LYSIMETERIC ESTIMATION OF CROP WATER USE OF WATERLEAF (TALINUM TRIANGULARE).

BY

YUSUF KEHINDE OLOKUNDE

MATRIC NO: 2005/21681EA

DEPARTMENT OF AGRICULTURAL & BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

FEBRUARY, 2012.

LYSIMETERIC ESTIMATION OF CROP WATER USE FOR WATERLEAF(TALINUM TRIANGULARE).

By

YUSUF KEHINDE OLOKUNDE

MATRIC NO:2005/21681EA

BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEETING (B.ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING,FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERSTATE.

FEBRUARY, 2012.

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

Yusuf, Kehinde Olokunde

01/02/12

Date

CERTIFICATION

This is to certify that the project entitled "Lysimeteric estimation of crop water use of waterleaf (talinum triangulare) using micro weighing lysimeters." by Yusuf Kehinde Olokunde meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

______________________ 01/03/2012

Dr. H.E Igbadun — Date

Supervisor

______________________ 02/03/2012

Engr. Dr. P. A. Idah — Date

Head of Department

______________________ 22-02-2012

External Examiner — Date

DEDICATION

This project work is dedicated to the Almighty God, through His son Jesus Christ and by the leading of His Holy Spirit who saw me through from the beginning to the end of this programme. May His name be glorified forever.

ACKNOWLEDGEMENTS

I acknowledged the Almighty God for his mercy on me throughout the five-year period of my schooling in this great citadel of learning. My sincere appreciation goes to all the lecturers both in the department and the School of Engineering at large that have in one way or the other imparted knowledge in me.

My profound gratitude goes to my supervisor, Dr. H. E Igbadun for giving me the opportunity to pursue this research as part of my degree requirement and for helping to direct the scope of this work. I also want to appreciate Dr. I. E. Ahaneku for his academic advice and Fatherly role played being the co-supervisor of this project work. The friendliness of all of the faculty, staff, and students in this department made the completion of this research a reality.

I appreciate the tireless effort of my parents, Cdr. & Mrs. D.Y Olokunde for their financial, moral, spiritual and material support that contributed immensely to my moving forward in life right from when I was born until this very moment. My profound gratitude also goes to Mr & Mrs Olugbemi, Dr & Mrs G.E.K Quatey, Mrs Shetu, Dr (Mrs) Z.D Osunde and Pastor Akinremi Bolaji who stood by me through thick and thin of my academic pursuit from my early days.

Finally, my appreciation goes to my entire classmates, friends especially Miss Oyinkansola Bakare and my siblings Dr. Tioluwa lois Olokunde, Miss Ifeyimika David, Master Taiwo Micheal Yusuf and Miss Onifeloluwa Olokunde. They all gave me the motivation and inspiration to move forward in my academic pursuit.

ABSTRACT

This project focuses on the lysimetric estimation of the crop water use of waterleaf (Talinum Triangulare). The crop water use of water leaf was determined using lysimetric estimation and the evapotranspiration (ET), a basic component of the hydrologic cycle was estimated. Three weighing lysimeter was constructed and set up on a field and the daily displacement of water in the vehicular tube was read on the connected hose attached to a meter rule due to change in weight as water enters or leaves the lysimeter tanks and translated to crop water use. The crop water use estimated using the lysimeters were compared with estimates based on weather data. Using ET measurements, a crop curve for waterleaf (Talinum Triangulare) was developed; the crop curve is critical to accurately determine irrigation-water requirements for agricultural crops. The ET was determined using the three sensitive micro weighing lysimeters. Daily reference evapotranspiration (ETo) was calculated using the Hargreaves FAO-56 computation standard. The results showed that the average daily water use of the waterleaf (Talinum Triangulare) from the lysimeters declined from 21.20 mm/day at the early crop growth stages to 17.00 mm/day at mid-season and increased to 43.2 mm/day at the end of the season.We used lysimeters to estimate the crop water use of waterleaf (Talinum Triangulare) from July 28, 2011 through September 25, 2011. These values can be used to estimate irrigation requirements and increase the efficiency of water use with respect to waterleaf (Talinum Triangulare). The mini-lysimetry technique has thus offered an easier and cheaper opportunity to estimate crop water use and other components of the soil water balance under rainfall condition.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

APPENDICES

`CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Waterleaf *(Talinum Triangulare)* is a non-conventional vegetable crop of the portulacea family which originated from tropical Africa and is widely grown in West Africa, Asia, and South America (Schippers, 2000). Waterleaf as a vegetable has some inherent characteristics which makes it attractive to small-holder farmers and consumers. Firstly, it is a short duration crop which is due for harvest between 35-45 days after planting (Rice et. al, 1986). Secondly, in the study area it is used as a "softener" when cooking fibrous vegetables. In Nigeria, it is widely accepted across various ethnic groups and some local names by which it is called are "gure" in Yoruba and mmon-mmongikong in Efic/Ibibio among others. Water leaf is a rich source of vitamin A, B, and C, which helps prevent constipation and promote digestion. It is also an acid neutralizer (Aduku and Olukosi.,1990).

The crop is propagated mostly by stem cutting and rearly by seed. The yield is higher when propagated by stem cutting as compared to the seed planting. The short maturity period of waterleaf is an advantage as compared to other vegetables

Waterleaf (*Talinum Triangulare*) has been proven to be high in crude-protein (22.1%), ash (33.98%), and crude fiber (11.12%) and also has some medicinal values in humans as well as acting as green forage for rabbit feed management (Aduku and Olukosi.,1990).

In addition, waterleaf production provides a complementary source of income to small-scale farming households (Udoh, 2005).

A lysimeter is a device that isolates a volume of soil or earth between the soil surface and a depth given which includes a percolating water sampling system at its bottom" (Kohnke et al. 1940).

They are the standard tools used to analyze relationships among soil, water, and plants, as well as water quality research. The first lysimeter to be used for water use studies is attributed to De la Hire of France in 1688 (Kohnke et al. 1940)

Lysimeters are used to define water movement across a soil boundary.

Weighing lysimeters determine ET directly by measuring changes in mass of a soil container with plants positioned on a scale or other weighing device. They have been in use for measuring crop water use since the first one was constructed in Coshoctan, OH, in 1937 (Kohnke et al. 1940).

1.2 Statement of the Problem

Essentially, all plants require water for survival. Crop water use is the water used by a crop for growth and cooling purposes. Water used by crops serves several purposes including; translocation of minerals from the soil into plant tissue; relocation of carbohydrates and other plant-produced substances from the leaves to stems, roots, fruit, and storage organs; and plant cooling by means of evaporation.

Knowledge of evapotranspiration rates in this region is the fundamental basis for determining the water use of water leaf (*Talinum Triangulare*). Using micro weighing lysimeters to measure crop water use and prescribed methods to compute reference evapotranspiration rates, as much work has not been done on the water use determining of water leaf (*Talinum Triangulare*) in the study area. It is therefore imperative that we carry out a study on the water use of waterleaf ((*Talinum Triangulare*) in order to maximize the advantage of its short maturity period, nutritious characteristics as well as its relative cheapness for small and large scale farmer both in its production and market value.

1.3 Objectives of the Study

The goals set forth in this research are as follows:

i. To determine daily and peak evapotranspiration of waterleaf (TalinumTriangulare) using weighing lysimeters.

ii. To determine the water balance of water leaf plant

1.4 Justification of the Study

As population increases, food security is threatened; thus the need for more vegetables such as waterleaf (Tallinum Triangulare). The continuous cultivation is of vital importance in order to achieve autonomy in terms of salad crop widely used in the preparation of soup (a major part of meals in Nigeria). Thus, an appropriate water management must be planned based on the rate of evapotranspiration and the crop water requirement of this crop.

1.5 Scope of the Study

In this project, the lysimeter method is used to measure and compute the crop evapotranspiration for waterleaf (Talium Triangulare).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background

Many experimentation had been conducted on the determination of evapotranspiration rate of several crops by some researchers. Although, with reference to the project area, few studies have been carried out so far on crops evapotranspiration.

Lysimeters used for evapotranspiration (ET) research are typically classified according to their design and use as follows: monolithic or reconstructed soil profiles, weighing or non-weighing designs, and gravity or vacuum drainage designs. Monolithic lysimeters attempt to preserve existing vegetation and soil properties that can be destroyed by the excavation and filling Schneider and Howell(1991) that is done when using reconstructed soil profiles in the container. Weighing lysimeters determine evapotranspiration directly, by the mass balance of the water; non-weighing lysimeters indirectly determine ET using the volumetric soil-water balance in the container (Howell et al., 1991). Vertical drainage through the soil column can be measured using either a gravity drainage design, or a design that uses a vacuum system (if the lysimeter is designed in such a way that gravity drainage is inconvenient).

2.2 Types of Lysimeter

Mainly there are two types of lysimeters, they differ in the way in which change in soil moisture is determined and are the weighing and non weighing lysimeters.

2.2.1 Weighing lysimeter (also called "evapotranspirometer) was developed to provide a direct measurement of ET. A lysimeter is a device, a tank or container, used to define the water movement across a boundary. Actually, only a "weighing lysimeter", can determine ET directly from the mass balance of the water, as contrasted to a non-weighing lysimeter which indirectly determines ET from the volume balance (Howell et al., 1991).

Thus, weighing lysimeter are usually containers placed in the field with soil cultivated in the same way as the surrounding field. The lysimeter leans on sensor (a balance) capable of measuring the weight variation due to loss of water. However, the weighing lysimeter data are not always representatives of the conditions of the whole field but, often, they only represent the ET of one point in the field (Grebet and Cuenca, 1991). If the lysimeter surface and area immediately around it are surrounded by drier vegetation or bare soil ,an oasis effect can occur. Net radiation in excess of latent heat is converted to sensible heat which is transported toward the lysimeter, resulting in a net supply of energy to the lysimeter vegetation. All these defaults cause an increase of ET as compared to the surrounding crop. This overestimation of ET can be particularly important in a high radiation climate such as in the Mediterranean region (Howell et al., 1985;1991). The weighing lysimeter, inspite of the problems and inconveniences that limited its use, is often considered to be the reference method, and is used in particular for well-watered crops to test the other ET measurement methods.

2.2.2 Non Weighing lysimeter: The Non weighing lysimeter (called indirect measurement micrometeorological approach), from the energetic point of view, evapotranspiration can be considered as equivalent to the energy employed for transporting water from the inner cells of leaves and plant organs and from the soil to the atmosphere. In this case, it is called “latent heat” and is expressed as energy flux density (Wm^{-2}). Under this form, ET can be measured with the so-called “micrometeorological” methods. These techniques are physically-based and carried out by applying the laws of thermodynamics and of transport of scalars into the atmosphere above the canopy. To apply the micrometeorological methods, it is usually necessary to measure meteorological variables with sensor and suitable equipment placed above canopy.

Micrometeorological methods measure the actual ET with error on the final value of ET around a fraction of mm of water. Thus, they remain very suitable methods for measuring ET in semi-arid and arid environments, where the values of ET are often very low during drought periods (from spring to summer). The only exception is the aerodynamic method, which can be used only below a crop height of 1.5 m.

Another advantage of the micrometeorological technique lies in the fact that they give accurate ET values on different time scales: the hour, the day and, consequently, also the week and the whole season. Therefore, they can be adopted for studying the theoretical aspects of water consumption and the response of the crop to the water supply. The micrometeorological methods cause small disruptions in the soil-canopy-atmosphere environment, since they require small sensors easy to install, even though good knowledge of electronics and informatics is needed. The micrometeorological methods include the Bowen ratio, the eddy covariance and the aerodynamic one.

2.3 Design

Advances in ET lysimetry have focused on duplicating field conditions in the container as closely as possible to the surrounding field through the use of larger lysimeters. Although some aspects of lysimeter design are often duplicated or reused, Kohnke et al. (1940) warns that "no one construction should be regarded as standard in a lysimeter and that a proper design can be made only by having an accurate knowledge of both the purpose of the experiment and of the pedologic, geologic, and climatic conditions." Pruitt and Lourence (1985) also caution lysimeter users to critically evaluate all agronomic aspects, to ensure high-quality ET data, since major errors in ET data are possible even with an accurate lysimeter.

The design of a lysimeter should always be appropriate to the type and scope of research performed. However, some main elements are inherent in all lysimeter designs: ET accuracy, shape and area, depth, soil profile characteristics, weighing mechanisms, construction, and sitting. Each design element is discussed in more detail as follows:

2.3.1 ET accuracy: ET measurement accuracy is dictated by the planned measurement interval (weekly, daily, hourly) and values ranging from 0.02 to 0.05 mm are commonly cited as the resolution or precision of weighing lysimeter systems (Allen et al., 1991).

2.3.2 Shape and area: The shape and area of the container should be a direct reflection of the expected crops to be studied and their root depths. Differences between lysimeter surface area and crop geometry can bias the soil water evaporation and crop transpiration relationship, but this may not critically affect ET measurements for grass, alfalfa, or small grains or other broadcast planted crops (Howell et al., 1991).

2.3.3 Depth: The depth of the lysimeter should be based on the rooting depth of the crop which is to be studied. Van Bavel (1961) advised that lysimeter depth should permit the development of normal rooting density and rooting depth and provide similar "available" water profiles to the field profile.

2.3.4 Soil profile characteristics: Although monolithic lysimeters may preserve the exact physical, chemical, and vegetation characteristics of the surrounding area. Many weighing lysimeters have utilized reconstructed soil profiles for ET measurements and, when carefully reconstructed, provided accurate ET data (Pruitt and Angus, 1960).

2.3.5 **Weighing mechanisms**: Mechanical scales have been widely used in weighing lysimeters since the 1950's and permit the precise measurement of the mass change of water within the lysimeter (Howell et al., 1991). Load cell lysimeters measure the total weight of the lysimeter; this leads to the accuracy of ET measurements being dependant on the accuracy of the load cells and the area to mass ratio of the lysimeter design.

2.3.6 **Construction**: Most lysimeter soil containers are made using either steel, reinforced fiberglass, or plastic as the primary construction material. The gap between the inner and outer tank of a weighing lysimeter should be designed as narrow as possible to prevent unnecessary wall heating while allowing for ample clearance to avoid contact between the inner and outer tanks. The gap between tanks must also be covered to prevent water intruding due to rainfall or irrigation.

2.3.7 **Location**: Windward fetch must be accounted for when choosing a site for any lysimeter. A sufficient distance of fetch consisting of the same vegetation and moisture regimes as the lysimeter is necessary to ensure that the lysimeter is representing the same environmental conditions as the entire field. Minimum fetch distances should be determined based on the height at which weather recording instruments are operating. For instance, if wind speed, humidity, and temperature are being recorded at a 2 m height above ground surface, then a windward fetch of 100 to 400 m should be provided given suggested fetch ratios that vary from a minimum of 1:25 (Allen et al., 1991) to as much as 1:200 (Jensen et al., 1990).

2.4 Operational Requirements

Potential lysimeter errors can be reduced using strict design and maintenance regimes. Lysimeter operators and users of lysimeter data must be knowledgeable about the constraints of proper environmental management for the lysimeter site and the resulting interpretation of lysimeter data. The accuracy of lysimeter data depends on the ability to achieve identical conditions between the lysimeter and the surrounding field. If lysimeters are designed to meet specific requirements for the research performed and are operated properly, then they can be utilized as precision tools to measure actual evapotranspiration. Through proper use, precision weighing lysimeters are the most practical research tool for direct measurement of daily evapotranspiration and an effective approach to conduct crop coefficient studies (Howell et al., 1985; Yrisarry and Naveso, 2000).

2.5 Evapotranspiration

Evapotranspiration (ET) is the loss of water from a vegetated surface through the combination of the evaporation of water from the soil or plant surface plus the transpiration of water that is transported through the plant and released to the atmosphere as water vapor. ET is a basic component of the hydrologic cycle. The knowledge of this water balance term is essential for the planning and operation of water resource projects. Evapotranspiration is the loss of water from a vegetated surface through the combination of the evaporation of water from the soil or plant surface plus the transpiration of water that is transported through the plant and expelled as water vapor. Evaporation and transpiration are affected by solar radiation, air temperature, humidity, wind speed, and soil moisture. Transpiration is also affected by soil moisture and crop characteristics. ET is commonly expressed in units of either depth per time (e.g. mmday^{-1}) or energy per unit area over a specified time (e.g. MJ m^{-}

$^{2}day^{-1}$). Cuenca (1989) gives a description of the evapotranspiration process as "the combination of water evaporated from the plant and soil surface plus that amount of water which passes through the soil into roots, through the stem of the plant, and to the leaves where it passes into the atmosphere through small pores termed stomates."

An accurate estimation of evapotranspiration is important to water supplies (surface and groundwater), water management, and the economics of multi-purpose water projects (i.e. irrigation, power, water transportation, flood control, municipal and industrial water uses, and wastewater reuse systems). The political implications of water use issues affected by evapotranspiration include the negotiation of water compacts and treaties and the litigation and adjudication of water rights in major river systems (Jensen et al., 1990).

2.5.1 Reference Evapotranspiration

The evapotranspiration rate from a reference crop surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_0. The methods for reference ET calculation can be categorized into four groups: combination, radiation, temperature and pan evaporation methods. Combination methods, the most commonly used methods, include radiation (energy balance) and aerodynamic (heat and mass transfer) terms. Typical combination methods are FAO Penman (Doorenbos and Pruitt, 1977), Kimberly Penman (Wright, 1982), Penman-Monteith (Allen et al., 1994a), the FAO Penman-Monteith (Allen et al., 1998) and the ASCE-EWRI Penman-Monteith (Walter et al., 2002). Penman (1948) established the modern reference evapotranspiration standard by separating the term into two components that drive the process simultaneously: an available energy term, and a mechanically derived term driven by atmospheric vapor transport. The combination of these two terms was the first time net radiation was introduced into the physical modeling of evapotranspiration. Doorenbos and Pruitt (1977) defined reference ET to be " the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall. Allen (1994) introduced the idea of a hypothetical reference crop so that crop characteristics could be applied to the reference evapotranspiration definition. Jensen (1990) defines reference ET as the rate at which readily available soil water is vaporized from specified vegetated surfaces. A recent definition of reference ET adds a minimum fetch specification to the requirements set by FAO 56: "the ET rate from a uniform surface of dense, actively growing vegetation having specified height and surface resistance, not short of soil water, and representing an expanse of at least 100 m of the same or similar vegetation" (Walter et al., 2005).

The standard method for determining ET_0 was established in 1990 during consultation of experts and researchers from the Food and Agricultural Organization (FAO) of the United Nations in collaboration with the International Commission for Irrigation and Drainage (ICID) and the World Meteorological Organization, to review methodologies on crop water requirements and to advise on procedures to use meteorological data to estimate ET_0(Allen et al., 1998). The method that was agreed upon for calculating reference evapotranspiration is known as the FAO-56 Penman Monteith (FAO 56 PM) method. The guidelines presented by Allen et al. (1998) can be used to compute crop water requirements for both irrigated and rainfall fed agriculture and for computing water consumption by agricultural and natural vegetation. A recent ASCE-EWRI standard method to calculate reference ET has been published (Walter et al., 2005), but for daily calculations of reference ET on grass, the guidelines are identical to the FAO 56 method.

2.5.2 Actual Evapotranspiration

Actual evapotranspiration or crop evapotranspiration (ET_C) is the actual amount of water removed from a surface and delivered to the atmosphere through the processes of evaporation and transpiration. This term has historically been difficult to measure directly, but with the advent and technological advances within the field of lysimetry, the term can be more readily measured. It is quite difficult to separate evapotranspiration into evaporation and transpiration, so the combination of the two is widely used in water balance studies.

Lysimeters have been considered the most reliable research tool for direct measurement of crop evapotranspiration and have been regarded as the standard for all other methods (Howell et al., 1985; Burman and Pochop, 1994; Burman et al., 1983). Howell et al. (1985) states that weighing lysimeters are considered the most practical research tools for the direct measurement of daily ETc. The actual evapotranspiration rate of any crop that is planted in a weighing lysimeter can be measured by monitoring the change in weight (or equivalently the change water storage) of the soil container. Monitoring and measuring all inputs and outputs of the lysimeter allows for the measurement of ETc. Positive changes in weight indicate an addition of water to the soil container in the form of either rainfall or irrigation while negative weight changes indicate the subtraction of water from the soil container through either actual evapotranspiration, drainage, or runoff. Thus, a soil water balance equation can be written:

$$ET = P + I \pm Ro = ET + D \pm \Delta W \quad (1)$$

2.6 Crop coefficient

A crop coefficient (K_C) is a numerical factor that relates actual evapotranspiration (ET_C) of an individual, well watered crop to the reference evapotranspiration (ET_C). The crop coefficient accounts for the characteristics of a certain crop and its phenological growth stages. Dimensionless K_C values are calculated (Doorenbos and Pruitt, 1975; 1977): Yrisarry (2000) states that precision weighing lysimeters are one of the most effective methodologies for direct crop coefficient studies. Using known values of ET_C and an estimate of ET_C, $K_C$can be solved for directly. A crop curve can be developed by plotting $K_C$over any period of time. The crop curve is useful for most hydrologic water balance studies, especially those involving irrigation planning and management, and for the development of basic irrigation schedules. Average crop coefficients (on a monthly basis) are usually more relevant and more convenient than the K_C computed using a daily time interval (Allen et al., 1998).

Knowledge of a crop coefficient can be a useful tool to establish crop water usage and can be used in the agricultural industry as a method to determine actual evapotranspiration based on estimated values of reference evapotranspiration. Practical crop water requirements are calculated using tabulated values of K_C and calculated values for ET_0using one of many reference evapotranspiration equations, preferably the FAO56 Penman-Monteith equation according to(Allen et al. 1998).

The knowledge of the crop water requirement on a monthly basis is critical for proper irrigation management. Given a known actual evapotranspiration for a specific crop and an estimated reference evapotranspiration for a reference crop (water leaf), one can calculate the crop coefficient for that specific crop using equation. The knowledge of specific monthly crop coefficients over a variety of crops and for a variety of seasonal conditions can lead to the better understanding and management of irrigation water resources.

2.7 Seasonal Consumptive Use

This is the total amount of water use in evapotranspiration by a cropped area during the entire growing season.

2.8 Irrigation

This refers to the application of water to land in accordance to crop water requirement throughout the crop growth and developmental period. While some areas have more than enough rainfall, agricultural land in other areas has to be irrigated. Not only arid and semi-arid regions are irrigated but also sub-humid areas where irrigation supplements natural rainfall (Lanthaler 2004). Irrigation aims to recharge soil to the field capacity in the layer from which roots absorb water. The amount of water applied depends on weather, soil, plant, crop and economic conditions. Insufficient water supply leads to a decrease of yield but too much irrigation will increase losses of percolation (and can cause a higher water table and salinization of soil) and evapotranspiration.

2.9 Relevance of Agriculture in the Economy

The estimated crop water use is an important parameter to use in planning and managing agricultural activities for food crops at country level. The estimated values clearly show the crops that are being produced under conditions of water stress, with a pronounced effect on yields. This means that different crop and soil water management practices need to be adopted (Pruitt and Angus, 1960) such as:

(i) Maximum use of rainfall (water harvesting, runoff reduction, early planting, etc.);

(ii) Minimizing water loss (evaporation reduction by mulching or rapid crop cover, wind shields, minimum tillage, weeding etc).

(iii) Being water-efficient (planting low water consuming crop species, adapting fertilization to the water available, optimal planting and seeding, selection of varieties that can complete their cycle within the length of the climatic growing period, etc.

These strategies allow a better use of the available water at the farm level.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of study Location

The field experiment was carried out during the 2011 rainy season at the experimental fields between the Department of Chemical Engineering and the Department of Agricultural and Bio-Resources Engineering in the Federal of University of Technology minna. An average maximum and minimum temperature for this region are 31°C and 28°C respectively. Minna lies on a latitude 09°34'N and longitude 06^{0}28'E. Niger State lies in the semi arid zone and is characterized by two distinct seasons, the wet and dry seasons respectively . The wet season starts in April and ends in October with the mean maximum rainfall recorded in August. Minna has a mean annual rainfall of 1220mm.The average maximum and minimum temperature for the region are 31°C and 28°C, respectively and mean annual relative humidity of 59%.

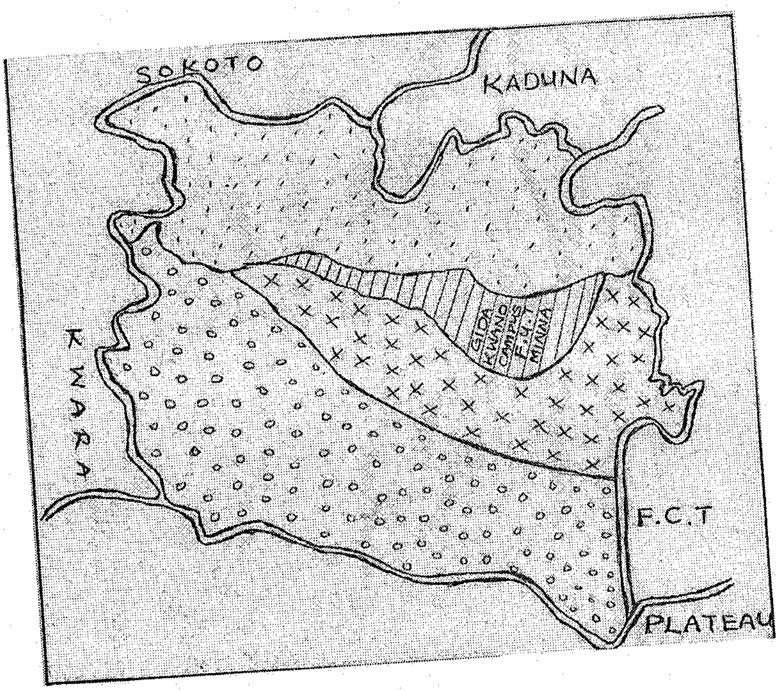


Fig 3.1. Map of Niger state, showing the study site.

The weather data of the study location for the period when the study was carried out is presented in Appendix U,V, W, X and Y.

3.2 Lysimeter Construction

A set of 3-drainage lysimeter were used to determine the the Evapotranspiration (ET) and Reference Evpotranspiration (ETo) for water leaf (TalinumTriangulare). A metal steel sheet of 16gage was cut into 500mm by 200mm in constructing the four sides of each lysimeter ,with an angle iron of 200mm to brace each sides of the metal sheet. An angle iron of 200 mm by 200 mm was used as the four stands, beneath the adjacent edges of the coupled metal steel sheet, an angle iron of 500mm by 500mm welded horizontally with a plywood of 490mm by 490mm seating on it. A 12mm by 12mm portion of plywood was cut out at the center for percolating water to drain into the drainage collection bottle. A tyre tube was filled with water and a flexible tube was fixed on its valve to enabe the easy observation of weight displacement on the meter rule as indicated on the tube. Also on the tyre tube was another plywood of the same dimension as the first with a drilled hole of 12mm on which the lysimeter pot filled with soil of 20 kg seats. One side of the lysimeter was an angle iron of 1500mm welded as vertical post which hold a meter rule of 750mm firmly and the flexible tube connected to the vespa tube was directed through the vertically welded angle iron on which the metre rule is attached to enable the reading of the displacement of the fluid(water) in the vespa tube for weight determination through the respective hight displacement.

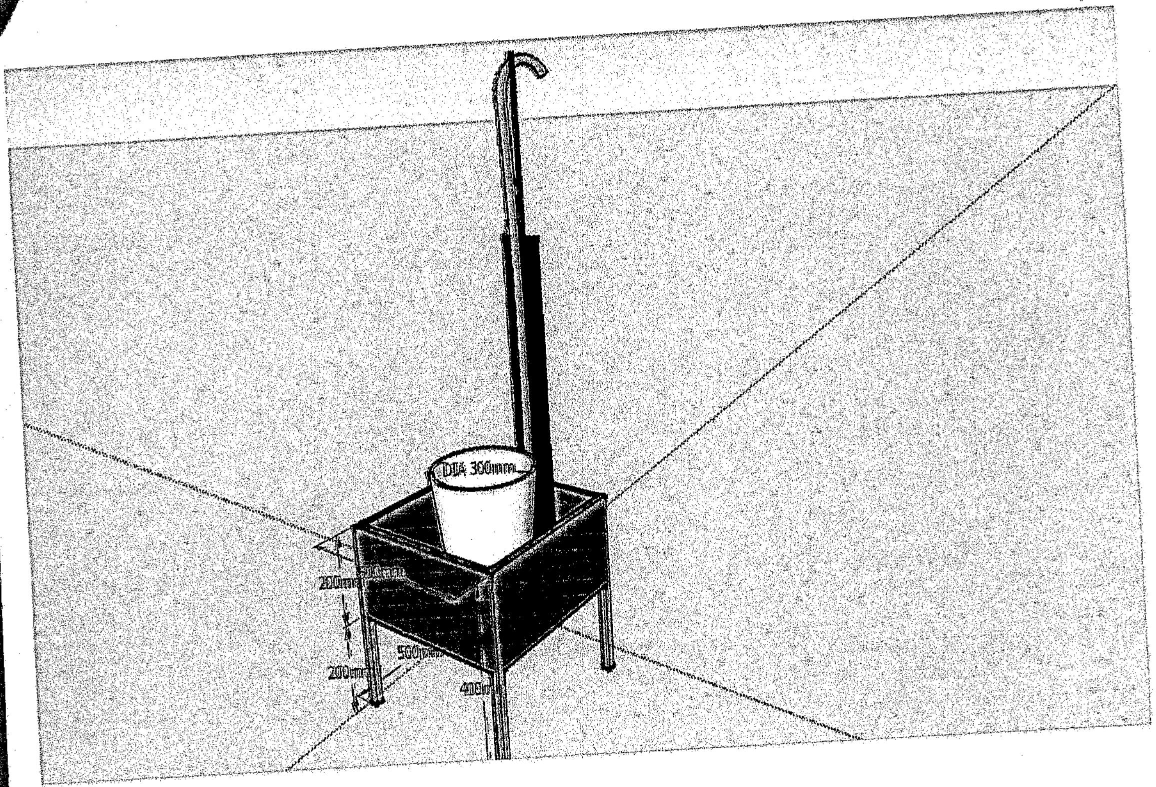


Plate 3.1:A micro weighing lysimeter.

3.3 LysimeterInstallation

Three sets of micro-lysimeters were assembled and used for this study. Each set of mini-lysimeter consisted of a plastic container of 30 cm diameter and 27.5 cm deep which serve as the lysimeter tank or pot where the crop was planted, the weighing system and the drainage systems. The weighing system consisted of a Vespa motorcycle tube filled with water to capacity and connected with a rubber hose to a meter rule of 750mm long. The meter rule was fixed to a vertical pole attached to the lysimeter in a vertical position so that water in the vehicular tube rose to a height in the attached tube and read on the metre rule depending on the pressure exerted on it. The vehicular tube was placed on a wooden platform and the lysimeter tank was placed on another platform of same diameter as the one below the vehicular tube so the change in weight of the lysimeter pot due to inflow and outflow of water into the pot causes a displacement of the water level in the connected tube that enables the meter rule readings of respective weight. The drainage system consisted of a plastic bottle of 25 cm diameter and 15 cm deep which collects the drained water from the bottom of the lysimeter tank. The lysimetric container was perforated at the bottom to allow for drainage of water beyond what the soil can hold. An opening was made in the center of the platform upon which the tube rested, into which the drainage collector was fitted such that the collector was suspended above the ground surface. This was done to prevent rainwater from the surrounding from entering into it the drainage collector.

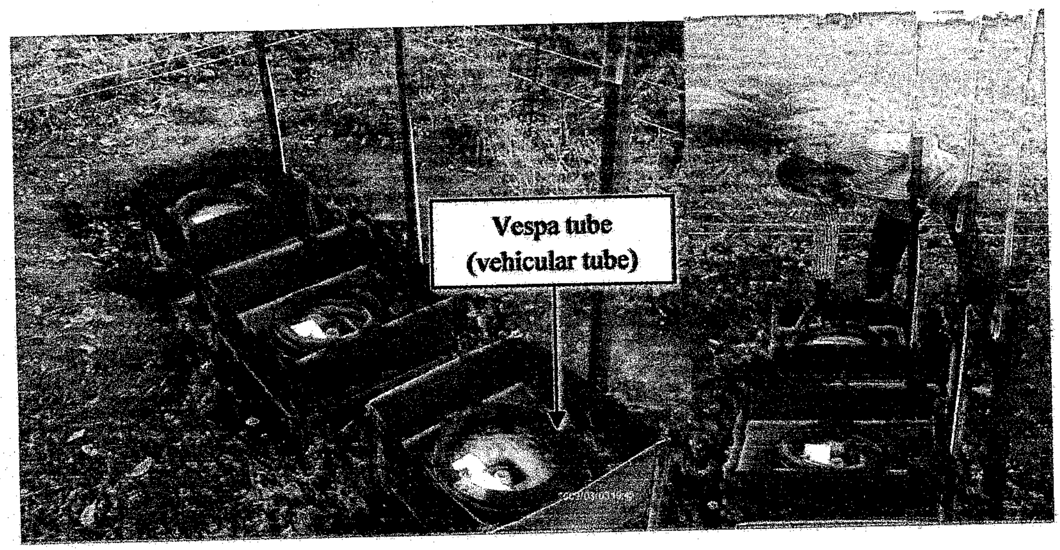


Plate 3.2: Lysimeter installation and spacing.

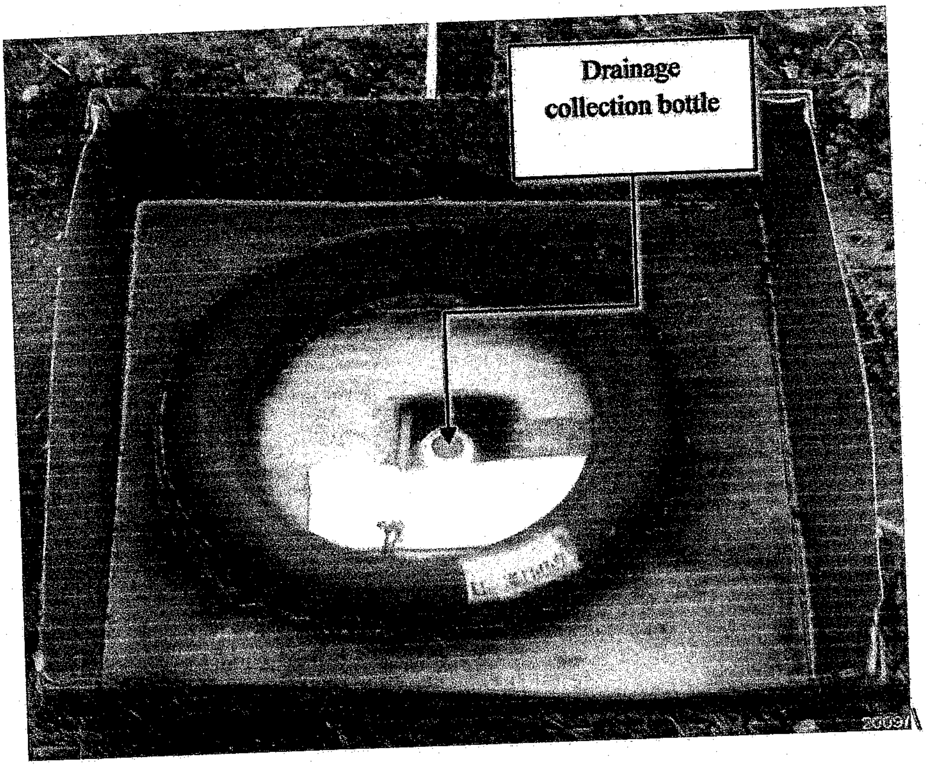


Plate 3.3: A vehicular tube with the tube that show fluid displacement as a result of weight change as well as the drainage collection plastic bottle.

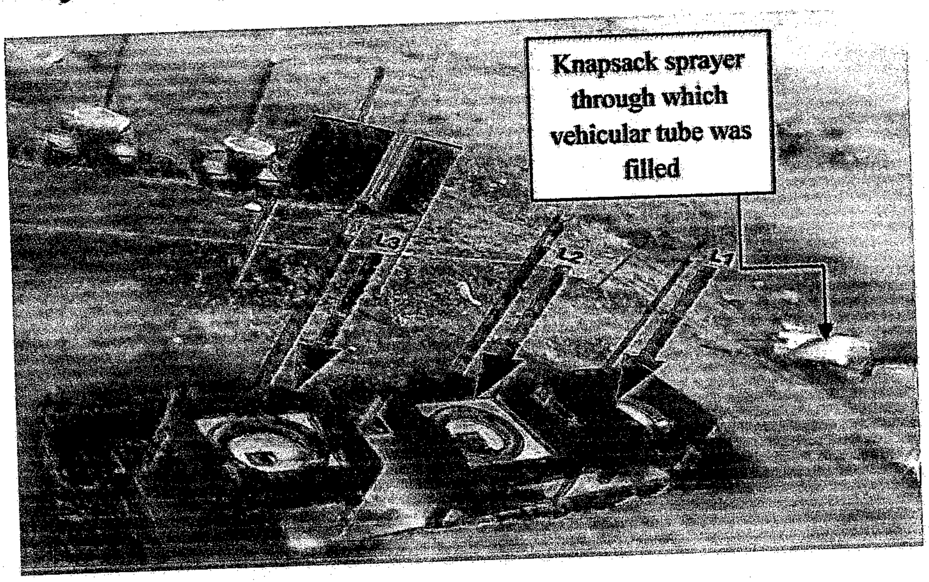


Plate 3.4: vehicular tube filled with water

3.4 Cultivation Of Water Leaf

Based on knowledge of the mode of propagation of waterleaf (*TalinumTriangulare*), the cultivation was done in the evening using one of the known methods of waterleaf cultivation which was the method of stem cutting, as samples of waterleaf steam was cut from an already existing waterleaf plant source with its leafs detached and then inserted into the soil in the lysimeter pot within a period of two hours after it was detached from source and watered.

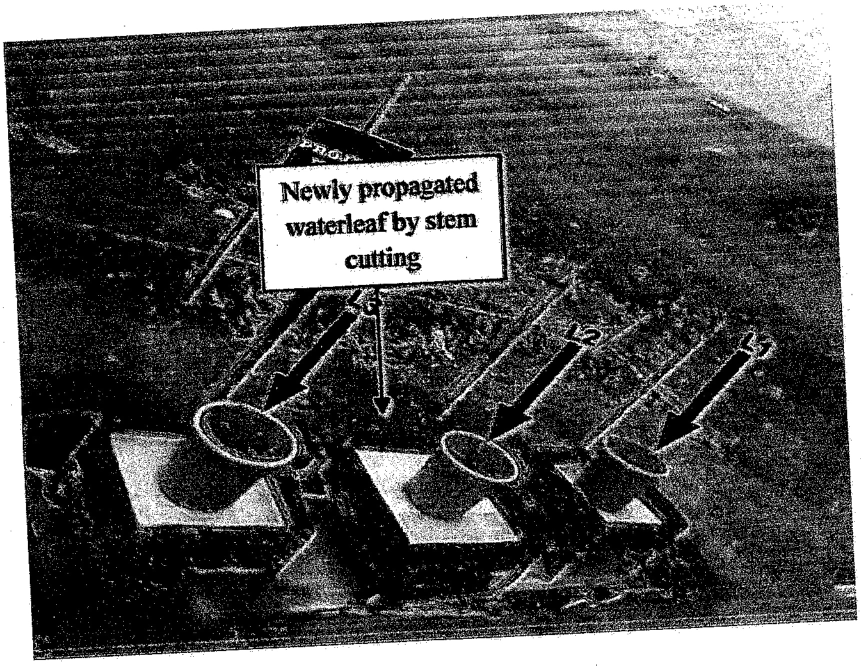


Plate 3.5: Cultivation of waterleaf (*TalinumTriangulare)* by the method of stem cutting.

3.5 Computation of crop water use from the lysimeters

Each rainfall added water to the lysimeter tank, this results in pressure on the vespa tubes due to increase in weight of the lysimeter tank and causes a rise in the water level in the tube through which meter rule takes relevant reading for this test. Water beyond what the soil could hold drained by gravity through the bottom of the lysimeter tank into the drainage collector. A rain gauge was installed on the field to measure daily rainfall depth. As evaporation took place and the crop used water for its metabolic activity on daily basis, the weight of the lysimeter tank and consequently the level of water as read in tube on the meter rule decreased. The levels of water in the tubes read on the meter rule were monitored 24 hourly throughout the crop growing season between 7:00 and 8:00 am. The drainage collectors was also inspected at three days intervals, and the depths of water found in them were noted. The difference in weight of the lysimeter tank between two consecutive measurements indicated by the difference in the level as read on the metre rule was as a result of the water added from rainfall, crop water use (evapotranspiration), water drained. When there is no rainfall, or drainage, the difference in weight would be due to crop water use. The weight of the lysimeter tank on any given day was determined from the level of water in the vespa tube as read with the metre rule using a relationship height of water in the tube and known weight packed into the lysimeter tank. The relationship was obtained as:

$$W = 0.5281 * H + 6.8057 \quad (2)$$

($r^2 = 0.9972$) as generated from Table k below

Table 3.1: Table of Respectives Read Weight of Stones,Computed Cummulative and Displacement of Water Read on Meter Rule

Stone	Weight(kg)	MH(mm)	CW(kg)
1	3.5		
2	2.4		
3	1.6	2.1	7.5
4	3.7	8	11.2
5	1.9	10.9	13.1
6	5.5	22.7	18.6
7	0.9	23.8	19,5
8	0.7	25.9	20.2
9	2.4	30.2	22.6
10	2	33.3	24.6

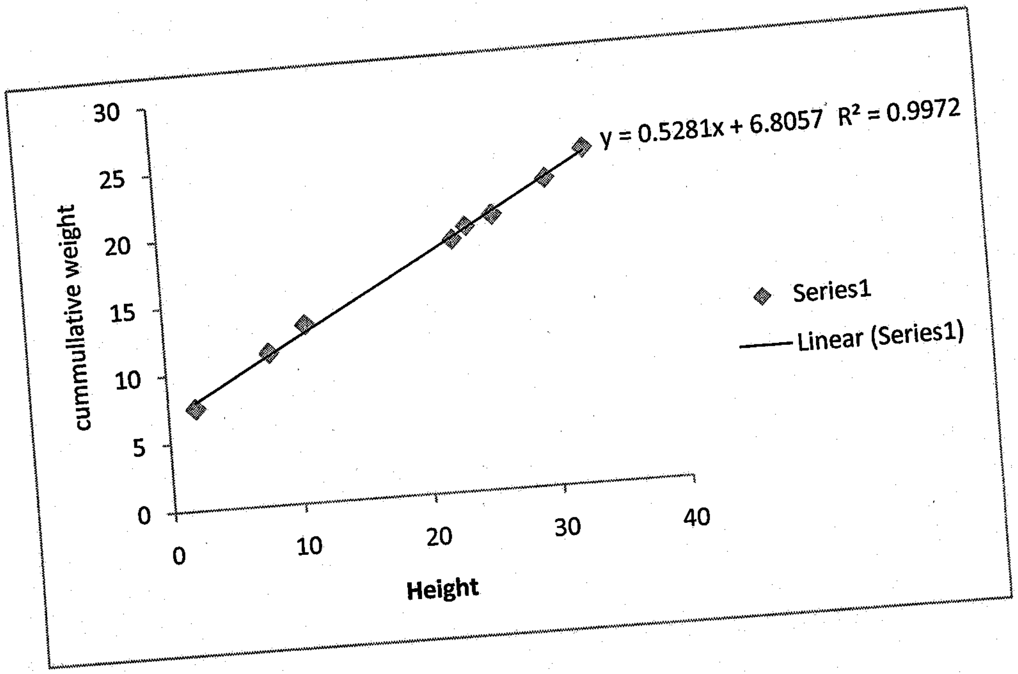


Figure 3.2: Graph of cumulative weight of stone against height.

where, W is weight of lysimeter in kg and H is height of water in the tube read on metre rule in cm.The differences in weight of the lysimeter tank thus obtained on daily basis were translated to depth of water in mm/day using a factor of 14.1. This factor was based on the surface area of the lysimeter tank and the density of water. When rainfall, drainage events occurred, their depths were first subtracted from the change in weight of the lysimeter tank, and the reminder was the crop water use.

The method used for this project was based on water balance equation given as the follows:

$$\text{Input} - \text{Output} = \pm \Delta W \qquad (3)$$

$$P + I - (Ro + Dr + ET) = \pm \Delta W$$

The incoming water flux for a given time period refers to

P = Precipitation.

I = Irrigation.

The outgoing water flux refers to ET = Evapotranspiration, which includes evaporation from the soil and transpiration of the crop.

D = Deep percolation or drainage water.

ΔW = Change of water content (W) of the isolated soil mass over a given period of time.

Ro = Surface runoff, to or out of the lysimeter. Normally the protruding rims of the lysimeter will prevent any to or out of the system.

To determine the evapotranspiration (ET) all other terms of the water balance equation must be measured according to:

$$ET = P + I - D \pm \Delta W \tag{4}$$

Precipitation (P) and irrigation (I) can be directly measured by conventional methods such as rainguages and calibrated containers. Special arrangement are made within the lysimeter to drain and measure the water percolating through the soil mass (D).ΔW will be change because the reading from meter rule is in millimeter(mm) and have to converted to weight and this was done by calibrating the lysimeter setup i.e.by adding a known weight into the lysimeter pot and getting different height on the manometer tube, a graph of weight against height was gottten and which gives W=0.06H-12.81.The water balance equation is re-write to be

$$Et = P - Dr - (W_{i+1} - W_i)*Cf. \tag{5}$$

Et = Evapotranspiration (mm/day).

P = Precipitation (mm)

Dr = Drainage in(mm) in day

W_i = Weight of lysimeter soil on day

W_{i+1} = Weight of lysimeter soil on an interval of the days after rainfall

Cf = A factor converting weight to an equivalent depth of water.

To convert mass of lysimeter pot to depth of water, convention factor need to be calculated thus: Density(kg/m^3) = mass(kg)/Volume(m^3)

Volume(m^3) = Mass(kg)/Density(kg/m^3)

Diameter of the pot = 30cm.

Surface area = $\pi d^2/4$

$3.142*(0.3)^2/4 = 0.071m^2$

Depth = Volume/surface area of pot

Depth(m) = 1000/0.071=14084.5m

Converting meter(m) to millimetre(mm)

14084.5/1000 = 14.1mm

Therefore the conventional factor is 14.1mm

Therefore Water balance equation:

$Et = P - Dr - (Wi+1 - Wi)*14.1$

Hence the first precipitation date 28/07/2011 was obtained as follow:

$Et = P - Dr - (Wi+1 - Wi)*Cf$

ET= 18.5– 14– [(40.2–41.2)*14.1] = 18.6mm/day

3.6 Computation of Reference Evapotranspiration (Eto).

Computation of ETo, using Hargreaves FAO-56 is based on meteorological data, particularly temperature and solar radiation factor as presented in Appendix I.

$$ETo = 0.0023R_a(T_{max} - T_{min})^{0.5}*(Tm+17.8) \quad (6)$$

ETo = Reference Evapotranspiration

T_m = The mean daily air temperature (0^c)

T_{max} = The daily maximum air temperature (0^c)

T_{min} = The daily minimum air temperature(0^c)

R_a = The extra-terrestrial radiation (mm/day)

For 1/08/2011 the Evapotranspiration rate, the reference evapotranspiration rate is:

$$ETo = 0.0023*Ra(T_{max} - T_{min})^{0.5}*(Tm + 17.8)$$

$$ETo = 0.0023*0.0575*(30-25)^{0.5}*(27.5+17.8)$$

$$ETo = 0.0023*0.0575*(2.236)*45.3$$

ETo = 0.013mm/day.

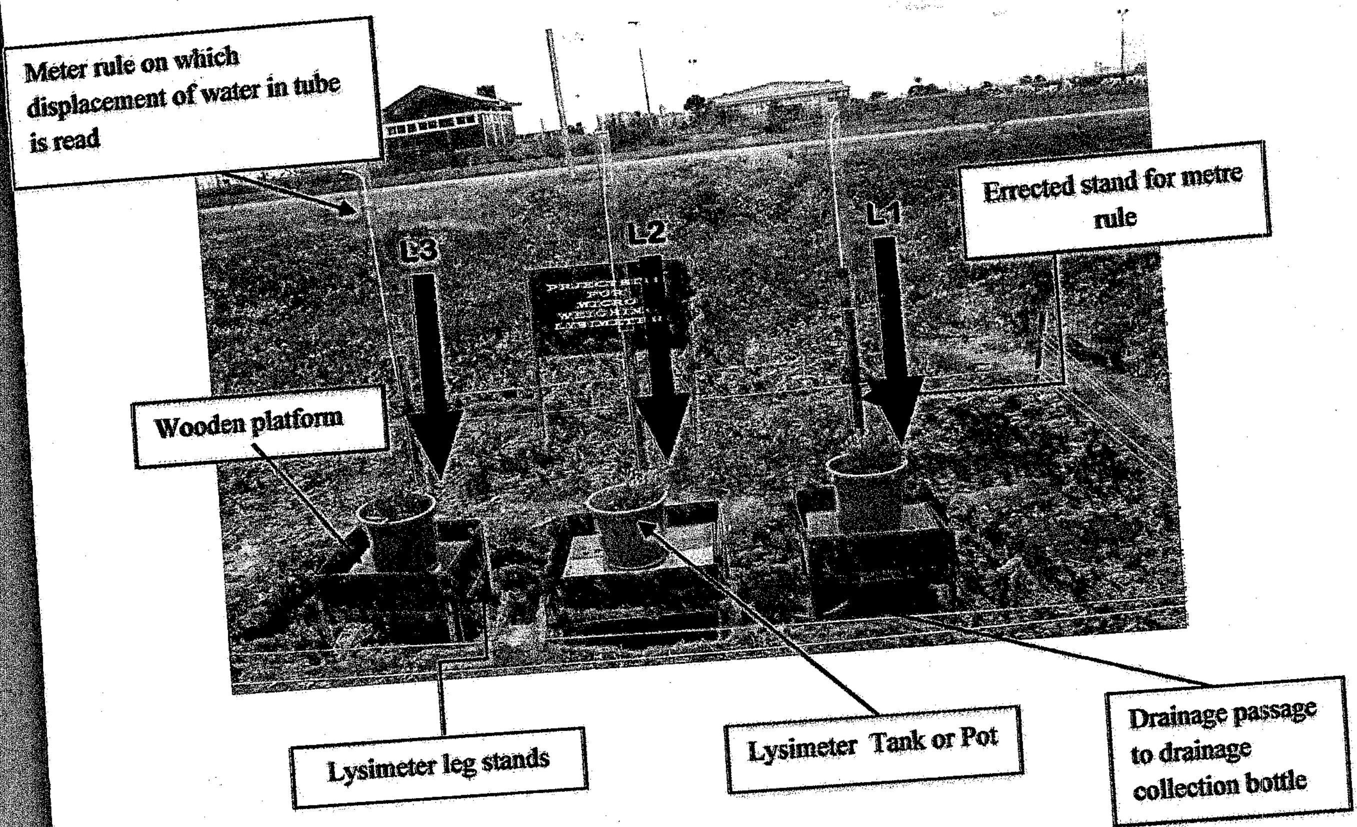


Plate 3:6complete lysimeter setup with grown waterleaf at flowering stage

CHAPTER FOUR

4.0 Results and Discussion

4.1 Presentation Of Result

The crop water use of waterleaf (*Talinum Triangulare*) was computed using the water balance equation and expressesed in the tables 4.1, 4.2 and 4.3 as follows

Table 4.1: Table of lysimetric computation indicating the drainage, rainfall and evapotranspiration for the first lysimeter 1

Days	Date	Height (mm)	Weight (Kg)	Drainage (mm)	Rainfall	Evapotranspiration
1	28-Jul	67.3	42.3		18.5	
2	29-Jul	65.1	41.2			
3	30-Jul	63.2	40.2	14		18.6
4	31-Jul	62.3	39.7			
5	1-Aug	60.7	38.9		25	
6	2-Aug	58.9	37.9	18		32.3
7	3-Aug	57.2	37.0			
8	4-Aug	55.7	36.2			
9	5-Aug	47.6	31.9	17	8	79.5
10	6-Aug	44.1	30.1			
11	7-Aug	45.8	31.0			
12	8-Aug	43.6	29.8	10		1.7
13	9-Aug	36.5	26.1		27	
14	10-Aug	26.4	20.7			
15	11-Aug	38.7	27.2	9		1.6

16	12-Aug	40.3	28.1			
17	13-Aug	38.6	27.2		19	
18	14-Aug	35.2	25.4	22		35.0
19	15-Aug	33.6	24.5			
20	16-Aug	31.2	23.3			
21	17-Aug	29.8	22.5	29	23	18.3
22	18-Aug	26.3	20.7			
23	19-Aug	24	19.5			
24	20-Aug	26	20.5	16		9.2
25	21-Aug	41	28.5		28	
26	22-Aug	36.2	25.9			
27	23-Aug	33.1	24.3	23		63.8
28	24-Aug	30.3	22.8			
29	25-Aug	28.4	21.8		11	
30	26-Aug	26.2	20.6	8		33.5
31	27-Aug	35.4	25.5		34	
32	28-Aug	37	26.3			
33	29-Aug	44.8	30.5	11		-47.0
34	30-Aug	27	21.1			
35	31-Aug	22.8	18.8		27	
36	1-Sep	21.9	18.4	24		41.0
37	2-Sep	19	16.8			
38	3-Sep	23	19.0			
39	4-Sep	20.9	17.8	5	9	7.9
40	5-Sep	18.8	16.7			
41	6-Sep	20.2	17.5		16	
42	7-Sep	18.1	16.4	4		26.2

43	8-Sep	17.2	15.9			
44	9-Sep	16.1	15.3			
45	10-Sep	14.9	14.7	9		24.1
46	11-Sep	13.3	13.8		4	
47	12-Sep	15.1	14.8			
48	13-Sep	14.4	14.4	0		-4.2
49	14-Sep	13.2	13.8			
50	15-Sep	12.1	13.2		41	
51	16-Sep	19	16.8	15		-17.2
52	17-Sep	23	19.0			
53	18-Sep	20.9	17.8			
54	19-Sep	18.8	16.7	19		53.3
55	20-Sep	15.3	14.9			
56	21-Sep	13.9	14.1		32	
57	22-Sep	12.1	13.2	20		35.8
58	23-Sep	10.8	12.5			
59	24-Sep	9.1	11.6			
60	25-Sep	7.3	10.7	15		43.1

Table 4.2 Table of lysimetric computation indicating the drainage, rainfall and evapotranspiration for the second lysimeter L2

Days	Date	Height (mm)	Weight (Kg)	Drainage (mm)	Rainfall	Evapotranspiration
1	28-Jul	65.1	41.2		18.5	
2	29-Jul	63.2	40.2			
3	30-Jul	61.6	39.3	12		18.4
4	31-Jul	60.4	38.7			
5	1-Aug	58.7	37.8		25	
6	2-Aug	57	36.9	15		35.3
7	3-Aug	56.1	36.4			
8	4-Aug	37.3	26.5			
9	5-Aug	34.6	25.1	20	8	165.1
10	6-Aug	31.3	23.3			
11	7-Aug	32.1	23.8			
12	8-Aug	30.2	22.8	13		3.2
13	9-Aug	22.5	18.7		27	
14	10-Aug	13.6	14.0			
15	11-Aug	27.4	21.3	17		-26.5
16	12-Aug	27.5	21.3			
17	13-Aug	25.3	20.2		19	
18	14-Aug	22.6	18.7	15		40.5
19	15-Aug	20.4	17.6			
20	16-Aug	18.9	16.8			
21	17-Aug	16.9	15.7	12	23	33.1
22	18-Aug	14.1	14.3			

23	19-Aug	12	13.1			
24	20-Aug	14.3	14.4	14		7.5
25	21-Aug	27.1	21.1		28	
26	22-Aug	23.2	19.1			
27	23-Aug	20.5	17.6	20		57.1
28	24-Aug	17.6	16.1			
29	25-Aug	21.7	18.3		11	
30	26-Aug	15.2	14.8	6		22.9
31	27-Aug	21.9	18.4		34	
32	28-Aug	23	19.0			
33	29-Aug	32.5	24.0	15		-59.9
34	30-Aug	15.2	14.8			
35	31-Aug	12.3	13.3		27	
36	1-Sep	14.1	14.3	14		21.2
37	2-Sep	17.5	16.0			
38	3-Sep	15.5	15.0			
39	4-Sep	13.7	14.0	18	9	37.3
40	5-Sep	10.2	12.2			
41	6-Sep	8.3	11.2		16	
42	7-Sep	7.4	10.7	12		33.8
43	8-Sep	6.2	10.1			
44	9-Sep	5.1	9.5			
45	10-Sep	4.2	9.0	5		25.9
46	11-Sep	3	8.4		4	
47	12-Sep	3.5	8.7			
48	13-Sep	2.6	8.2	2		5.0
49	14-Sep	2	7.9			

50	15-Sep	1.4	7.5		41	
51	16-Sep	17.5	16.0	12		-86.4
52	17-Sep	15.5	15.0			
53	18-Sep	13.7	14.0			
54	19-Sep	10.2	12.2	26		54.5
55	20-Sep	5.6	9.8			
56	21-Sep	4.2	9.0		32	
57	22-Sep	3.1	8.4	24		26.6
58	23-Sep	2.1	7.9			
59	24-Sep	0.4	7.0			
60	25-Sep	0	6.8	5		42.6

Table 4.3: Table of lysimetric computation indicating the drainage, rainfall and evapotranspiration for the third lysimeter L3

Days	Date	Height (mm)	Weight (Kg)	Drainage (mm)	Rainfall	Evapotranspiration
1	28-Jul	66.5	41.9		18.5	
2	29-Jul	64.1	40.7			
3	30-Jul	61.4	39.2	12		26.6
4	31-Jul	59.2	38.1			
5	1-Aug	57.2	37.0		25	
6	2-Aug	56.3	36.5	16		30.6
7	3-Aug	55.1	35.9			
8	4-Aug	33.1	24.3			
9	5-Aug	28	21.6	9	8	217.8
10	6-Aug	27.6	21.4			

11	7-Aug	26.9	21.0			
12	8-Aug	24.1	19.5	15		19.1
13	9-Aug	20.5	17.6		27	
14	10-Aug	17.2	15.9			
15	11-Aug	23	19.0	12		-3.6
16	12-Aug	25.7	20.4			
17	13-Aug	23.7	19.3		19	
18	14-Aug	21.5	18.2	17		33.3
19	15-Aug	22.1	18.5			
20	16-Aug	20.7	17.7			
21	17-Aug	18.8	16.7	24	23	19.6
22	18-Aug	16.3	15.4			
23	19-Aug	15.1	14.8			
24	20-Aug	11.6	12.9	19		39.0
25	21-Aug	27.4	21.3		28	
26	22-Aug	24.5	19.7			
27	23-Aug	21.6	18.2	20		51.2
28	24-Aug	18.7	16.7			
29	25-Aug	22.6	18.7		11	
30	26-Aug	20.5	17.6	3		-5.4
31	27-Aug	22.8	18.8		34	
32	28-Aug	23	19.0			
33	29-Aug	30.5	22.9	20		-43.3
34	30-Aug	18.3	16.5			
35	31-Aug	16	15.3		27	
36	1-Sep	16.5	15.5	5		35.4
37	2-Sep	14.9	14.7			

38	3-Sep	12.3	13.3			
39	4-Sep	10.3	12.2	21	9	40.3
40	5-Sep	9.2	11.7			
41	6-Sep	7.6	10.8		16	
42	7-Sep	9	11.6	6		20.5
43	8-Sep	8.1	11.1			
44	9-Sep	7	10.5			
45	10-Sep	6.1	10.0	0		11.5
46	11-Sep	5.2	9.6		4	
47	12-Sep	6.2	10.1			
48	13-Sep	5.1	9.5	8		-3.3
49	14-Sep	4.2	9.0			
50	15-Sep	3	8.4		41	
51	16-Sep	14.9	14.7	12		-50.7
52	17-Sep	12.3	13.3			
53	18-Sep	10.3	12.2			
54	19-Sep	9.2	11.7	28		36.1
55	20-Sep	6.1	10.0			
56	21-Sep	4.6	9.2		32	
57	22-Sep	2.9	8.3	12		43.8
58	23-Sep	1.3	7.5			
59	24-Sep	0.1	6.9			
60	25-Sep	0	6.8	23		43.8

Table 4.4: Table of collected drainages, respective computed total and average

Days	Date	Drainage (mm)	Drainage (mm)	Drainage (mm)	Total Drainage (mm)	Average Drainage (mm)	Rainfall (mm)
1	28-Jul				0	0	18.5
2	29-Jul				0	0	
3	30-Jul	14	12	12	38	12.7	
4	31-Jul				0	0	
5	1-Aug				0	0	25
6	2-Aug	18	15	16	49	16.3	
7	3-Aug				0	0	
8	4-Aug				0	0	
9	5-Aug	17	20	9	46	15.3	8
10	6-Aug				0	0	
11	7-Aug				0	0	
12	8-Aug	10	13	15	38	12.7	
13	9-Aug				0	0	27
14	10-Aug				0	0	
15	11-Aug	9	17	12	38	12.7	
16	12-Aug				0	0	
17	13-Aug				0	0	19
18	14-Aug	22	15	17	54	18	
19	15-Aug				0	0	
20	16-Aug				0	0	
21	17-Aug	29	12	24	65	21.7	23
22	18-Aug				0	0	

23	19-Aug				0	0	
24	20-Aug	16	14	19	49	16.3	
25	21-Aug				0	0	28
26	22-Aug				0	0	
27	23-Aug	23	20	20	63	21	
28	24-Aug				0	0	
29	25-Aug				0	0	11
30	26-Aug	8	6	3	17	5.7	
31	27-Aug				0	0	34
32	28-Aug				0	0	
33	29-Aug	11	15	20	46	15.3	
34	30-Aug				0	0	
35	31-Aug				0	0	27
36	1-Sep	24	14	5	43	14.3	
37	2-Sep				0	0	
38	3-Sep				0	0	
39	4-Sep	5	18	21	44	14.7	9
40	5-Sep				0	0	
41	6-Sep				0	0	16
42	7-Sep	4	12	6	22	7.3	
43	8-Sep				0	0	
44	9-Sep				0	0	
45	10-Sep	9	5	0	14	4.7	
46	11-Sep				0	0	4
47	12-Sep				0	0	
48	13-Sep	0	2	8	10	3.3	
49	14-Sep				0	0	

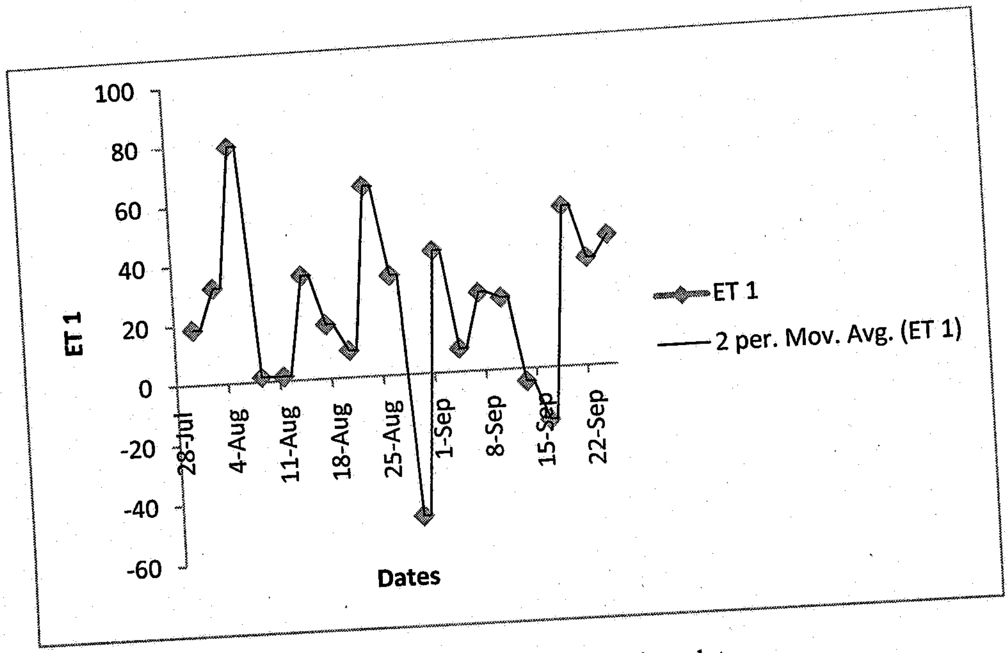
50	15-Sep				0	0	41
51	16-Sep	15	12	12	39	13	
52	17-Sep				0	0	
53	18-Sep				0	0	
54	19-Sep	19	26	28	73	24.3	
55	20-Sep				0	0	
56	21-Sep				0	0	32
57	22-Sep	20	24	12	56	18.7	
58	23-Sep				0	0	
59	24-Sep				0	0	
60	25-Sep	15	5	23	43	14.3	

Table 4.5: Table of respectively computed evapotranspiration ET 1,ET 2,ET 3,Total ET, Average ET and Reference ET_O

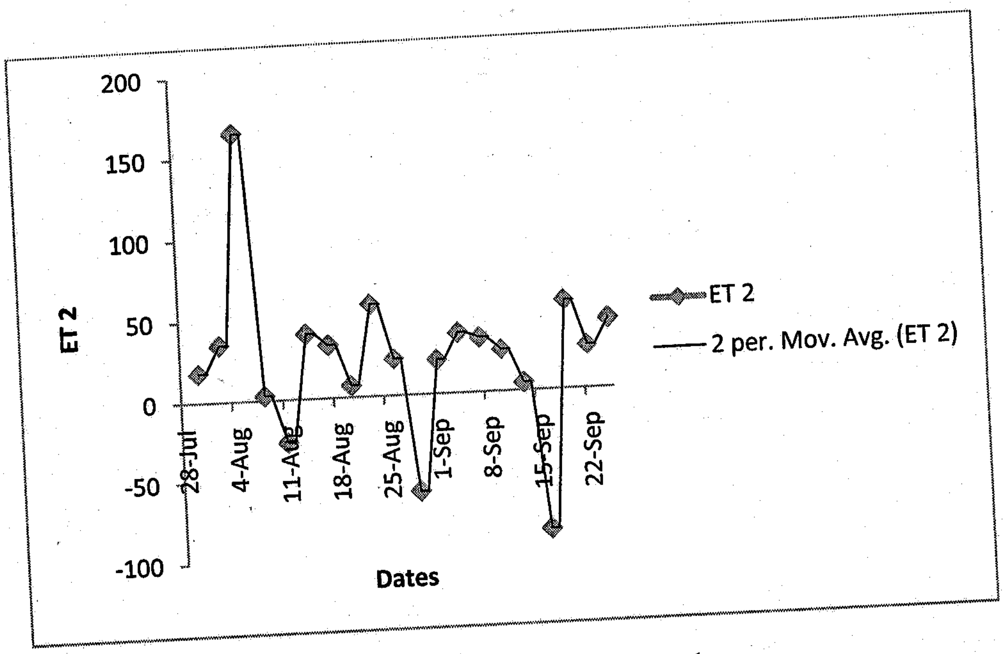
Days	Date	ET 1	ET 2	ET 3	Total ET	Average ET	Reference Evapotranspiration ET_O
1	28-Jul				0	0	
2	29-Jul				0	0	
3	30-Jul	18.6	18.4	26.6	63.6	21.2	0.013
4	31-Jul				0	0	
5	1-Aug				0	0	
6	2-Aug	32.3	35.3	30.6	98.2	32.7	0.014
7	3-Aug				0	0	
8	4-Aug				0	0	
9	5-Aug	79.5	165.1	217.8	462.4	154.1	0.009

10	6-Aug				0	0	
11	7-Aug				0	0	
12	8-Aug	1.7	3.2	19.1	24	8	0.01
13	9-Aug				0	0	
14	10-Aug				0	0	
15	11-Aug	1.6	-26.5	-3.6	-28.5	-9.5	0.012
16	12-Aug				0	0	
17	13-Aug				0	0	
18	14-Aug	35	40.5	33.3	108.8	36.3	0.014
19	15-Aug				0	0	
20	16-Aug				0	0	
21	17-Aug	18.3	33.1	19.6	71	23.7	0.012
22	18-Aug				0	0	
23	19-Aug				0	0	
24	20-Aug	9.2	7.5	39	55.7	18.6	0.016
25	21-Aug				0	0	
26	22-Aug				0	0	
27	23-Aug	63.8	57.1	51.2	172.1	57.4	0.009
28	24-Aug				0	0	
29	25-Aug				0	0	
30	26-Aug	33.5	22.9	-5.4	51	17	0.013
31	27-Aug				0	0	
32	28-Aug				0	0	
33	29-Aug	-47	-59.9	-43.3	-150.2	-50.1	0.039
34	30-Aug				0	0	
35	31-Aug				0	0	
36	1-Sep	41	21.2	35.4	97.6	32.5	0.01

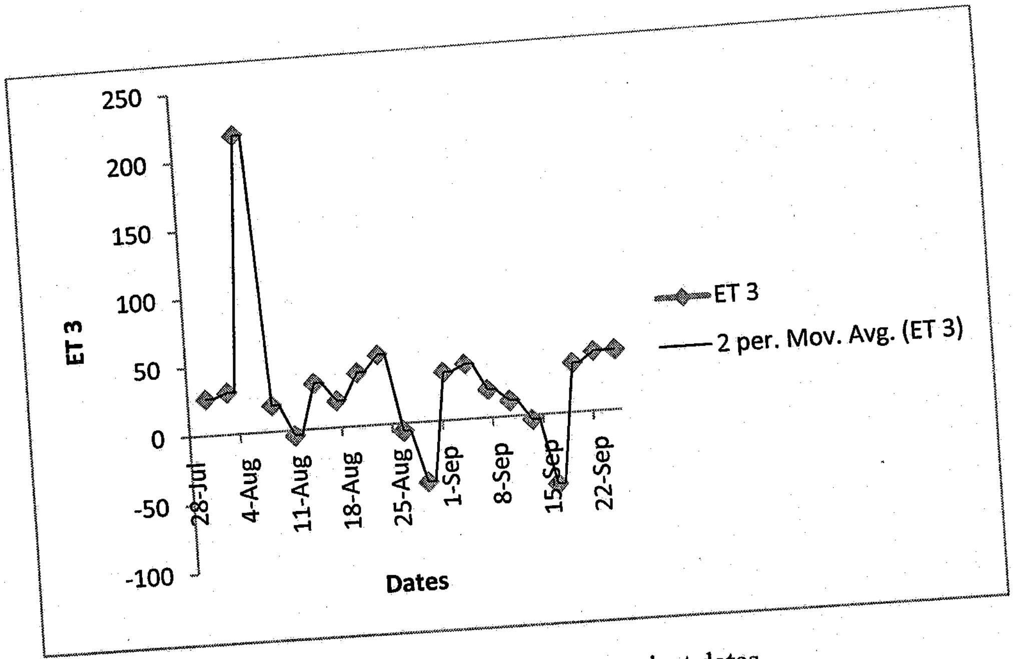
37	2-Sep				0	0	
38	3-Sep				0	0	
39	4-Sep	7.9	37.3	40.3	85.5	28.5	0.012
40	5-Sep				0	0	
41	6-Sep				0	0	
42	7-Sep	26.2	33.8	20.5	80.5	26.8	0.016
43	8-Sep				0	0	
44	9-Sep				0	0	
45	10-Sep	24.1	25.9	11.5	61.5	20.5	0.015
46	11-Sep				0	0	
47	12-Sep				0	0	
48	13-Sep	-4.2	5	-3.3	-2.5	-0.8	0.016
49	14-Sep				0	0	
50	15-Sep				0	0	
51	16-Sep	-17.2	-86.4	-50.7	-154.3	-51.4	0.01
52	17-Sep				0	0	
53	18-Sep				0	0	
54	19-Sep	53.3	54.5	36.1	143.9	48.0	0.016
55	20-Sep				0	0	
56	21-Sep				0	0	
57	22-Sep	35.8	26.6	43.8	106.2	35.4	0.01
58	23-Sep				0	0	
59	24-Sep				0	0	
60	25-Sep	43.1	42.6	43.8	129.5	43.2	0.015



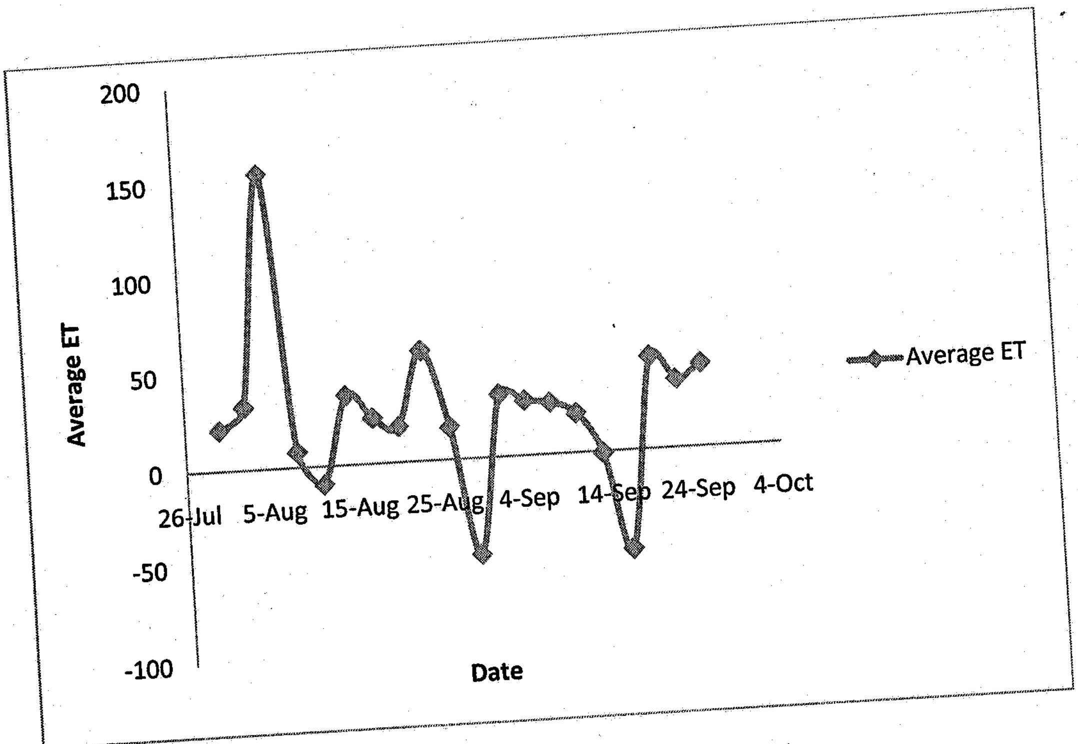
Figurre 4.1 Graph of ET1 against dates.



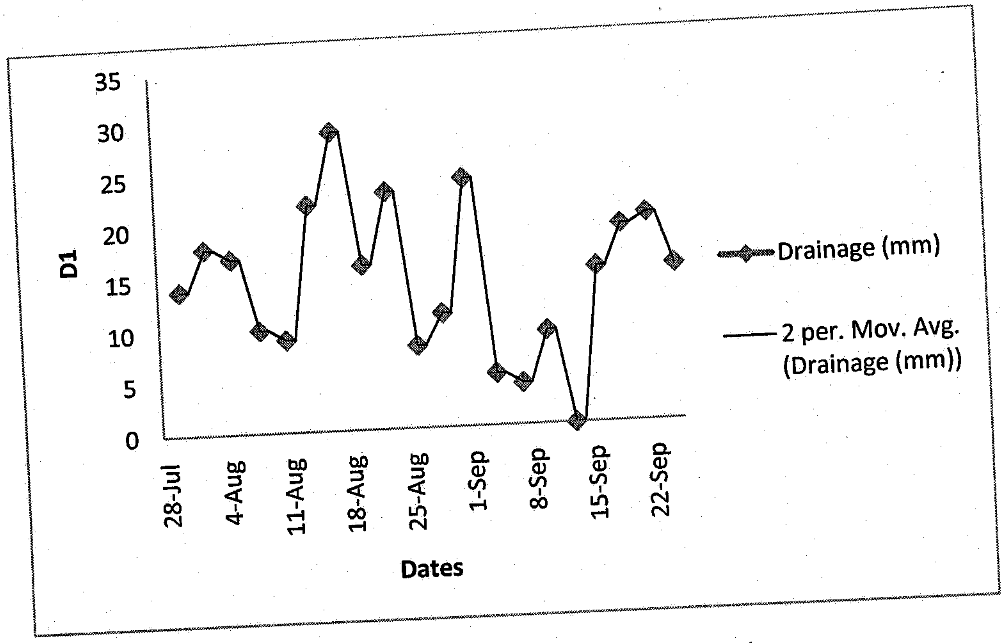
Figurre 4.2: Graph of ET2 against dates.



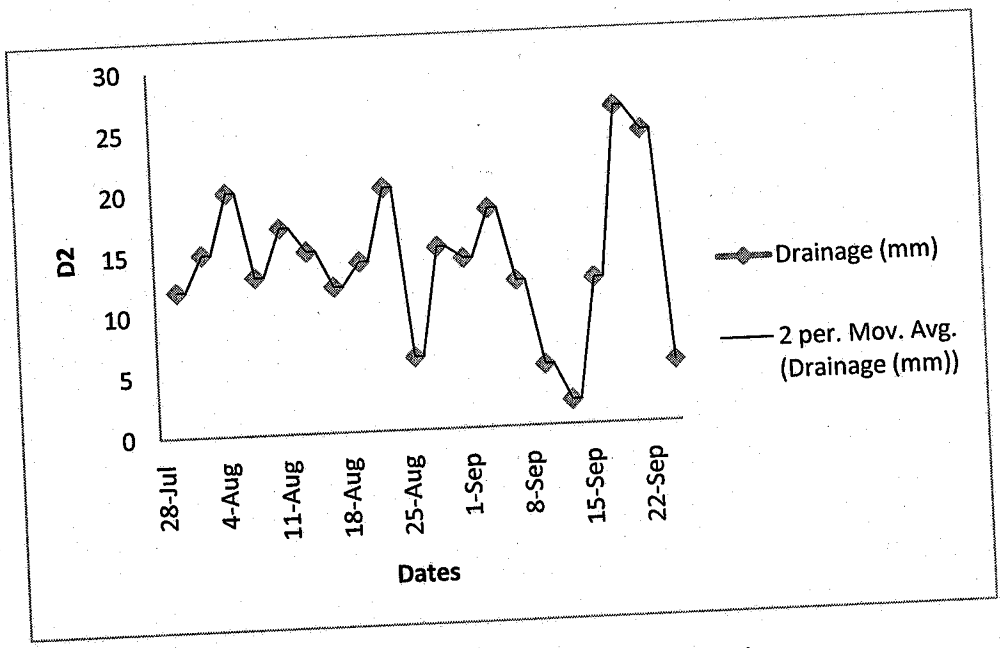
Figurre 4.3: Graph of ET3 against dates.



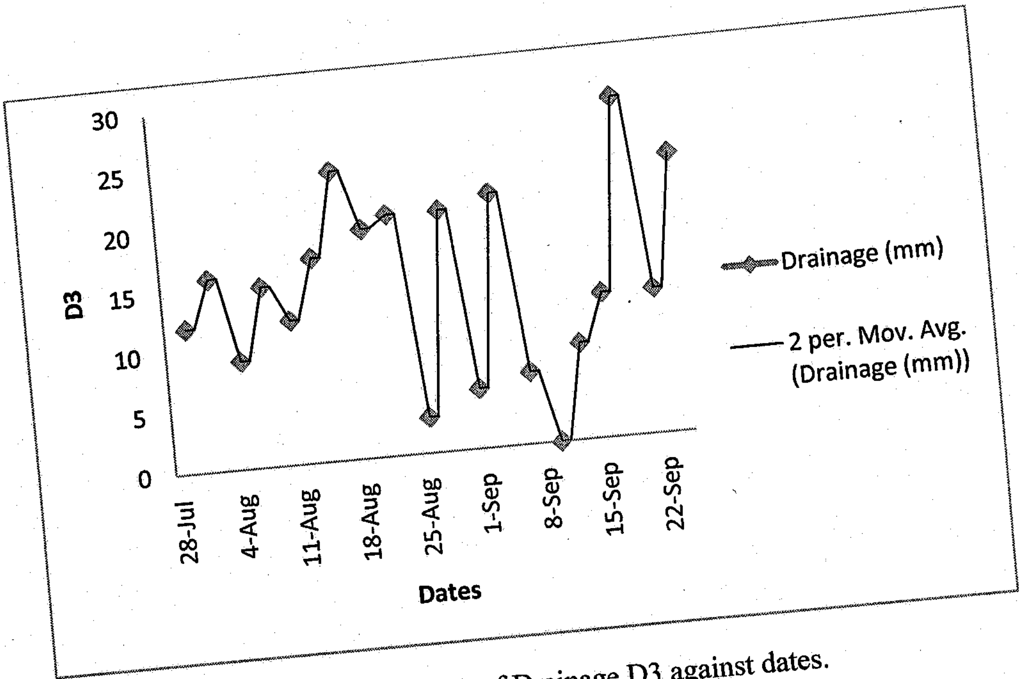
Figurre 4.4: Graph of Average ET against dates.



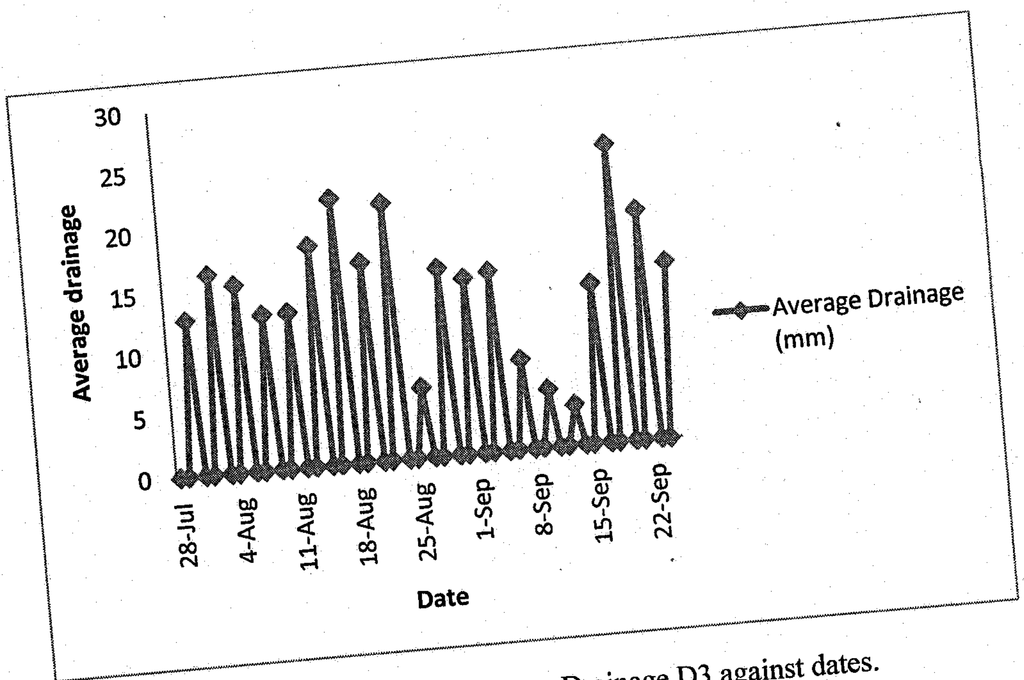
Figurre 4.5: Graph of Drainage D1 against dates.



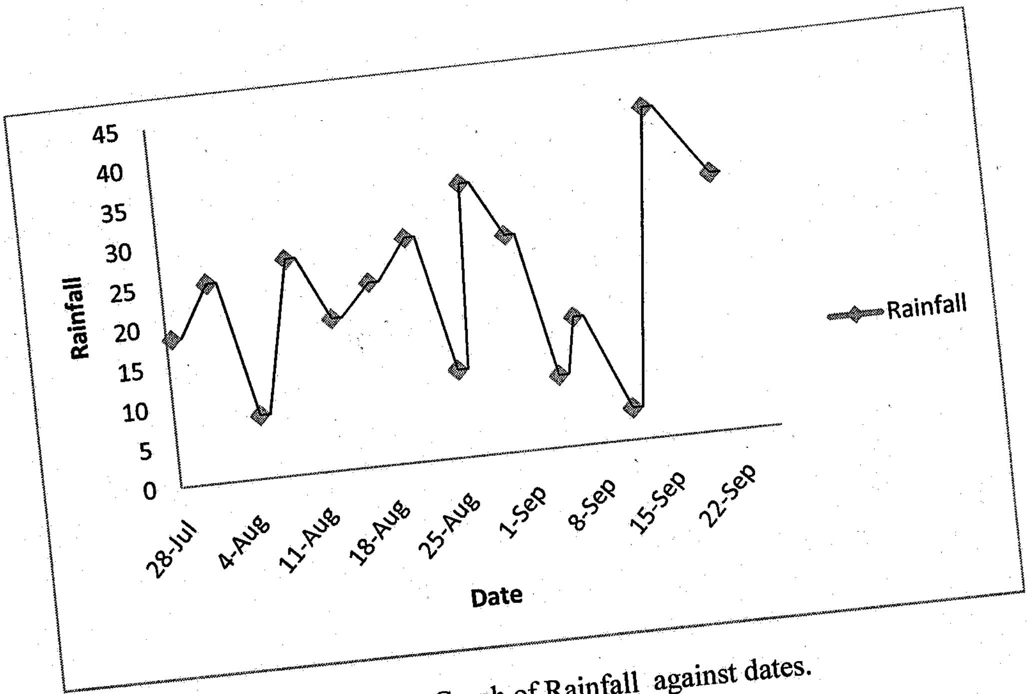
Figurre 4.6: Graph of Drainage D2 against dates.



Figurre 4.7: Graph of Drainage D3 against dates.



Figurre 4.8: Graph ofAverage Drainage D3 against dates.



Figurre 4.9: Graph of Rainfall against dates.

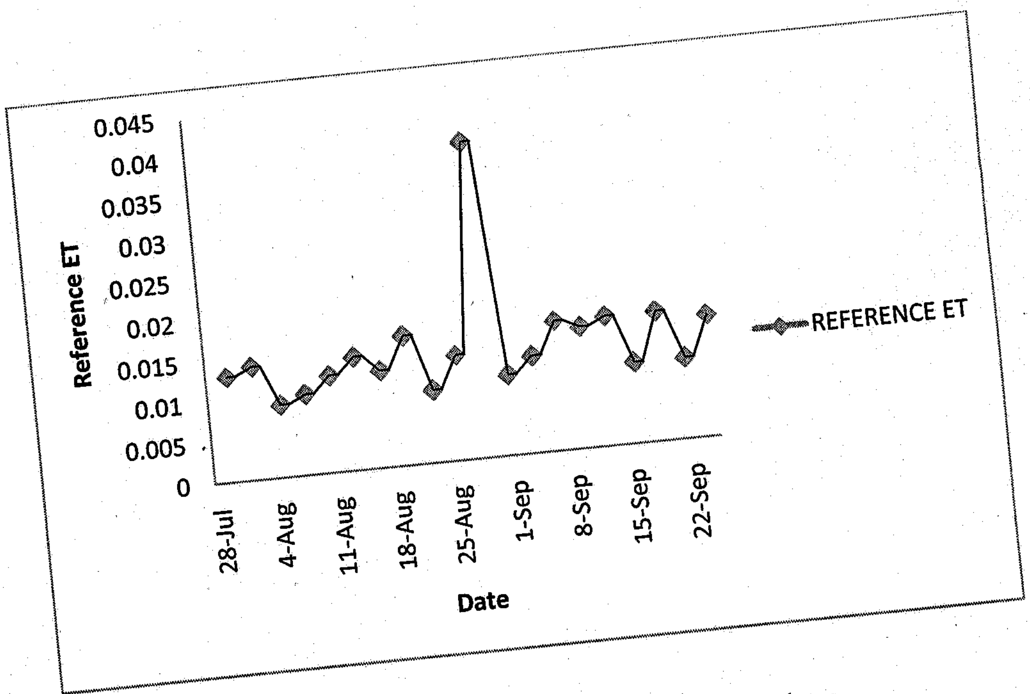


Figure 4.10: Graph of Reference ET against dates.

4.2 Discussion of Result

4.2.1 Rainfall Depth, Drainage Depths, Evapotranspiration and Reference ET

Figures 4.1 to 4.10 show the depths of rainfall, drainage, crop water use and respective weight from the waterleaf (*Talinum Triangulare*) lysimeters, respectively. A total of 15 rainfall events was recorded in waterleaf field. The rainfall depths varied from 4 to 41mm. The peak rainfall amount was experienced in September in the study location. The drainage depths varied from 0 to 28.

4.2.2 Precipitation

From the experiment carried out with the aid of micro weighing lysimeter on waterleaf,it was observed that the amount of rainfall that fell affected the growth rate of waterleaf and the rate of evapotranspiration(ET) for three days spacing of computation.From Table 4.1, the highest rainfall was on 15/09/2011 and computed crop water use for the rainfall of 41mm computed in 18/09/2011 and 21/09/2011 respectively was 48mm/day and 35.4mm/day, conversely, the evapotranspiration rate(ET) of 4mm rainfall was -0.8mm/day and

-51.4mm/day respectively.

4.2.3 Drainage

From the test carried out, ,the drained water collected varied for the three days interval. This was due to the amount of water retained by the soil. When the soil moisture is very high, the drained water is on the high side and when the soil moisture is low the drained water was on low scale. From Table 4.5, it was found that the higher the drainage the lower the crop evapotranspitation(Et).

4.2.4 Evapotranspiration (ET)

This test indicated that the rainfall, drainage, moisture content and environmental conditions such as (relative humidity, sunshine radiation, wind velocity, e.t.c) affects the evapotranspiration estimation of waterleaf. Increased drainage lead to adecrease in evapotranspiration rate of the crop and vice versa.

The relatively high values derived from the computation of evapotraspiration in this lysimetric estimation of water use of waterleaf was due to the following:

- Lysimeter pot are in isolation.
- The use of micro lysimeters.
- Low atmospheric humidity .
- High wind velocity.
- The lysimeter are not represented in a field condition.

CHAPTER FIVE

5.0 Conclusion and Recommendation

5.1 Conclusion

In conclusion The water use of waterleaf (*Talinum Triangulare*) were estimated through the aid of mini lysimeters. From the computed results, a deduction was made that the water use computation of waterleaf and the Hargreaves FAO-56 analysis are influenced by climatic factors such as temperature, wind, sunshine radiation, rainfall and relative humidity. Hence the higher the days temperature, the lower the drainage and the higher the rate of Evapotranspiration(ET). The average daily and peak evapotranspiration of waterleaf was found to decline from 21.20 mm/day at the early crop growth stages to 17.00 mm/day at mid-season and increased to 43.2 mm/day at the end of the study period. The ET is also influences by leaves spread rate within the growing season.

5.2 RECOMMENDATION

From the test carried out the following recommendation are advised

i. Tilt of soil is required occasionally to enable aeration

ii. .The lysimeter must be sited at a specific place to avoid obstruction that will result in difficulty in the taking of reading

iii. The surrounding area should be free from weed in order to prevent insect from attacking the crop

iv. The plant must be treated regularly to avoid insect infection using insecticides.

REFERENCES

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. Crop Evapotranspiration. Guidelines for Computing Crop Water Requirements. FAO Irrig. Drain. Paper No. 56. Rome, Italy.

Allen, R. G., W.O. Pruitt, and M.E. Jensen. 1991. Environmental requirements for lysimeters. pp. 170-181 in Allen, R. G., Howell, T. A., Pruitt, W. O., Walter, LA., and Jensen, M. E. (Editors). Lysimeters for Evapotranspiration and Environmental Measurements. Proceedings of the ASCE International Symposium on Lysimetry, Honolulu, HA, ASCE, New York, NY.

Allen, R.G., M. Smith, A. Pereira, and L.S. Pereira. 1994a. An Update for the Definition of Reference Evapotranspiration. ICID Bull., 43(2):1-34.

Allen, R.G., M. Smith, A. Pereira, and L.S. Pereira. 1994b. An Update for the Calculation of Reference Evapotranspiration. ICID Bull., 43(2):35-92.

Aduku, A. O. and Olukosi, J. O. (1990). Rabbit Management in the tropics. lving books series, G. U. publication, Abuja, Nigeria. Burman, R., R.H. Cuenca, and A. Weiss. 1983. Techniques for estimating irrigation water requirements. In: Advances in Irrigation, Vol. II. D. Hillel (ed.) Academic Press, NY. pp. 336-394.

Burman, R., and L.O. Pochop. 1994. Evaporation, Evapotranspiration and Climatic Data. Elsevier, New York, 278pp.

Doorenbos, J., and W.O. Pruitt. 1975. Guidelines for Prediction of Crop Water Requirements. FAO Irrig. Drain. Paper No. 24. Rome, Italy.

Doorenbos, J., and W.O. Pruitt. 1977. Guidelines for Prediction of Crop Water Requirements. FAO Irrig. Drain. Paper No. 24 (revised). Rome, Italy.

Grebet, P., and Cuenca, R.H. 1991. History of lysimeter design and effects of environmental disturbances. pp. 10-18 in Allen, R. G., Howell, T. A., Pruitt, W. O., Walter, LA., and Jensen, M. E. (Editors). Lysimeters for Evapotranspiration and Environmental Measurements. Proceedings of the ASCE International Symposium on Lysimetry, Honolulu, HA, ASCE, New York, NY.

Howell, T.A., R.L. McCormick, and C.J. Phene. 1985. Design and installation of large weighing lysimeters. Trans. ASAE 28(1): 106-112.

Howell, T. A., A. D. Schneider, and M. E. Jensen. 1991. History of lysimeter design and use for evapotranspiration measurements. pp. 1-9

Jensen, M.E., R.D. Burman, and R.G. Allen. 1990. Evapotranspiration and Irrigation Water Requirements. ASCE Manuals and Reports on Engineering Practices No. 70, ASCE, New York.

Kohnke, H., F.R. Dreibelbis, and J.M. Davidson. 1940. A Survey and Discussion of Lysimeters and a Bibliography on their Construction and Performance. Misc. Publ. No. 372, USDA, Washington, D.C. 68p.

Penman, H.L. 1948: Natural evaporation from open water, bare soil and grass. *Proc. Roy. Soc. Ser-A,* 193, 120-148.

Pruitt, W.O. and D.E. Angus. 1960. Large weighing lysimeter for measuring evapotranspiration and dewfall. J. Agric. Eng. Res. 4:161-173.

Pruitt, W.O. and F.J. Lourence. 1985. Experiences in lysimetry for ET and surface drag measurements. Pp. 51-69. In: Advances in Evapotranspiration, ASAE, St. Joseph, MI.

Rice, R. P., I. W. Rice and H .D. Tindau (1986). Fronts and Vegetables in the tropics. Macmillian Educational books Ltd., London.

Schippers, R. R.(2000). African Indigenous Vegetables - An overview of the cultivated species, NRI/ACP, EU, Chatten, UK

Schneider, A.D. and T.A. Howell. 1991. Large, monolithic, weighing lysimeters. pp. 37-45.

Udoh, E.J., 2005. Technical Inefficiency in Vegetable Farms of Humid Region: An Analysis of Dry Season Farming by Urban Women in South-South Zone, Nigeria. J. Agric. & Social Sci., 1: 80-85.

Van Bavel, C.H.M. 1961. Lysimetric measurements of evapotranspiration in the eastern United States. Soil Sci. Soc. Am. Proc. 25:138-141.

Van Bavel, C.H.M. and L.E. Myers. 1962. An automatic weighing lysimeter. Agric. Eng. 43:580-583, 586-588..

Walter, I.A., R. G. Allen, R. Elliott, M. E. Jensen, D. Itenfisu, B. Mecham, T. A. Howell, R. Snyder, P. Brown, S. Echings, T. Spofford, M. Hattendorf, R. H. Cuenca, J. L. Wright, and D. Martin. 2005. The ASCE Standardized Reference Evapotranspiration Equation. http://www.kimberly.uidaho.edu/water/asceewri. July 5th 2005.

Yrisarry, J.J.B., and F.S. Naveso. 2000. Use of weighing lysimeter and bowen-ratio energy-balance for reference and actual crop evapotranspiration measurements. Acta Hort. 537:143-150.

APPENDICES

APPENDIX U: Daily Wind Velocity Of Minna, Nigeria [2011]

JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST
5	5	4	3	4	7	4	7
6	4	6	4	3	4	4	5
6	6	6	4	3	4	8	6
6	5	5	4	3	3	4	4
5	5	5	6	3	7	3	5
4	6	4	4	4	9	3	6
3	5	4	4	5	8	4	4
4	5	4	3	3	3	3	4
4	4	5	4	4	4	3	4
3	5	4	6	4	5	4	5
3	3	5	5	5	4	4	4
4	4	5	5	6	5	4	5
4	5	6	4	4	3	3	3
4	4	5	4	4	3	3	5
5	4	5	5	4	7	3	5
4	4	4	6	5	5	3	4
4	5	4	4	3	5	3	3
4	4	3	4	4	3	5	5
3	5	3	4	9	5	5	4
4	4	4	3	5	3	4	3
4	9	3	5	6	5	3	5
4	4	3	7	4	4	3	4
5	4	4	4	4	3	4	5
4	5	4	4	7	4	3	5

4	4	4	4	5	3	4	4
4	4	4	8	4	6	3	5
4	5	4	4	6	3	4	5
4	4	4	4	7	6	3	4
6	-	4	3	3	7	4	5
4	-	3	4	3	3	3	4
5	-	3	-	4	-	3	5

APPENDIX V: Mean Daily Temperature Of Minna, Nigeria [2011].

JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
27	29.5	31.5	31.5	31.5	24	25.5	27.5	25
26	31	32	33.5	32	26	27	27	26
27.5	30.5	32.5	32	32	28	23.5	29.5	30
27.5	31	31.5	32	32	27.5	26	30	29
26	30	32	32.5	31.5	28.5	27	29	29.5
26.5	30	31	29	32	27	27	29	27.5
26	31	32	32	32.5	28	25.5	26.5	28.5
27.5	30.5	33	34	33	26	26.5	24.5	27.5
26.5	29.5	33	33	33	28.5	25.5	27.5	30
27	31	31	32	33	27.5	26	29	26.5
27.5	29.5	33	31	33	26	30.5	26.5	31
28.5	30	32.5	29.5	32	28.5	26.5	29	25
29	30.5	32.5	31	31.5	26	26	26	28
29	31.5	31.5	31.5	32	28.5	27	30.5	26.5
29	30	32	30.5	33	27.5	28	24	29.5
29	31.5	31	32	30	26.5	26	26	31
30	31.5	31.5	32	28	28	26.5	25	27
28.5	32.5	33.5	31.5	31	25.5	25.5	28	26.5
30	33	34.5	29.5	29	28	25	23.5	29
29.5	31	33	30	29	26	26.5	26	28.5
29	32.5	33	31.5	31.5	26	26	25	28.5
29	31.5	32.5	32.5	31	26	26	25	25
29	32	32.5	30	29.5	27.5	26.5	30	29

27.5	30	32	31	30	24.5	26.5	29	28.5
29	32.5	35.5	31.5	28	27	27.5	25.5	28.5
28	33	33	31.5	27.5	27	25	30	29
27.5	32.5	33.5	29.5	28	27	27	25.5	26.5
29.5	32	32	32	26	27	26.5	24	25.5
28	-	32.5	32.5	25.5	25	27.5	28.5	27
27.5	-	32	32	28.5	26	27.5	29	26
29.5	-	32.5	-	29.5	-	26	27	27

APPENDIX W: Daily Temperature Of Minna,Nigeria [2011].

DAYS	JANUARY Tmax, Tmin	FEBRUARY Tmax, Tmin	MARCH Tmax, Tmin	APRIL Tmax, Tmin	MAY Tmax, Tmin	JUNE Tmax, Tmin	JULY Tmax, Tmin	AUGUST Tmax, Tmin	SEPTEMBER Tmax,Tmin
1	34,20	37,22	36,27	37,22	40,23	26,22	30,21	30,25	28,22
2	33,19	39,23	39,25	39,23	40,24	31,21	30,24	31,23	30,28
3	34,21	39,22	39,25	39,22	39,26	32,24	28,19	32,27	31,29
4	35,20	38,24	39,25	38,24	39,24	32,23	30,22	31,29	32,26
5	33,19	38,22	38,25	38,22	39,25	33,24	31,23	30,28	30,25
6	35,18	37,23	37,27	37,23	37,25	31,23	31,23	30,28	29,26
7	35,17	40,22	38,27	40,22	38,28	31,25	28,23	28,25	31,26
8	36,19	40,21	40,26	40,21	39,27	30,22	30,23	28,21	30,25
9	35,18	37,22	38,28	37,22	39,27	33,24	29,22	29,26	32,28
10	36,18	39,23	38,28	39,23	38,24	31,24	30,22	30,28	29,24
11	35,20	37,22	38,28	37,22	39,27	29,23	39,22	29,24	33,29
12	35,22	37,23	38,26	37,23	39,26	32,25	30,23	31,27	28,22
13	35,23	37,24	38,25	37,24	38,27	30,22	29,23	28,24	30,26
14	36,22	38,25	37,27	38,25	38,25	33,24	31,23	32,29	29,24
15	37,21	36,24	38,28	36,24	38,26	33,22	32,24	27,21	31,28
16	35,23	39,24	36,24	39,24	38,24	31,22	30,22	30,22	33,29
17	36,24	36,27	32,24	36,27	39,24	31,25	30,23	27,23	28,26
18	35,22	39,26	36,26	39,26	40,27	30,21	27,24	31,27	29,24
19	37,23	40,26	35,23	40,26	42,27	31,25	28,22	32,25	30,28
20	36,23	37,25	33,25	37,25	39,27	31,21	30,23	28,24	31,26
21	36,21	38,27	37,26	38,27	30,27	29,23	30,22	29,21	33,24
22	34,24	38,25	35,27	38,25	38,27	30,22	29,23	28,22	29,21
23	35,23	39,25	34,25	39,25	38,27	31,24	30,23	31,29	30,28
24	35,20	40,20	36,24	40,20	38,26	27,22	30,23	30,28	31,26

25	36,22	37,28	34,22	37,28	42,29	31,23	32,23	29,22	32,25
26	36,20	39,27	30,25	39,27	39,27	29,22	28,22	31,29	31,27
27	36,19	39,26	34,22	39,26	39,28	32,22	31,23	28,23	28,25
28	36,23	40,24	30,22	40,24	38,26	32,24	29,24	27,21	29,22
29	34,22	-,-	29,22	-,-	40,25	29,21	32,23	33,24	31,23
30	35,20	-,-	33,24	-,-	39,25	29,23	31,24	30,28	30,22
31	37,22	-,-	33,26	-,-	40,25	-,-	28,24	329,25	-,-

APPENDIX X: Mean Monthly Radiation And Radiation Factor Of Minna, Nigeria[2010].

MONTH	SUNSHINE RADIATION	RADIATION FACTOR
JANUARY	7.3	0.0914
FEBRUARY	7.7	0.09634
MARCH	6.8	0.0851
APRIL	7.3	0.0914
MAY	7.1	0.0888
JUNE	6.8	0.0851
JULY	4.9	0.0661
AUGUST	4.6	0.0575
SEPTEMBER	5.5	0.0688
OCTOBER	6.4	0.0801
NOVEMBER	8.9	0.1114
DECEMBER	7.1	0.088