INFLUENCE OF SUBIRRIGATION REGIMES ON CROP (MAIZE) YIELD

BY

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CERTIFICATION

This is to certify that this project was carried out by Abioye Abdulwaliu, registration No. 92/2388 of Agricultural Engineering Department, Federal University of Technology Minna, under my supervision.

.... 29/12/98 ....

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DEDICATION

This piece of work is dedicated to my beloved and caring parent, ALHAJI IDRIS ATANDA ABIOYE and ALHAJA MUSILIAT A. ABIOYE, in recognition of the immeasurable favour shown to me right from my child hood up to this period of obtaining my University education.

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The praise be to Allah the cherisher and sustainer of the world. Most gracious, most merciful, master of the day of judgement. Thee do we worship and thine aid we seek. Show us the straight way, the way of the one whom has bestowed thy grace, those whose (portion) is not wrath and who go not astray (Ameen). Glory be to Allah a number of times equal to the number of his creatures, to the extent of his pleasure, equal to the weight of his throne and as many as his words.

I am using this priveledge to give my words of appreciation to my project supervisor Engr. N.A. Egharevba for his understanding and cooperation given to me in the course of research project. I will like us to say a big thank you to my H.O.D., Dr. M.G. Yisa and all members of staff of the department for their unrelenting effort and for giving me the necessary information required, in order to fulfil the requirement in obtaining degree of Bachelor of Engineering (B.Eng.) in Agricultural Engineering Department

I am using this prayer that may Allah, my Lord, bestow on my parent (Alh. I.A. Abioye & Alhaja M.A Abioye) thy mercy even as they cherished me in childhood, to give my unreserved appreciation and gratitude to them for their effort right from my childhood up to this period of obtaining my university education. O our Lord cover (us) with thy forgiveness me, my parents, and (all) believers, on the day that the reckoning will be established. My prayer is that may Allah reward them abundantly with his mercy (Amin).

I equally give my appreciation and thanks to all members of my family for their various contribution in one form or the other to make me whom I am today. I say may Allah forgive them of their short comings and may Allah accept their righteous deeds as an act of worship (Amin). I am obliged to recognise my elder brothers, sisters and the younger ones for their roles in making things easy for me, I pray that may Allah make their affairs an easy

task for them all (Amin).

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ABSTRACT

The experiment carried out on influence of subirrigation regimes on crop (maize) yield is presented. The experiment was carried out in the green house environment at National Cereals Research Institute (NCRI), Badeggi in Bida local government area of Niger State. DMR - YE maize variety (Yellow maize) were planted in metallic containers of internal diameter of 40cm and 72cm depth respectively. The parameters monitored during the cropping season (June-Sept 1998) within the green house environment were leaf area, plant height, water use as well as grains yield. Water use at the first 10 days interval after planting were as follows: 6.58cm, 12.39cm, 13.80cm and 17.25cm for the treatments 30cm, 45cm, 60cm and free drainage of water table depths respectively. The cumulative water use over 90 days are 35.69cm, 79.49cm, 94.76cm and 109.25cm respectively for 30cm, 45cm, 60cm, and Fd depths. The 30cm water table depth had no grain yield, the 45cm water table depth gave 0.65kg, the 60cm water table depth produced 0.52kg and free drainage gave 0.43kg. The experiment established that for successful irrigation design using subirrigation method water table for the soil (Sandy loam) could be between 45cm and 60cm below the soil surface.

CHAPTER ONE

INTRODUCTION

1.1 GENERAL BACKGROUND

Looking at the population explosion of humanity, there is need for adequate and constant food production to meet the trend in which humanity is growing and for its survival. Since all factors of survival of humanity depends on regular provision of food, then the question is, how to combat food production with population explosion of humanity and its survival. There are some factors which determine high productivity of food and these determinants are natural phenomena in occurrence. The major factor that influence high productivity of food is climatic condition of the atmosphere. One of the elements of climatic condition is rain. Rain is very vital in the production of food. This precipitation has its constituents that also affect high crop yield such as amount of rain fall, its intensity and period of rainfall. All these are to be carefully observed and maintained for adequate food production.

Rain needs to be utilized and preserved for crop production through farming system, in a situation of adverse effect of either lack of rain or excessive rainfall. The chain of technological advancement tracking on agriculture has made it possible only through a systematic system of irrigation. Excess water can be stored by constructing dams, reservoirs and releasing it to the fields whenever needed (Gupta, 1972). In technical term, this system of technological advancement in agriculture is known as irrigation system. It is a very important system for the increased yield of crops, in order to meet the required expectation of food production for the survival of humanity and to curb famine.

Irrigation system had been in existence as far back 3300 B.C. in Egypt practiced near river Nile. However, with the trend of development in engineering and technology, irrigation can be practiced on large scale project as means of curbing the population explosion of humanity by providing high productivity of food. In ancient practice of irrigation, surface irrigation method was being practiced such as furrow, basin, borders, flooding, checks but in technological age, the practice of irrigation has been extended beyond surface irrigation in which irrigation water is applied to the soil surface and infiltrate through the soil within the root zone of crops.The modern practice of irrigation methods includes sub-surface known as subirrigation, sprinkler, trickle or drip.

High productivity of food is achieved when there is available of food at affordable cost to the generality of humanity. By taking this into consideration, there are some factors that influence irrigation regimes which are suitable for irrigation system applicability and not undermine the output. In view of this, there involve some considerations in the selection of a suitable irrigation regimes for a farm or a region and such considerations include the following factors(Dyaron and Reger, 1990);

1. The technical efficiency in terms of control of the amount of water applied
2. The cost of investment operation and maintenance
3. The cropping system and
4. General economic data that is, the availability and cost of capital, labour, and cost of inputs and outputs. In addition, general data pertaining to the crop(s) to be irrigated.

1.2 NATURE OF PROBLEM

In most developing countries, farming system depends solely on rainfall which restrict production of food only during raining season. Irrigation system is a way to this climatic dependence of rain but the problem lies in inadequate estimate of irrigation water requirement of crops(Linsley, Franzini, Freybers, and Tehobanoglous, 1992). These problems among others are:

1. Determination of sources of available water
2. Design of storage reservoir to assure necessary water
3. Analysis of chemical quality of available water
4. Economic analysis of the project to determine whether the estimated cost is returnable from the potential benefit and
5. Financial analysis to establish a repayment plan.

Therefore, there is urgent need to address some of the problems poised to irrigation project scheme with adequate and correct data for successful implementation of the project.

1.3 JUSTIFICATION OF THE OBJECTIVES

Irrigation is an expensive scheme that involves large sum of capital in the initiation of the project. Success of irrigation project depends on available data/information in designing irrigation project. In addition irrigation system is a means to enhance food supply for the humanity.

1.4 AIMS AND OBJECTIVES OF THE PROJECT

In an attempt to find available data ready for proper irrigation design for crop (maize), the following are to be established:

1. To obtain the required water needs for crop (maize) and its relationship to yield.
2. To determine the effect of water table depth on crop yield.
3. To determine the crop (maize) root zone depth for proper root growth.

CHAPTER TWO

LITERATURE REVIEW

Generally, irrigation is understood as systematic application of water to soil for the purpose of supplying the moisture essential for plant growth.

2.0 IRRIGATION ENGINEERING AND SCOPE OF IRRIGATION SCIENCE

Irrigation technology includes design of works related to river control, drainage of water logged areas and generation of hydro-electric power. It also deals with design, construction of all related works, such as dams, head - works distribution systems in connection with storage or diversion of water and its distribution as well as sub soil drainage (Gupta, 1972).

The application of water to the crops at the proper time in proper quantities, its distribution on the fields and the best method for its application is also an aspect of irrigation science. In a broader approach, irrigation water serve the following purposes:

1. Acts as a solvent for the nutrients
2. Supplies moisture to the soil.
3. For the chemical actions within the plant leading to its growth.
4. Controls temperature of the soil
5. Dilutes the salts present in the soil
6. It softens the tillage pans

2.1 METHODS OF IRRIGATION

Basically, irrigation is accomplished with the following methods:

1. Surface irrigation
2. Sub-surface irrigation (subirrigation)
3. Sprinkler irrigation

4. Drip or trickle irrigation

2.1.1 SURFACE IRRIGATION

This method involves application of irrigation water on soil surface with the aid of force of gravity. This irrigation method is further classified as follows:

1. Border strip flooding
2. Check flooding
3. Basin flood
4. Furrow method

2.1.2 SUBIRRIGATION

This is the application of water below the surface of the soil, thus causing the water table to rise. This is done by maintaining an artificial water table at some depth depending upon the soil texture and the depth of the plant roots. The applied water to the soil reaches the plant roots through capillary actions. This method favours soils that have reasonably uniform texture and permeable enough for water to move rapidly both horizontally and vertically within and for some distance below the crop root zone.

Subirrigation is used for soils having a low water holding capacity and a high infiltration. With this method of water application, water level is maintained at optimum depths for crop needs at different growth stages. Subirrigation does not interrupt cultivation of fields (Michael, 1978).

2.1.3 SPRINKLER IRRIGATION

The method of applying water to the surface of the soil in the form of a spray (Simulated rainfall). Sprinkler irrigation requires a pressurized system. This pressure is provided by gravity flow from a high elevation reservoir or elevated tank or directly from ι pump. sprinkler method of irrigation have large potentialities for all types of soil, lands)f widely different topography, slopes and for many crops (Hansen, Israelsen and Strughan, 1979).

2.1.4 DRIP OR TRICKLE IRRIGATION

It is the laying of perforated pipe along the ground at the base of row of plants. The perforations are designed to emit a trickle and spaced to produce a wetted strip along the crop or a wetted bulb at each plant. This method of irrigation has advantage of excellent control of water which is close to the rate of consumption by the plant. Evaporation from the soil surface is minimal and deep percolation almost entirely avoided. Application of nutrients could be done directly to the plant roots by adding liquid fertilizer to the water. (Hansen, Israelsen and Stughan, 1979)

2.2 DRAINAGE

The purpose of drainage is to remove excess water from field otherwise it will affect crops. Adequate drainage of crop producing lands require a general lowering of shallow water tables. The following methods are used in lowering water table (Salami, 1997).

1. Open channel drains
2. covered (buried) clay or concrete pipe
3. Pumping ground water.

2.2.1 EFFECT OF POOR DRAINAGE

The effect of inadequate drainage system in any farmland can be summarized as follows:

1. Result in poor aeration
2. Uptake of nutrient and water are restricted

3. Nitrogen becomes limiting factor that is not easily absorb by root hair.

4. High water table destroy soil structure

5. Soil temperature is affected

2.3 SOIL PHYSICAL PROPERTIES INFLUENCING IRRIGATION

Soil is made up three phase components such as solid phase made of mineral, organic matter and various chemical compounds, the liquid phase called soil moisture and the gaseous phase called soil air. The solid phase includes soil particles, size and shape. Numerous living organisms are included in the soil as its constitute and these organisms such as bacteria, fungi, algae, protozoa, insects and small animals which directly or indirectly affect soil structure and plant growth.

2.3.1 SOIL COMPOSITION (MECHANICAL COMPOSITION)

Solid phase is composed of mineral constituents known as mechanical composition of soil. It consists of rock particles developed in situ by weathering or deposited in bulk by wind or water. Mineral soil particles are classified according to their size. Mechanical composition of soils are gravel, sand, salt and clay. The gravel is of large size in diameter between 2cm and 2mm. Minerals of lesser diameter than 2mm is the fine earth. sand and silt particles are approximately spherical or cubical in shape. Clay particles are plate or lath shaped (Michael, 1978).

2.3.2 SOIL TEXTURE

Soil texture is determined by the relative proportion of sand, silt and clay. Designation of soil texture is done using the names of the predominant size fractions of mineral solid constituents. A soil texture classified as loam entails all three major size fraction occur in sizeable proportions. Modification of textural properties of a soil is appreciably done by organic matter content, types of clay mineral present and types of ions associated with them. Soil texture forms the basic factors of voids aerated in the soil formation is dependent on the textural classified of the soil (Michael, 1978).

2.3.3 CHEMICAL NATURE OF SOILS

Mineral components of soil are made largely of silica and silicates. Chemical composition of particles varies from profile to profile which contains the larger particles having higher silica while finer particles contain more potassium, calcium and phosphorous. Dominant minerals are quartz in sand, quartz and feldspars in fine sand and silt, mica, vermiculite, montmorillonite kaolinite and amorphous colloids in clay (Michael 1978).

2.3.4 SOIL STRUCTURE

Cementation of soil particles to form natural units of compound particles or aggregates separated by pores, cracks, or planes of weakness is described as soil structure. Structure is used to describe arrangement of primary particles into natural aggregates or peds. Structural units are of four principal types.

1. More or less flat or platy
2. Prism - shaped, predominantly vertically bounded by flat surfaces.
3. Blocky or many sided
4. More or less round or spheroidal

Aggregates are classified as fine, medium, or coarse, depending on their sizes. Soil organic matter plays a major role in soil aggregation. A good soil structure has ability of increasing soil aeration, water holding capacity and facilitates microbiological activity (Yodeowei, Ezedinma, and Onazi, 1986).

2.3.5 PLANT STRUCTURE

The morphology of a plant consists of roots, stem and leaves. Leaves are borne throughout stem in all plants. These organs are mainly responsible for the loss of water. Pores on leaves are the stomata and surranded by guard cells. The stomata regulate the loss of water as vapours and exchange of carbondioxide in the leaf and other organs. The leaves maintain their continuity of structure with stem which has conducting tissues which are xylem and phloem. Xylem are the main channels of water transport. Root hair is largely involved in water uptake (Michael, 1978).

2.3.6 MOISTURE STRESS AND PLANT RESPONSE

Miximov (1929) found that large yield reductions in cereals occurred when water was applied during the state of rapid elongation prior to heading. Stress is also important during the maturation of grain filling state. Denmead and Shaw (1960), found a yield reduction of 21% due to moisture stress during the ear filling period in corn.

Earlier, Robins and Domingo (1953) found that deletion of moisture to wilting percentage for 1 or 2 days during tasseling resulted in as much as a 22% grain yield reduction of about 50%. More recent works by researchers (Cloaosen and Shaw, 1970, Wilson, 1968), showed that moisture strees, occuring at various vegetative and productive stages of growth and development of crops reduced final grain yield.

The yield of a crop is the integrated result of a number of physiological processes. Water stress can affect photosynthesis and respiration. It can also affect growth and reproduction. Reduction in leaf area, cell size and inter-cellular volume are common under water stress.

2.3.7 MOVEMENT OF WATER AND NUTRIENTS IN PLANTS

Soli (1998) worked on the effect of groundwater table depth (10-30cm) as it influence maize performance in a green house environment. He concluded that high water table affect the yield of crop (maize) and that lower water table favours the yield of crop (maize). Movement of water from cell to cell is through osmosis. Osmosis involves mass flow of water through pores of different permeable membrances.

Movement of nutrients in plants involves ions from soil to root surfaces, ion accumulation in root cells, movement of ions from root surfaces into the xylem and finally their translocation from roots to shoots. Plants nutrients such as fertilizer, fertilizers are substance that when added to the soil supply those elements required in the nutrition of plants.

Tisdale and Nelson (1966) reported that when fertilizer is properly applied to soil, it increases their productivity. Benjamin (1991) shows that the response of maize to nitrogen fertilizer is dependent not only on the amount of nitrogen supplied but also on the prevailing environmental conditions, most particularly temperature, humidity, and moisture and finally Benjamin (1991) concluded that improve maize variety will normally respond better to management practices such as irrigation and fertilizer application than an unimproved local variety.

2.4 EVAPORATION, TRANSPIRATION AND CONSUMPTIVE USE

Evaporation is a process which converts water into vapour. The convertion occurs through absorption of heat energy. Evaporation of liquid water transformation to vapour from open water, bare soil, or vegetation with soil beneath.

Transpiration occurs as that part of the total evaporation which enter the atmosphere from the soil through the plants.

Evapo transpiration is the sum of the amount of water transpired by plant during the growth process and that amount that is evaporated from soil and vegatation around the growing crop (Ekwue,1990). Potential evapo-transpiration (PET) is the evapo-transpiration from large vegetation covered land surface with adequate moisture at all times (Thornthwaite, 1948). Penman (1947) concluded that potential evapotranspiration as the evapotranspiration from an activity growing short green vegetation completely shading the ground and never short of moisture availability.

2.5 WATER RELATIONS OF SOIL

Pore spaces in soil is partly filled with soil air, liguid vapour and partly with liquid phase of soil water. Ghuman and Maurya (1986) gave the assertion that irrigation water becomes very necessary, because a large amount of irrigation water would affect the suitability of the soil for crop production. Water affects intensely many phsyical and chemical reactions of soil as well as plant growth. Soil serves as storage reservoir for water.

2.5.1 MOVEMENT OF WATER INTO SOILS

The movement of water in the soil is complex because of the various states and directions water moves and also because of the forces that cause it to move. The movement of water from the surface and through the soil is called soil water intake (Obiechefu, 1990).

2.5.2 INFILTRATION

Infiltration refers specifically to entry of water into the soil surface. Infiltration capacity is the measure of the extent a given soil under specified conditions can take in water, (Obiechefu. 1990). It is quantitatively found to be equal to the difference between the initial moisture content and the moisture content at saturation (Okoro, 1978). Horton (1940) defined infiltration capacity as the maximum rate which a given soil, when in a given condition can absorb rain as it falls. Infiltration rate is the rate of water entry into the soil.

2.5.3 PLANT WATER RELATIONSHIP

The importance of water to living plants is given by Chapman and Carter (1776) as follows:

a. Water is the major constituent of the living cell between 85% and 95% of the live weight of most plant tissues in plant.

b. Water in the living cells is a universal solvent that carries essential nutrients through the plant and allows critical chemical reactions to occur.

c. Water through its complex relations with osmotic substance (such as salts) in the cell is essential for cell turgidity and for cell elongation.

The metabolic activity of cells and plants is closely related to their water content. Growth of plants is controlled by the rates of cell division and enlargement and by the supply of organic and inorganic compounds required for the systhesis of new protoplasm and cell walls. Water plays a leading role in photosynthesis of a plant.

2.6 MAIZE (ZEA MAYS)

Maize can be successfully grown as a rainfed crop and under irrigation with family names Graminea.

BOTANY:- Maize is an annual plant belonging to the grass family, it matures over a short period of a few months. Height varies from about 1.5m in short varieties to over 3m. Maturity time is usually 100-120 days, but some variation exists in this respect. Male flowers called tassels, emerge after 50-60 days at the apex of the plant. Female flowers, called silks, emerge from the leaf axils shortly after tasselling. The seeds are formed on cobs which are the compacted stalks of female inflorescences.

VARIETIES AND YIELDS

Maize is an out-pollinated species with many varieties most of which are adapted to or bred for particular geographical areas. Maize varieties have been classified on the basis of the grain. Three main groups are grown in tropical countries:

1. Dent Maize:- These have large cobs and large grains which shrink on drying to produce a shallow hollow at the end of each grain.
2. Flints:- These generally have smaller cobs which bear hard round grains.
3. Sweet Corn:- The grains are soft and sweet with little starch and are grown for eating as a fresh vegetable.

High-yielding maize varieties are often smaller plants with vertical leaves rather than very large spreading leaves (Williams, Chew and Rajaratnam, 1980).

CLIMATE AND SOILS

Temperature affects moisture requirements and generally more moisture is required under tropical conditions than under temperature conditions. Maize is specially sensitive to moisture stress around the time of tasselling and fertilisation and under tropical conditions a 25mm deficit of moisture at the two weeks around fertilisation will cause a significant yield reduction. Maize also needs optimal moisture at planting when the soil should be near field capacity. Very humid conditions are not considered good for maize, particularly during the maturation period. This is due to the low sunshine which is associated with humid conditions, and to the development of diseases of the flowers, cobs, and leaves with high humidity. Another problem of very humid and rainy regions is poor pollination which produces cobs with many missing grains.

Maize is grown on a wide variety of soils. One essential requirement however is good drainage. Maize will grow on moderately acid soils but does best on soils with pH values above 5.0. Maize can be grown well on alkaline soils provided nutrient deficencies of iron and mananese are countered.

PLANTING:- Seed should be drilled or planted 2 - 3 cm deep and may be planted on the flat, on the top of ridges, or in the furrows of ridges depending on conditions. Many flint varieties are small varieties and are best planted at above 60cm row spacing. Smaller varieties with more erect foliage have a higher yield potential, when planted more closely. In regions of a short rainy season planting must be done promptly so as to make full use of the rain and maize varieties maturing quickly should be grown.

WEED CONTROL: Weeds greatly reduce all crop yields and maize is no exception. The seeds should be planted as soon as possible after tillage of the soil, so that they can grow before the weeds. Herbicide can be used with a simple knapsack sprayer.

HARVESTING AND STORAGE

Maize is harvested by hand over most of the tropical world. Cobs are picked before they are fully ripe as sweet cob. If required for the grain they are left till the grains harden. Maize cobs should be stored in a dry place. Seeds cobs are chosen from the crop at the time of harvest.

CHAPTER THREE
MATERIALS AND METHOD

3.0 FIELD LAYOUT (NATIONAL CEREALS RESEARCH INSTITUTE)

National Cereals Research Institute (NCRI) is situated along kilometer 143 on Bida - Suleja road near Badeggi in Niger State. It is zoned in the southern guinea zone of savanah region of latitude 9° 45′ North and longitude 6° 07′ East. Badeggi with its catchment of 1219mm rainfall annually. During raining season, the wet period are experienced in June, July, August and September. While dry season is observed in November to March with less than 38mm of rainfall. The ralative humidity ranges from 80% (June - september) to 60% (January - February). Harmattan wind prevails for long period of time. Mean temperture ranges from 20.1°C (June - February) to 30.2°C (October - May) rising to 36.70°C between March and April.

3.1 GREEN HOUSE

The experiment was set up in green house condition. The green house facilitates completely prevention of rainfall for adequate study on the influence of subirrigation on crop yield. The green house is designed to stimulate the field condition but only with absence of rainfall. Dimension of the green house in which the experiment covered as follows:

Length is 13.2m and breadth is 6.3m respectively, wall height from ground floor is 1.25m.

Net mesh height from wall to rafter is 1.8m

Height of rafter from wall to rafter is 0.85m.

The green house is covered with white transparent plastic to allow radiation of sunlight for photosynthesis to take place. For adequate water supply taps are installed in the green house to facilitate water application to crops.

3.2 EXPERIMENTAL DESIGN

Metallic containers were used for the experiment. The containers are of 72cm height and 40cm is diameter respectively. Four treatments were observed with four replicates except for 30cm water table depth with no replicate. This was due to financial contraints as well as scarcity of the metallic containers in Minna area.

Treatments for the experiment were perforated at different depth which served as water table depth for each treatment. The treatments were as follows: 30cm, 45cm, 60cm and free drainage. The free drainage containers where perforated beneath the containers, to allow drain out of water after saturation was reached. Soil was put into each of the containers of the same soil texture and structure. Water was applied to the containers till saturation was reached at different water table depth level by seepage of water through the perforated holes on the containers.

3.3 PLANTING

DMR-YE variety was sowed with two seeds per hole about 2.5cm deep and at a distance of 25cm between holes within container. DMR-YE variety was selected because of its early maturation which ready for harvest as dry grains between 90-100 days after planting. This variety is suitable for human and livestock consumption. Ten days after planting, the plants were thinned to one plant per container. Crop (maize) were plannted on 12th June, 1998.

3.4 WATER APPLICATION

Water was applied at ten days interval using measuring cylinder and plastic container. The amount of water applied on each container was recorded. Water was applied at the edge of the container gradually till the level gets to the required water table depth. Raw data and the analysed data are presented in chapter four.

3.5 FERTILIZER APPLICATION

N.P.K. of ratio 20 - 10 - 10 was applied at 25 days after planting. 5.0g of NPK fertilizer was applied per container with the recommendation of six to twelve bags of 20-10-10 per hectare (300kg - 600kg/10,000m^2) from NCRI recommendation on fertilizer application. Therefore, 5.0g of NPK of ratio 20-10-10 per 0.1257m^2 which is the area of the metallic container. Second fertilzer application was done at 65 days after planting of the same quantities.

3.6 DATA OBSERVED

The following data were observed: plant height, leave area, water applied as well as the grain yield. The raw data and analysed data are presented in chapter four.

3.7 HARVEST

The crops were harvested 90 days after planting. Crop yields (dry - matter grain) were dried to a constant weight and adjusting to 12.5% grain moisture on dry weight basis. The grain yields result is presented in chapter four and further analysis is done on the grain yield with graphical presentation of grain yield versus treatments.

3.8 DETERMINATION OF SOIL PHYSICAL PROPERTIES

The following soil physical properties were determined: soil texture, bulk density, porosity, moisture content, fieldcapacity, moisture holding capacity and organic matter.

3.8.1 SOIL TEXTURE

Determination of soil texture used for the experiment which is refers to the fineness or coarseness of the mineral particles of the soil and it is the relative proportions of sand, silt and clay, using mechanical analysis data in conjunction with the texture triangle as shown in (table 4.9.5).

Initial weight of empty sieves of different sizes in diameter were taken. Soil sample was put into the sieves and thorough shaking was done using mechanical vibrator, to allow passing of soil particles of different diameter in size, those whose sizes are larger than the sieve diameter were retained. The sieves were re-weighed plus soil particles, difference in weight gives the weight of soil particle retained. The soil classification is presented in Table 4.9.5.

3.8.2 BULK DENSITY

Bulk density was determined using core method. Soil sample core was driven into the field using auger. Height of soil sample core was taken and its diameter. The sample were transfered into can with initial weight of can was recorded and the weight of soil sample plus can was taken again. The soil sample placed in oven for drying the soil moisture content at 105° C for 24 hours. After oven drying at that specification mentioned above dried soil sample were weighed to give mass of dried soil sample. Result is shown in table 4.9.5

3.8.3 POROSITY

The porosity of a soil is related with availability of pore space in the soil. Porosity of a soil is determined through this relationship.

$$\text{Porosity} = 1 - \frac{\text{bulk density}}{\text{particle density}}$$

Bulk density of soil sample is determined as in 3.8.2. Particle density of the soil sample is determined as follows; empty pycrometer bottle was weighed. 10 grams of soil sample was taken and transfered quantitatively into the bottle. The bottle plus soil was weighed again. The bottle was half filled with water and boiled over a hot plate, this was done to elimiate entrapped air in the soil. The soil moisture was allowed to cool and the bottle was refilled to the brim with water and weighed again. The soil mixture was thrown away and the bottle was refilled with water only and weighed. The temperature of water was taken. The computed data is presented in chapter four.

3.8.4 MOISTURE CONTENT

To determine moisture content, weight of empty can was taken. Weight of soil sample plus can was recorded. The soil sample was put into oven for drying the soil moisture at 105°C for 24 hours. After oven drying at that specification, dried soil was weighed again to give mass of the dried soil sample. The available moisture content of the soil sample is presented in chapter four.

3.8.5 FIELD CAPACITY

Determination of field capacity which is the moisture content above which water will freely drain out from soil by gravity was done by putting soil sample into a perforated container underneath the container. Moisture content of the soil was taken as described in 3.8.4 water was applied to the soil sample till saturation was reached . After two days, the soil sample was taken to know the available moisture content of the soil sample after water might had drained out freely from soil sample by gravity. The result is presented in table 4.9.5

3.8.6 ORGANIC MATTER CONTENT

To determine organic matter content, Onegramme of soil sample for different treatments at different depth were seived and measured using 0.5mm sieve. The sieved sample of 1g each were put into conical flask. 10ml of potassium dicromate ($K_2 Cr_2 O_7$) and 20ml of concentrated sulpuric acid (H_2SO_4) were added to soil sample. The soil sample solutions were cooled, 100ml of distilled water and 4 to 5 drops of barium diphemy-amine sulphonate (indicator) were added respectively to the soil sample solution. 0.5 normal $FeSO_4$ was titrated against the soil sample solution to obtain an end point of grey cast colour was observed. A solution of blank sample was prepared without soil sample which served as control experiment.

CHAPTER FOUR

RESULTS AND DISCUSSION

The parameters monitored during the cropping season (Jun-Sept.,1998) in the green house environment are discussed in this chapter.

4.1 LEAF AREA

The raw data and analysed data of the leave measurement are presented in the appendix (A). The statistical analysis for variance of leave area in table (4.9.7) shows that leaf area are non-significant from day one after planting up to 30 days after planting using completely randomised design. It could be observed that at 60 days after planting the leave area are non-significant. Table (4.9.7) display the analysis of variance of leaf area. This indicates that leaf area were about the same dimension in length from the base to the tip and the maximum width irrespective of water table depth of the treatments. However, the leaf area difference became signiticant as from 40 days after planting at 1% level, 50 days after planting at 1% and 70 days after planting at 5% respectively as indicated in table (4.9.7). This shows that there are also difference in the rate of water use at different water table depth. From 71 to 90 days after planting some of the leaves were observed to be changing to yellow from green colour.

4.2 PLANT HEIGHT

The raw data and analysed data of plant height are presented in the appendix (A). The statistical analysis of variance of plant height in table (4.9.9) shows that plants grow in response to water use of the plants in all the four treatments. Plant height are significant at 1% level except as 20 days after planting which could be observed in table (4.9.9) that it is significant at 5% level. Plant height is non-significant at 30 days after planting. These could be as a result of water up take rates at different depths. It can be said that plant roots developed fast to enable it to tap soil moisture through capillary action even at deeper depth (60cm).

4.3 WATER USE

The raw data of water use is presented on appendix (A) while the analysed data is given in table (4.6). The analysis of variance of water using statistical analysis shows that all the treatments are significant at 1% level except at 10 days after planting which is significant at 5% level. These considerable difference in water use are due to difference in water table depths in the containers in which plants were grown. Plants consumptive use also contribute to the highly significance of the treatments at different water table depth. In table (4.6) it can be observed that water use at the first 10 days interval are as follows 6.58cm, 12.39cm, 13.80cm and 17.25cm for the treatments 30cm, 45cm, 60cm and free drainage of water table depths respectively. The cummulative water use over 90 days are given in table (4.7), the values are 35.69cm, 79.49cm, 94.76cm and 109.25cm for water table depths at 30cm, 45cm, 60cm and free drainge resepectively.

4.4 EVAPOTRANSPIRATION VERSUS WATER USE

The evapotranspiration of the crop using Blaney Criddle model could be observed in table (4.2) which indicate high monthly consumptive use within the vegetable growth period of 31 to 60 days after planting. But the actual use behaved differently which could be observed in table (4.3). The Blaney Criddle model gives the cummulative water use as 420.81cm. The actual water use at different water table depths starting from 10cm, 20cm, 30cm, as indicated in earlier work of Soil (1998) were 29.52cm, 23.37cm, 30.5cm and free drainage 37.66cm respectively. The actual water use for water table depth of 30cm, 45cm 60cm and free drainage are as follows; 35.69cm, 79.49cm, 94.76cm and 109.25 respescptively as shown in table 4.7.

4.5 GRAINS YIELD

The grains yield result is shown on tables 4.9.2 and with the analysed result. The statistical analysis of variance of grains yield shows that grains yield are significant at 1% level. It could be observed that the treatments beginning with low water application depth and production increased rapidly with increase in water application depth. The 30cm water table yielded no grain with cummulative water use of 35.69cm. The 45cm water table depth produced 0.6472kg of grain with cummulative water use of 79.49cm. The 60cm water table depth gave 0.5156kg with cummulative water use of 94.76cm and free drainage yields 0.4250kg with cummulative water use of 109.25cm, as shown in table 4.9.4. Table 4.9.4 shows the treatments of 45cm and 60cm water table depth record high grains yield but free drainage is lower. The 45cm water table depth gives good free drainage and available soil moisture for plant growth. Graphical presentation of grains yield and water use is given fig (4.9). These results did not give the same relationship, as it was reported by Ayotamuna and Dike (1997) that the crop yield versus water use relationship is neither linear nor directly proportional right through. Finally the the water use efficiency (WUE) for each water table depth were 45cm gave 0.65, 60cm gave 0.43 and free drainage gave 0.31 respectively.

4.6 ANALYSIS OF VARIANCE

TABLE 4.1

Analysis of variance of water applied for 10 dap

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	10754.48	3584.83	6.47*	3.86	6.99
Error	9	6648.64	553.89			
Total	12	17403.12				

CV = 18.8%
*b = Singificant at 5%

Analysis of variance of water applied for 20 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	2921.03	973.68	9.08**	3.86	6.99
Error	9	1286.87	107.24			
Total	12	4207.90				

CV = 14.15%
**b = Significant at 1%

Analysis of variance of water applied for 40 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	4351.95	1450.65	373.88**	3.86	6.99
Error	9	46.52	3.88			
Total	12	4398.47				

CV = 2.1%
**b = Significant at 1%

Analysis of variance of water applied for 50 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	5688.96	1896.34	136.82**	3.86	6.99
Error	9	166.33	13.86			
Total	12	5855.29				

CV = 4.5%
**b = Significant at 1%

Analysis of variance of water applied for 60 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	12573.74	4191.25	47.74**	3.86	6.99
Error	9	1053.45	87.89			
Total	12	13627.19				

CV = 7.5%
**b = Significant at 1%

Analysis of variance of water applied for 70 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	15065.01	5021.67	32.00**	3.86	6.99
Error	9	1883.07	156.92			
Total	12	16448.08				

CV = 10.3%
**b = Significant at 1%

Analysis of variance of water applied for 80 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	6691.89	2230.63	103.41**	3.86	6.99
Error	9	258.8	21.57			
Total	12	6950.69				

CV = 4.8%
**b = Signficant at 1%

Analysis of variance of water applied for 90 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	11417.52	3805.84	67.24**	3.86	6.99
Error	9	679.25	56.60			
Total	12	12096.77				

CV = 9.5%
** b = Signficant at 1%

Table 4.2
Consumptive use of water (CU) for Maize crop at NCRI Badeggi (9°045N) Using Blaney - Criddle formula

Month	Mean monthly temperature °C	Monthly crop coefficient (K)	Percent day light hrs (P)	Monthly CU (cm)
June	28.5	0.70	8.54	127.27
July	28.0	0.80	8.81	149.14
August	27.0	0.80	8.72	144.40
September	29.0	0.60	8.26	105.15

Table 4.3
Mean of water applied for all replicites for different treatment level

Treatment	Water applied monthly (cm)		
	(1-30 DAP)	(31-60 DAP)	(61-90 DAP)
30	10.88	12.93	11.80
45	19.27	32.29	27.92
60	22.18	35.63	36.95
FD	26.87	40.08	42.28

Table 4.4
Cummulative data for water applied for all replicates for different treatment for the period of 1 - 30 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	10.96			
45	14.66	20.02	22.21	20.20
60	18.14	21.27	23.50	25.82
FD	26.96	29.95	22.31	28.26

Cummulative data for water applied for all replicates for different treatment for the period of 31-60 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30 cm	12.93			
45 cm	31.15	30.23	34.66	33.10
60 cm	36.25	36.25	35.00	35.00
FD	40.08	40.00	40.20	40.05

Cummulative data for water applied for all replicates for different treatment for the period of 61 - 90 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30 cm	11.8			
45 cm	25.78	25.66	29.75	30.50
60 cm	35.65	38.90	37.48	35.75
FD	43.75	42.71	39.78	44.88

Table 4.5

Cummulative data water applied for all replicates for different treatments

Treatment	Replicates			
	P1	P2	P3	P4
30 cm	35.69			
45 cm	71.59	75.91	86.62	83.80
60 cm	90.04	96.42	95.98	96.57
FD	110.79	112.66	102.29	111.19

Table 4.6
Mean of water applied for all replicates for different treatments of water table depth at 10days interval (cm)

			Days after planting						
Treatment	10	20	30	40	50	60	70	80	90
30	6.58	4.38	-	5.0	2.50	5.43	4.75	4.15	2.90
45	12.39	6.89	-	9.63	9.60	13.06	11.78	9.82	6.32
60	13.80	8.39	-	10.81	10.5	14.31	14.85	11.66	10.44
FD	17.25	9.63	-	12.08	10.5	17.50	17.32	12.80	12.17

Table 4.7
Cummulative water use for all the treatments over period of 90 days

Treatments	Amount of water use (cm)
30 cm	35.69
45 cm	79.49
60 cm	94.76
FD	109.25

Table 4.8
Cummulative water use of different water table depths

Treatments	Amount of water use (cm)
10 cm	29.52
20 cm	23.37
30 cm	30.50
45 cm	79.49
60 cm	94.76
FD	109.25

Values for 10cm, 20cm and 30cm were obtained from earlier study (soli, 1998)

Table 4.9
Grain yield (kg) of maize for different water table depth

Treatment	Replicates			
	P1	P2	P3	P4
30	X	X	X	X
45	0.080	0.72	0.094	0.094
60	0.064	0.090	0.075	0.074
FD	0.071	0.057	0.058	0.055

Table 4.9.1
Analysis of variance of grain yield data

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	0.0058	0.00193	29.00**	3.86	6.99
Error	9	0.0008	0.000066			
Total	12	0.0066				

CV = 15.1%
**b = Significant at 1%

Table 4.9.2
Grain yield (kg) (grain yield per container)

Treatment	Replicates				
	P1	P2	P3	P4	TOTAL
30	X	X	X	X	X
45	0.1601	0.1429	0.1560	0.1882	0.6472
60	0.1274	0.0898	0.1498	0.1498	0.5156
FD	0.1428	0.0568	0.1151	0.1103	0.4250

Table 4.9.3
Summarized table of grain yield (kg) per container

Treatments	Minimum yield (kg)	Maximum yield	Mean yield
30	-	-	-
45	0.1429	0.1882	0.1618
60	0.0898	0.1498	0.1289
FD	0.0568	0.1428	0.1063

Table 4.9.4
Summarized results of effect of water table depth on yield of DMR-YE maize grown in sandy loamy

Treatments	Water use (cm)	Maximum grain yield (kg)
10 cm	29.52	0.043
20 cm	23.37	0.143
30 cm	30.50	0.144
45 cm	79.49	0.188
60 cm	94.76	0.149
FD	109.25	0.142

Table 4.9.5

Soil physical properties

S/No.	Soil property	Value
1	Bulk density	1.49 g/cm^3
2	Porosity	33%
3	Moisture content	13.45%
4	Organic matter	95.0%
5	Field capacity	7.37%
6	Water holding capacity	10.98 cm/m
7	Soil texture	Sandy loamy
8	Sandy loamy composition	60% sand 20% silt 20% clay

The above soil properties taken at 0 - 20cm depth

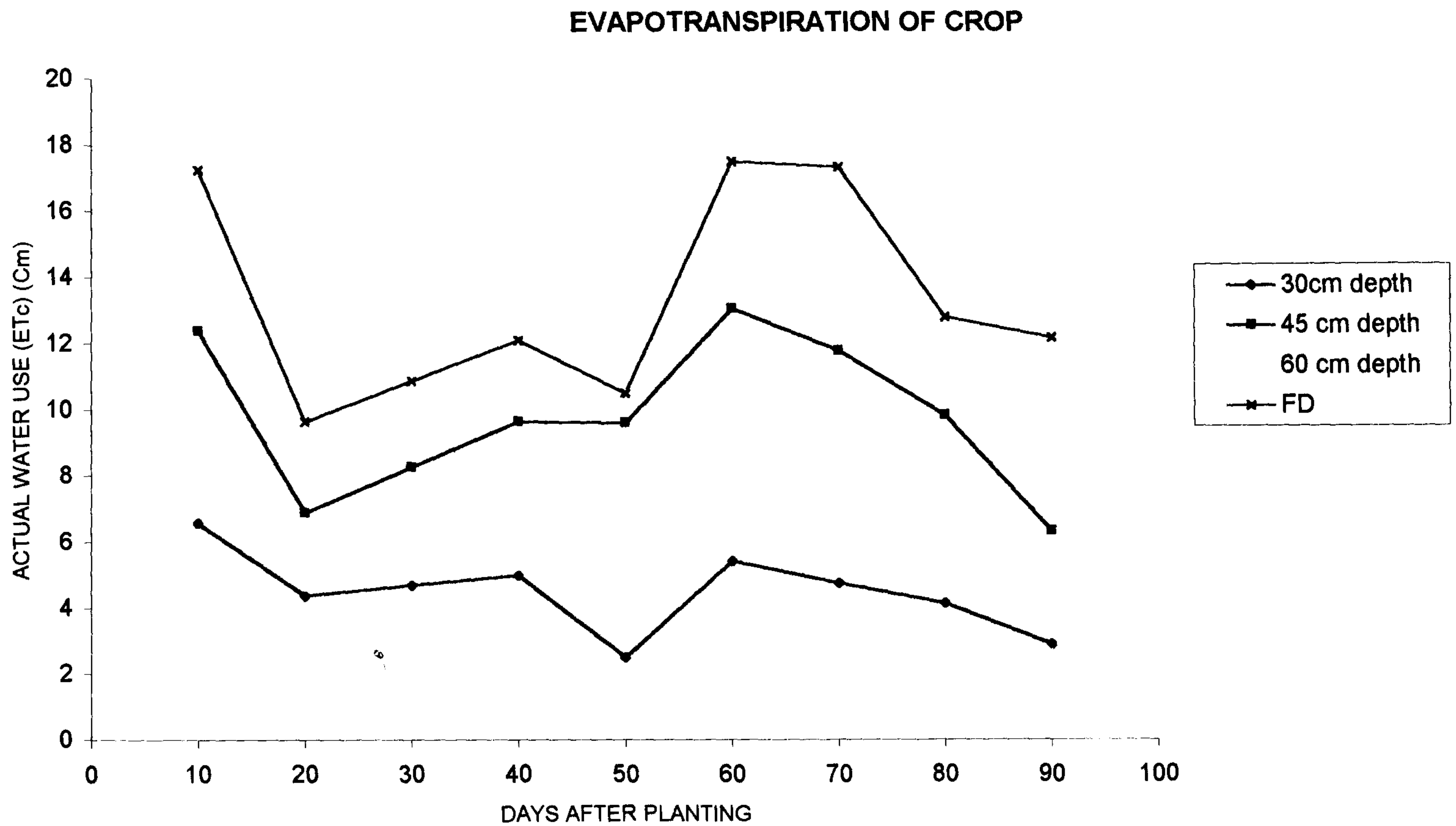

EVAPOTRANSPIRATION OF CROP
ACTUAL WATER USE (ETc) (Cm)
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
DAYS AFTER PLANTING
30cm depth
45 cm depth
60 cm depth
FD

FIGURE 4.1

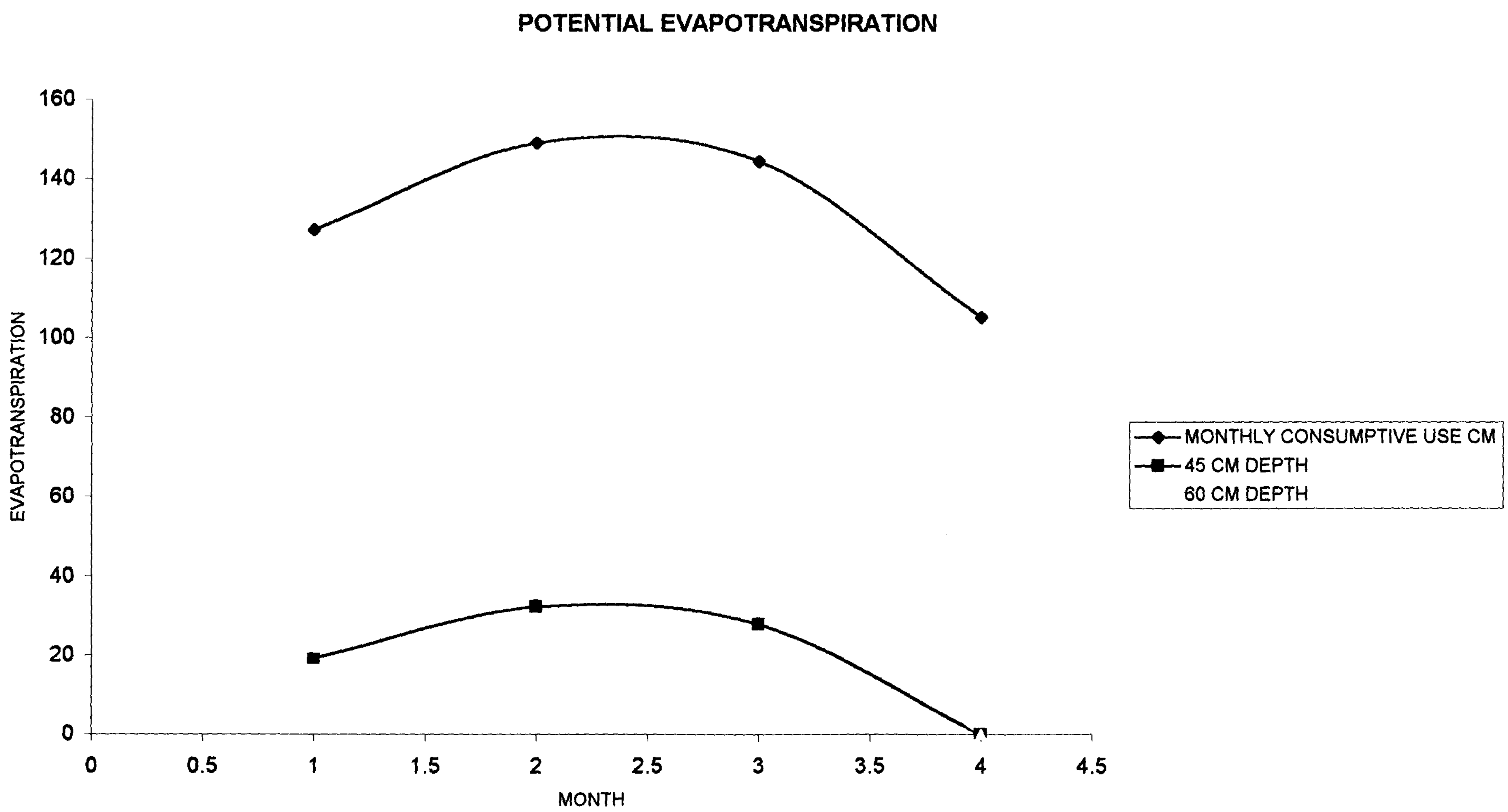

POTENTIAL EVAPOTRANSPIRATION
160
140
120
100
80
60
40
20
0
EVAPOTRANSPIRATION
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
MONTH
MONTHLY CONSUMPTIVE USE CM
45 CM DEPTH
60 CM DEPTH

FIGURE 4.2

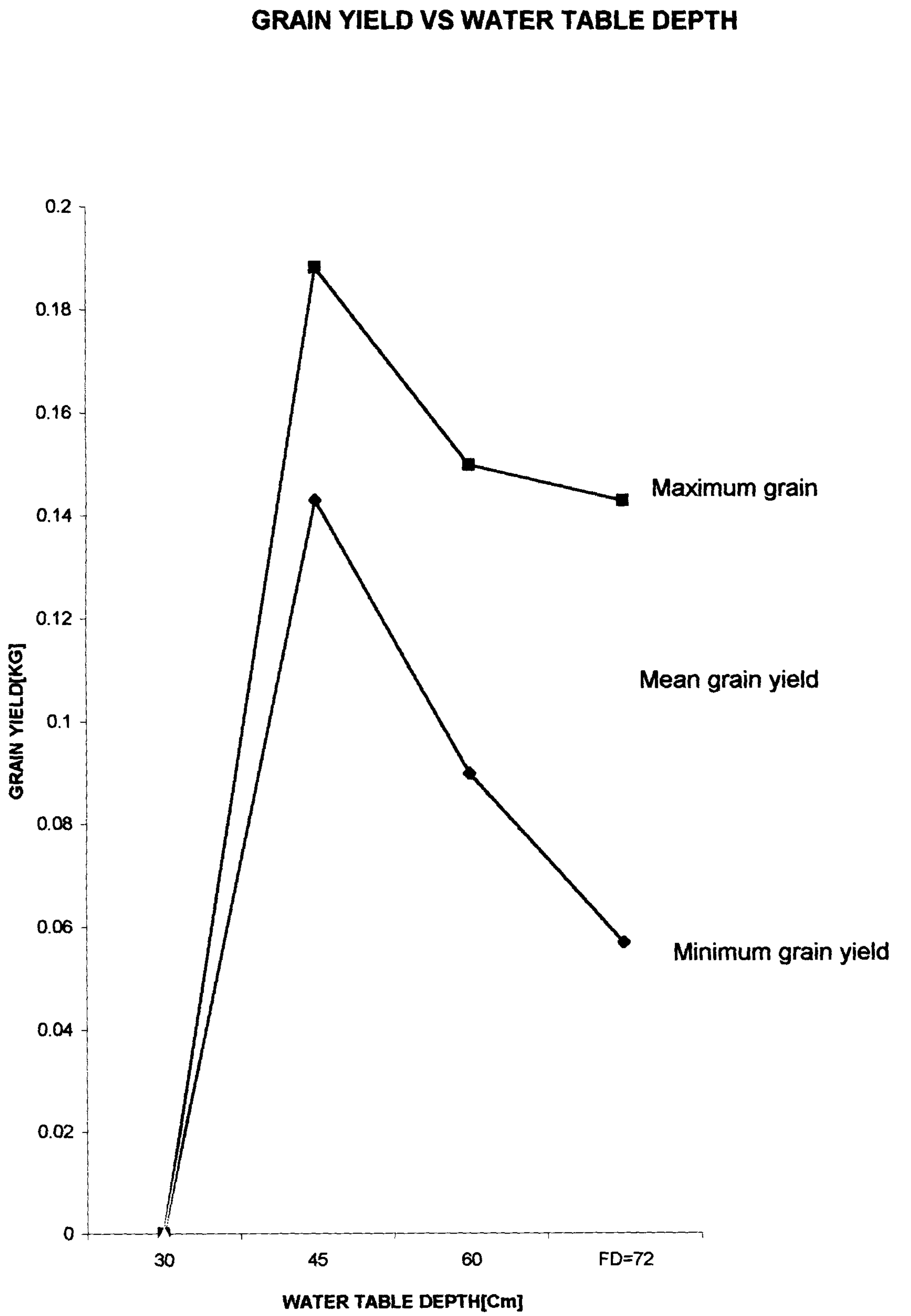

GRAIN YIELD VS WATER TABLE DEPTH
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
GRAIN YIELD[KG]
Maximum grain
Mean grain yield
Minimum grain yield
30
45
60
FD=72
WATER TABLE DEPTH[Cm]

Figure 4.3

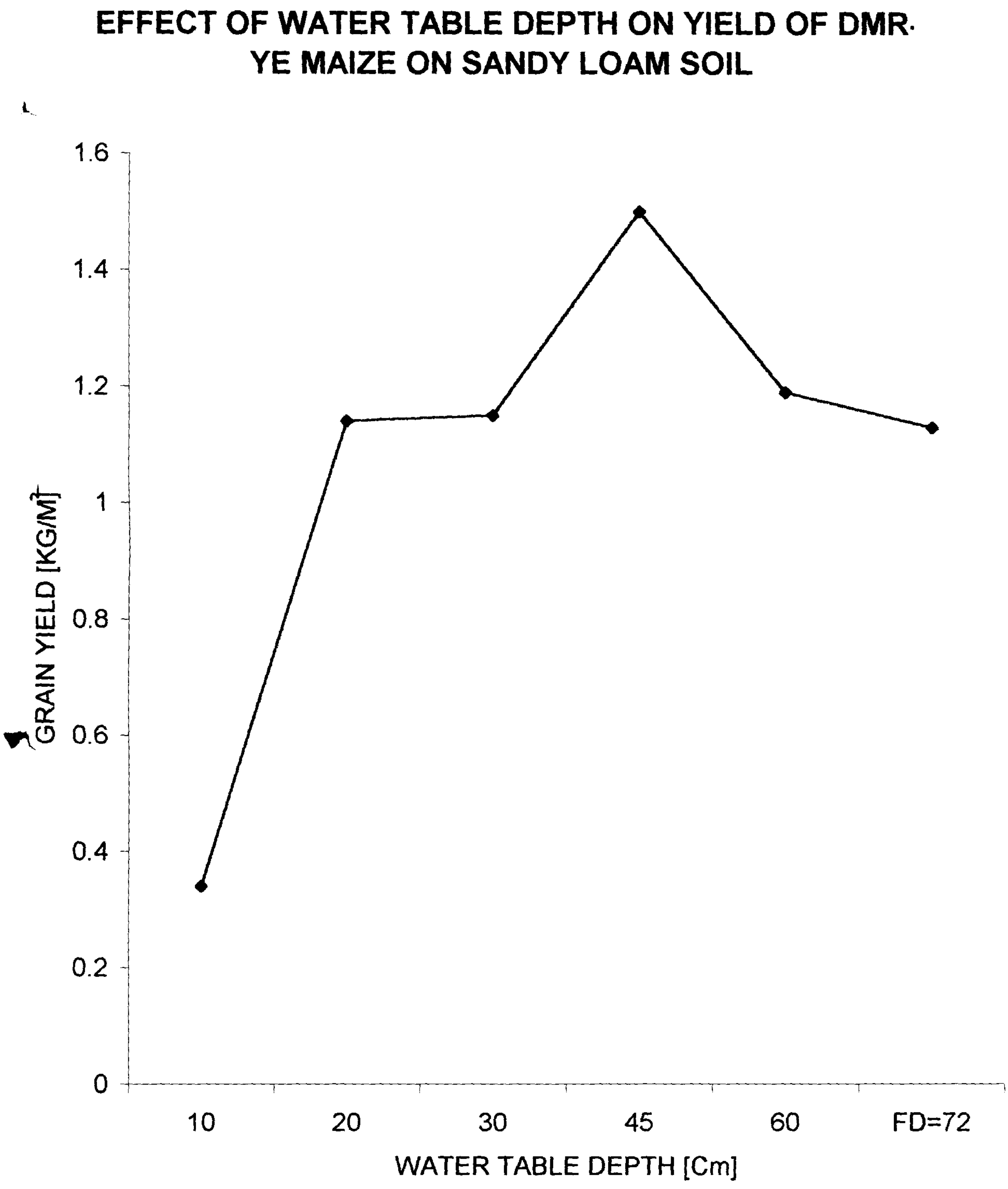
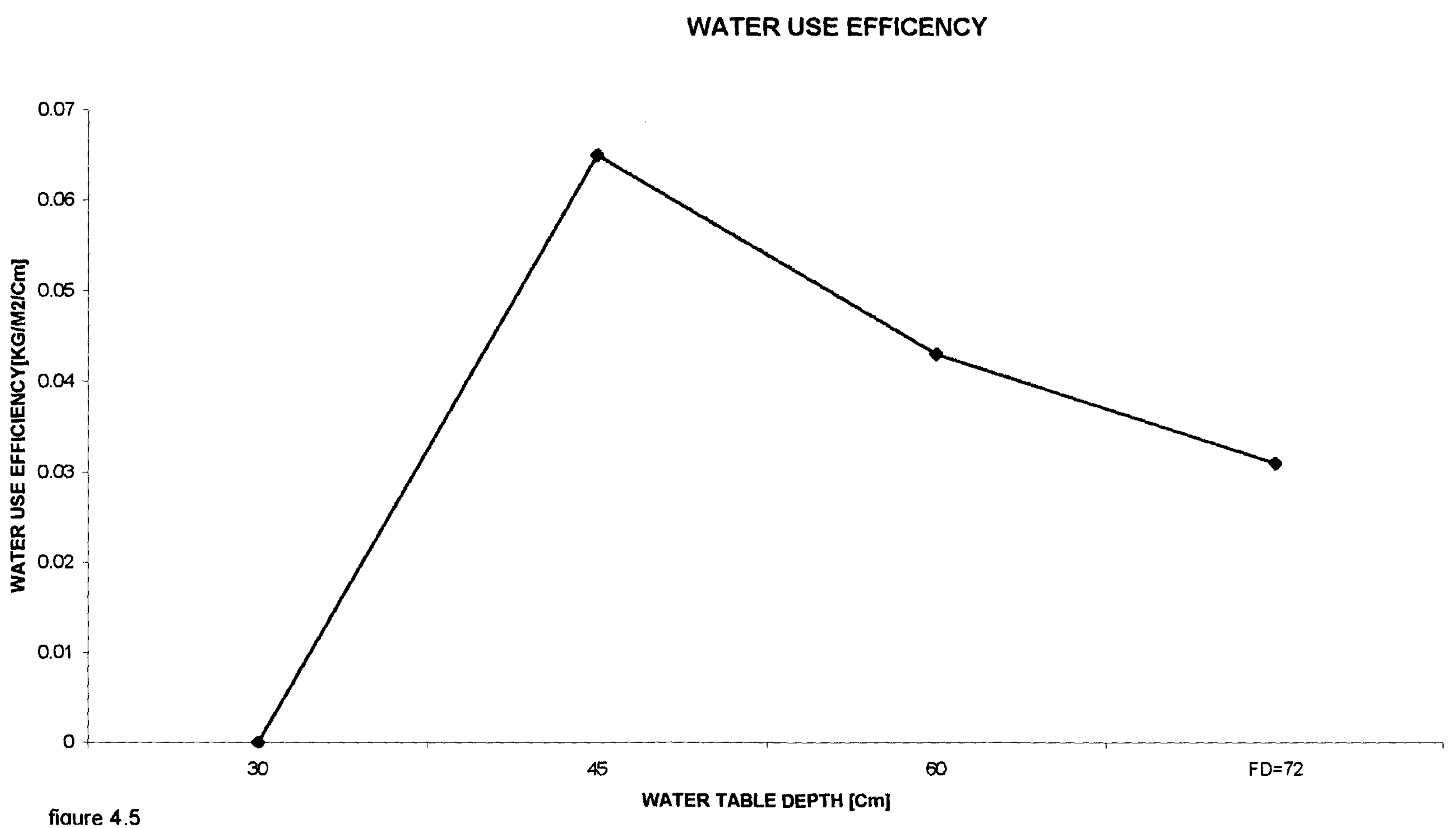

EFFECT OF WATER TABLE DEPTH ON YIELD OF DMR-YE MAIZE ON SANDY LOAM SOIL
GRAIN YIELD [KG/M²]
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
20
30
45
60
FD=72
WATER TABLE DEPTH [Cm]

figure 4.4


WATER USE EFFICENCY
WATER USE EFFICIENCY[KG/M2/Cm]
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
30
45
60
FD=72
WATER TABLE DEPTH [Cm]

fiaure 4.5

CHAPTER FIVE
CONCLUSION/RECOMMENDATION

5.1 CONCLUSION

The observation made during the experiment established that for successful irrigation design using subirrigation method water table for the soil (Sandy loam) could be raised between 45cm and 60cm below that soil surface. Crop yield increased rapidly with increase in water application depth and water table depth less than 45cm or greater than 60cm greatly reduce crop yield. The analyses establish that the crop yield versus water use relationship is neither linear nor directly proportional right through as sometimes assumed.

5.2 RECOMMENDATION

Water table depth of 45cm to 60cm is recommended for maize (DMR-YE) for adequate free drainage. This will prevent poor aeration and improve effective uptake of nutrient and water. Further work could be continued on influence of subirrigation regimes on crop yield and to minimise experimental error, the experimental field layout should be nearer to observer for more details observation and records of data on daily basis.

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APPENDIX A

4.0 RESULTS

Leave area data for 10 DAP (m^2)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.003			
45	0.004	0.003	0.003	0.002
60	0.003	0.002	0.002	0.003
FD	0.002	0.002	0.002	0.002

Leave area data for 20 DAP (m^2)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.007			
45	0.013	0.011	0.012	0.008
60	0.007	0.007	0.006	0.008
FD	0.007	0.006	0.009	0.007

Leave area data for 30 DAP (m^2)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.009			
45	0.031	0.026	0.019	0.016
60	0.028	0.022	0.018	0.017
FD	0.018	0.011	0.026	0.016

Leave area data for 40 DAP (m²)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.021			
45	0.057	0.045	0.062	0.050
60	0.052	0.048	0.052	0.042
FD	0.039	0.041	0.051	0.043

Leave area data for 50 DAP (m²)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.021			
45	0.059	0.043	0.063	0.048
60	0.053	0.048	0.056	0.044
FD	0.044	0.047	0.051	0.045

Leave area data for 60 DAP (m²)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.037			
45	0.053	0.063	0.073	0.090
60	0.065	0.073	0.070	0.069
FD	0.064	0.071	0.069	0.062

Leave area data for 70 DAP (m^2)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.044			
45	0.065	0.062	0.079	0.085
60	0.064	0.072	0.064	0.058
FD	0.062	0.066	0.065	0.060

Leave area data for 80 DAP (m^2)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.044			
45	0.065	0.062	0.079	0.085
60	0.064	0.072	0.064	0.058
FD	0.062	0.066	0.065	0.060

Leave area data for 90 DAP (m^2)

Treatment	Replicates			
	P1	P2	P3	P4
30	0.044			
45	0.065	0.062	0.079	0.085
60	0.064	0.072	0.064	0.058
FD	0.062	0.066	0.065	0.060

4.2 Analysis of variance

Table 4.9.7

Analysis of variance of leave area for 10 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F^b	Tabular F 5%	1%
Treatment	3	2.231×10^{-6}	7.437×10^{-7}	2.97^{ns}	3.86	6.99
Error	9	3×10^{-6}	2.5×10^{-7}			
Total	12	5.231×10^{-6}				

CV = 19.0%

b = Non significant

Analysis of variance of leave are for 20 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F^b	Tabular F 5%	1%
Treatment	3	4.205×10^{-5}	1.4016×10^{-6}	0.015^{ns}	3.86	6.99
Error	9	0.0109	9.083×10^{-4}			
Total	12	0.0109				

CV = 373.8%

b_{ns} = Non significant

Analysis of variance of leave are for 30 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F^b	Tabular F 5%	1%
Treatment	3	1.829×10^{-4}	6.0967×10^{-5}	2.22^{ns}	3.86	6.99
Error	9	3.295×10^{-4}	2.7458×10^{-5}			
Total	12	5.124×10^{-4}				

CV = 29.4%

b_{ns} = Non significant

Analysis of variance of leave area for 40 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F	
					5%	1%
Treatment	3	0.0009	0.0003	7.20**	3.86	6.99
Error	9	0.0005	4.167×10^{-5}			
Total	12	0.0014				

CV = 15.4%

**b = Significant at 1%

Analysis of variance of leave area for 50 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F	
					5%	1%
Treatment	3	0.0008	2.667×10^{-4}	8.00**	3.86	6.99
Error	9	0.0004	3.33×10^{-5}			
Total	12	0.0012				

CV = 13.5%

**b = Significant at 1%

Analysis of variance of leave area for 60 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F^b	Tabular F	
					5%	1%
Treatment	3	0.0009	0.0003	3.6^{ns}	3.86	6.99
Error	9	0.001	8.33×10^{-5}			
Total	12	0.0019				

CV = 15.0%

b = Non significant

Analysis of variance of leave area for 70 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	0.0007	2.33×10^{-4}	5.59*	3.86	6.99
Error	9	0.0004	4.167×10^{-5}			
Total	12	0.0012				

CV = 10.5%

*b = Significant at 5%

Table 4.9.8

Water applied (10 DAP) (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	65.8			
45	76.6	130.2	141.6	147.0
60	101.1	130.9	150.0	169.9
FD	164.6	194.5	153.1	177.6

Water applied (20 DAP) (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	43.8			
45	70.0	70.0	80.5	55.0
60	80.3	81.8	85.0	88.3
FD	105.0	105.0	70.0	105.0

Water applied (30 DAP) (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	-			
45	-	-	-	-
60	-	-	-	-
FD	-	-	-	-

Water applied data for 40 DAP (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	50			
45	97.5	96.0	96.3	95.5
60	112.5	105.0	105.0	110.0
FD	120.8	120.0	122.0	120.5

Water applied data for 50 DAP (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	25.0			
45	92.5	91.3	95.0	105.5
60	110.0	105.0	105.0	100.0
FD	105.0	105.0	105.0	105.0

Water applied data for 60 DAP (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	54.3			
45	121.5	115.0	155.3	130.5
60	140.0	152.5	140.0	140.0
FD	175.0	175.0	175.0	175.0

Water applied (70 DAP) (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	47.5			
45	113.75	105.0	122.5	130.0
60	140.0	162.5	151.3	140.0
FD	200.0	175.0	156.3	161.3

Water applied (80 DAP) (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	41.5			
45	89.5	93.2	105.0	105.0
60	115.0	120.3	118.8	112.5
FD	125.0	132.3	127.0	127.5

Water applied (90 DAP) (mm)

Treatment	Replicates			
	P1	P2	P3	P4
30	29.0			
45	54.5	58.3	70.0	70.0
60	101.5	106.2	104.7	105.0
FD	112.5	119.8	114.5	140.0

Table 4.9.9

Plant height data for 10 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	5.7			
45	7.6	4.9	5.1	3.3
60	4.9	4.4	3.6	3.4
FD	3.1	3.5	3.3	3.0

Plant height data for 20 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	9.7			
45	15.0	10.5	12.5	9.2
60	9.0	7.6	8.0	9.2
FD	9.1	8.4	8.7	8.2

Plant height data for 30 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	14.5			
45	29.5	25.0	18.0	18.0
60	24.0	20.0	18.0	17.0
FD	17.5	15.0	18.5	16.5

Plant height data for 40 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	30.3			
45	67.5	54.0	63.8	52.5
60	49.00	40.5	44.0	48.5
FD	47.00	35.0	43.5	37.0

Plant height data for 50 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	51.5			
45	159.5	135.0	146.0	125.0
60	139.0	102.5	110.0	119.0
FD	117.5	71.0	110.0	85.0

Plant height data for 60 DAP (cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	80.0			
45	173.3	167.5	195.5	204
60	185.0	177.0	190.0	173.5
FD	189.0	168.0	185.0	181.5

Plant height data for 70 DAP(cm)

Treatment	Replicates			
	P1	P2	P3	P4
30	110.0			
45	175.0	169.5	198.5	204.0
60	187.0	177.0	193.0	175.0
FD	191.5	197.5	186.0	182.0

Plant height data for 80 DAP(cm)

Treatment	Replicates			
	P1	P2	P3	P4
30				
45	180.0	175.0	205.0	210.0
60	192.0	183.0	200.0	182.0
FD	200.0	204.0	192.0	190.0

Plant height data for 90 DAP(cm)

Treatment	Replicates			
	P1	P2	P3	P4
30				
45	175.0	169.5	198.5	204.0
60	187.0	177.0	193.0	175.0
FD	191.5	197.5	186.0	182.0

Table 4.9.9.

Analysis of variance of plant height for 10 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	10.21	3.4	170**	3.86	6.99
Error	9	0.91	0.02			
Total	12	10.40				

CV = 3.1%

**b = Significant 1%

Analysis of variance of plant height for 20 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	28.65	9.55	5.34*	3.86	6.99
Error	9	21.43	1.79			
Total	12	50.08				

CV = 13.9%

*b = Significant at 5%

Analysis of variance of plant height for 30 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F^b	Tabular F 5%	1%
Treatment	3	91.57	30.52	2.79^{ns}	3.86	6.99
Error	9	131.12	10.93			
Total	12	222.69				

CV = 17.9%

b = Non significant

Analysis of variance of plant height for 40 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	1070.26	356.75	14.08**	3.86	6.99
Error	9	303.92	25.33			
Total	12	1374				

CV = 27.29%

**b = Significant at 1%

Analysis of variance of plant height for 50 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	8261.13	2753.71	11.77**	3.86	6.99
Error	9	2808.56	234.05			
Total	12	11069.69				

CV = 15.1%

**b = Significant at 1%

Analysis of variance of plant height for 60 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	9729.15	3243.05	29.21**	3.86	6.99
Error	9	1332.24	111.02			
Total	12	11061.39				

CV = 6.7%

**b = Significant at 1%

Analysis of variance of plant height for 70 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	5457.73	1819.24	17.84**	3.86	6.99
Error	9	1223.5	101.96			
Total	12	6681.23				

CV = 6.0%

**b = Significant at 1%

Analysis of variance of plant height for 80 DAP

Source of Variation	Degree of Freedom	Sum of squares	Mean square	Computed F	Tabular F 5%	1%
Treatment	3	34400.17	11466.72	108.28**	3.86	6.99
Error	9	1270.75	105.90			
Total	12	35670.92				

CV = 7.1%

**b = Significant at 1%

APPENDIX B

Steps to compute analysis of variance are:

Step 1: Construct an appropriate outline of the analysis of variance of data from plot sampling based on the experimental design used. For this example, the form of the analysis of variance is shown in chapter four.

Step 2: Construct the replication treatment table of total (RT) and compute the replication total (R), the treatment totals (T) and the grand total (G).

Step 3: Compute the correction factor and the sums of squares as

(i) $CF = G^2/Trs$

(2) Total SS = ΣX^2 - CF

(3) Replication SS = $\Sigma R^2/ts$ - CF

(4) Treatment SS = ΣT^2 - CF

(5) Experimental errors = $\Sigma(RT)^2/S$ - CF - SSR - SST

(6) Sampling errors SS = Total SS - (Sum of all other SS)

Step 4: For each source of variation, computer the mean square by dividing the SS by its corresponding d.f

(1) Replication MS = Replication SS/r - 1

(2) Treatment MS = Treatment SS/t - 1

(3) Sampling error MS = Sampling error SS/(r-1)(t-1)

(4) Sampling error MS = Sampling error SS/tr(s - 1)

Step 5: To test the significance of the treatment effect, compute the F value as

F = Treatment MS/Experimental error Ms

and compare it with the tabular F values (appendix E) with F2 = (t-1) and F2 = (r-1)(t-1) (page 635 by Gomez)

Step 6: Enter all values obtained in step 2 to 5 in the analysis of variance outline of step 1.

Step 7: For mean comparison, compute the standard error of the difference between the treatment as

$Sd = \sqrt{2(MS^2)/rs}$

Where MS^2 is the experimental error MS in the analysis of variance.

Step 8: Compute the grand mean and the coefficient of variance cr as follow

Grand mean = G/n

Cr = $\sqrt{\text{error MS}}$ x 100/Grand mean

The CV indicates the degree of precision with which the treatments are compared and is a good index of the reliability of the experiment.

APPENDIX C

To calculate consumptive use (CU) of crop using Blaney - Criddle formula

$$ETcrop = 0.46\ PK\ (t + 18)$$

Where P = monthly percentage of day time hours of the year (See Table 4.2)

K = Crop coefficients

t = Mean temperature

N.B. P and t are matereological data based on localities in which the crops are planted.

TABLE D1 CLIMATOLOGY REPORT AT EMILUGI (PROJECT SITE) 1998, LAT. 09"45' NORTH, LONG. 06"07' EAST, ALT 70.57m

Month	Rainfall	Max. Temp. °C	Min. Temp. °C	Relative humidity %	Mean Monthly Temp. °C
Jan	0.0	35	17	52	26
Feb	0.0	39	21	43	30
Mar	0.0	40	23	33	31.5
Apr	67.1	39	27	68	33
May	213.2	34	25	82	29.5
Jun	75..5	33	24	82	28.5
Jul	239.7	32	24	85	28
Aug	145.5	30	24	84	27
Sep	153.7	31	23	85	27
Oct	103	33	24	82	28.5
Nov					
Dec					

Source: NCRI Badeggi Meteorological Department

Plate 1 30 days after planting

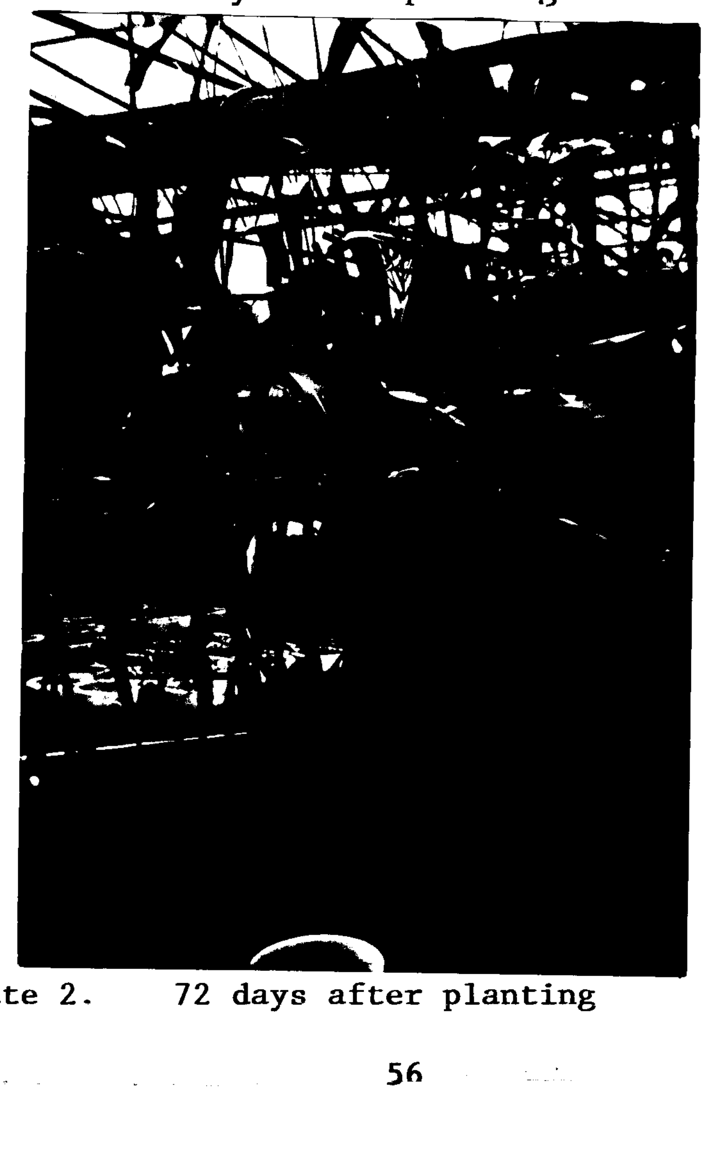

Plate 2. 72 days after planting

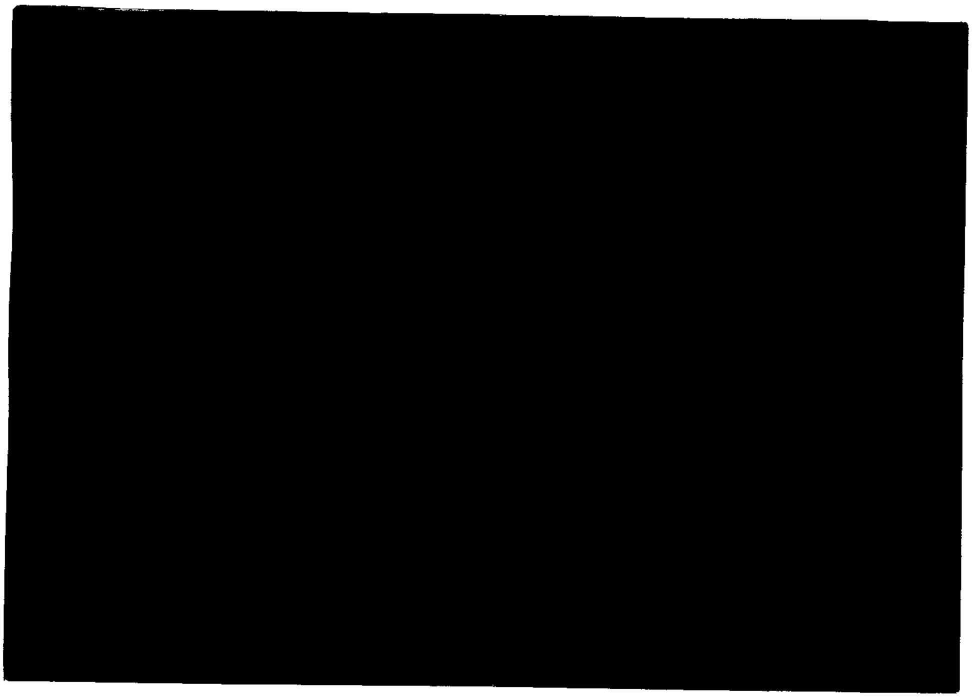

Plate 3   Front view of green house