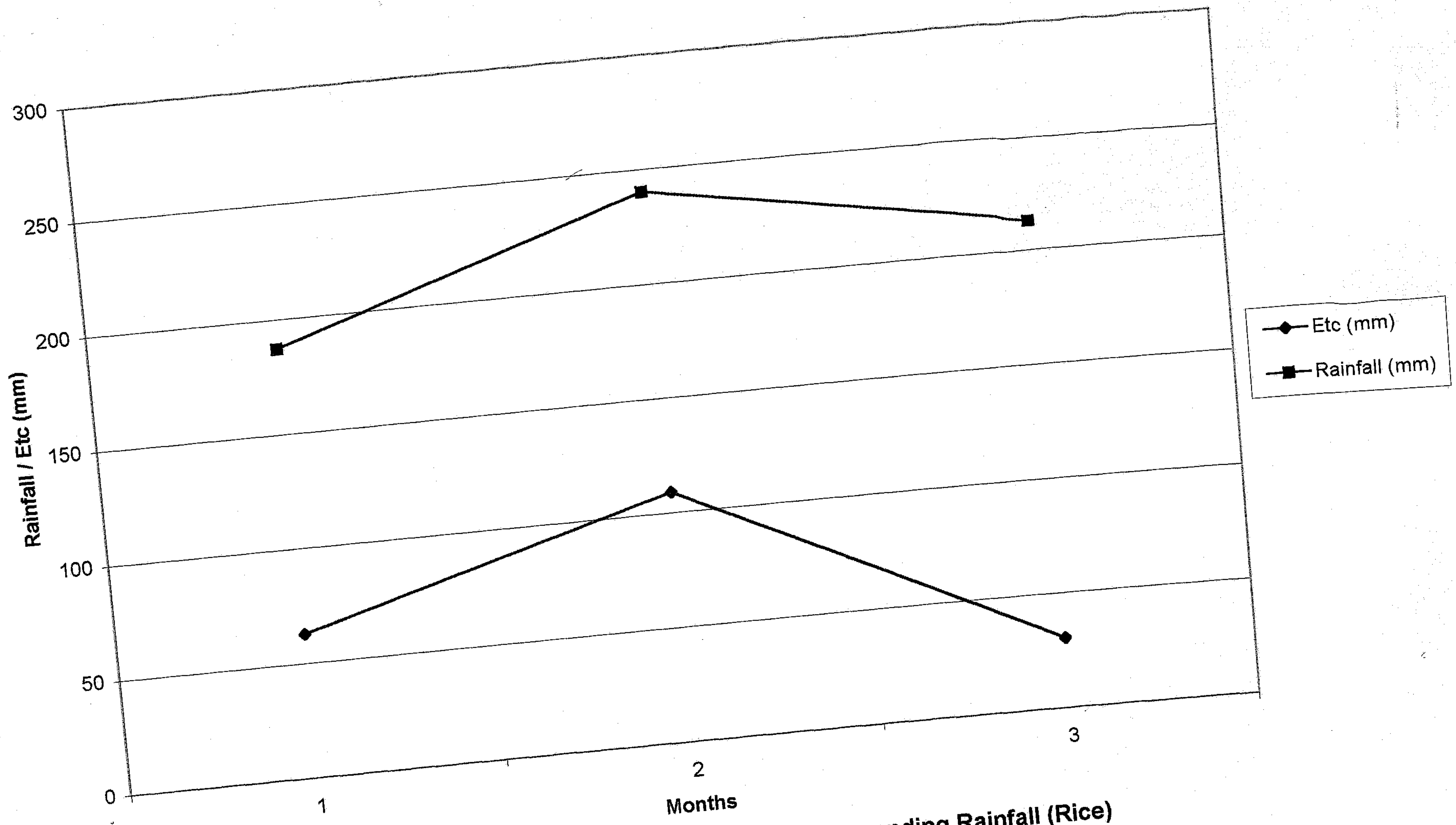
Average Rainfall E_{tc} E_{tp} for 14 years (1987 – 2000)

Crop	Stage of Growth	Amount of Rainfall (mm)	E_{tp} BMN calculated (mm/month)	E_{tp} BMN calculated (mm/ day)	E_{tc} (mm/month)	E_{tc} (mm/day)
Maize	1st Month	176.2	112.5	3.75	54	1.8
	2nd Month	187.2	114	3.8	125.4	4.18
	3rd Month	240.1	70.2	2.34	38.7	1.29
Rice	1st Month	187.2	114	3.8	62.7	2.09
	2nd Month	240.1	70.2	2.34	108.9	3.63
	3rd Month	213.5	101.1	3.37	30.3	1.01

See next two pages for Graph of Average Etc and corresponding Rainfall



Graph of Average Etc and Corresponding Rainfall



Graph of Average Etc and Corresponding Rainfall (Rice)