LYSIMETRIC ESTIMATION OF CROP WATER USE FOR SPINACH (SPINACIA OLERACEA)

BY

AGBEYEMI, SEGUN GABRIEL

MATRIC No. 2008/3/29003EA

L YEAR PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
MENTS FOR THE AWARD OF BACHELOR OF ENGINEERING
EE IN AGRICULTURAL & BIORESOURCES ENGINEERING,
ERSITY OF TECHNOLOGY, MINNA, NIGER STATE

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

Agbeyemi, Segun Gabriel

07/03/2012

Date

CERTIFICATION

This is to certify that the project entitled "Lysimetry Estimation of Crop Water Use For Spinach (SPINACIA OLERACEA) Using Weighing Micro Lysimeter" by Agbeyemi, Segun Gabriel 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.

Engr. Dr., H.E. Igbadun
Supervisor

21/06/2012
Date

Engr. Dr. P.A. Idah
Head of Department

02/03/2012
Date

External Examiner

22-02-2012
Date

DEDICATION

This project work is dedicated to God Almighty the creator of my soul.

ACKNOWLEDGEMENT

I give thanks to God Almighty for he is good and his mercy endureth forever. He is the source of my aspiration to undertake this project to the final stage.

I acknowledge the assistance given to me by my supervisor, Engr. Dr. H.E. Igbadun, to the Engr. Dr. I.E. Ahanekun for his fatherly guidance, advise and encouragement all along and to the head of Agricultural and Bioresources Engineering Department, Engr. Dr. P.A. Idah and entire staff of the Agricultural and Bioresources Engineering Department.

I am especially grateful to my parents, Pastor and Mrs E.A. Agbeyemi for their immeasurable support, my lovely brothers and sisters, Nike, Ayo, Funmi, Tope for their support during my course of study.

I appreciate my brother, Seun Agbeyemi and my project colleague Adeola, Oyewale Moses and others for their contributions, assistances and material supplies.

My appreciation also goes to those who stood by me unconditionally and always believe that, there is "Hero behind Zero", that is, my beautiful family all around and good people out there. May God Almighty Bless, help and keep you right for me. (Amen).

ABSTRACT

Successful crop production depends upon the grower establishing the optimal interplay between numerous, inter-related soil, plant, climatic and economical factors. The availability of soil water is one of the factors that frequently limits plant performance and subsequent crop yield. . This research was conducted to determine water balance and crop water use for spinach (spinacia oleracea) grown under favourable environmental conditions (low wind speed, rainfall, temperature, radiation , relative humidity). A set of three micro-lysimeters were fabricated and installed inside a dug out foundation of 500mm depth, 800mm width, and 2800mm length. The highest and minimum values of rainfall with their corresponding crop evapotranspiration rates for the period of study were 41mm and 4mm and 23.1mm/day and 5.8mm/day, respectively. It is assumed that the application of irrigation during the growth stages will assist in irrigation management and provide precision water applications for the region of study.

TABLE OF CONTENT

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

List of tables

List of Figures

List of Plates

NOTATIONS

Dr = Drainage

DAP = Days after Planting

ET = Evapotranspiration

ETc = Crop Evapotranspiration

ETo = Reference evapotranspiration

Kc = Crop Coefficient

I = Irrigation

GDD = Growing Degree Days

List of Appendices

CHAPTER ONE

1.0. INTRODUCTION

1.1. Back ground of the study

Increase in population leads naturally to increase in food demand, which is a major concern of Agricultural and Bioresources Engineers. To achieve the increased food demand, there is the need for all year cropping. Since rainfall does not fall at all the time, irrigation is the key to achieving all year crop production. To design an irrigation system, it is necessary to know the crop water requirements. This can be achieved through the use of lysimeter.

A lysimeter is most accurate when vegetation is grown in a large soil tank which allows the rainfall input and water lost through the soil to be easily calculated. By recording the amount of precipitation that an area receives and the amount lost. The amount of water lost by evapotranspiration can be worked out by calculating the difference between the weight before and after the precipitation input. A weighing lysimeter, for example, reveals the amount of water crop use by constantly weighing a huge block of the soil in a field to detect losses of soil moisture. (Wikipedia, 2008.).

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality of the arid, semi-arid, and tropical regions and also during dry season. (Michael, 1998).

Vegetable are 80 to 90 percent water think of them as sacks of water with a small amount of flavoring and some vitamins, because vegetables contain so much water, their yield and quality suffer rapidly when subjected to a drought. Thus, for good yields and high quality irrigation is essential to the production of most vegetables. If water shortages occur early in the crop's development maturity may be delayed and yields reduced. If a moisture shortage occurs late in the growing season, quality is often reduced even though total yields may not be affected. The most important cultural practice for a healthy and productive home vegetable garden is irrigation. (Sturttevant, 2009).

Spinach is a hardy cool weather crop, ideal for an early New England market. Currently spinach is a minor crop with most of the crop grown for roadside markets or delivered directly to wholesalers. It is a crop that has increased in popularity as a salad crop and so there would seem to be potential for additional wholesale markets. It is also a potential processing crop which grown annually either in dry season or rainy season. (University of Florida, 2006)

The cultivation of spinach throughout the year can be achieved by determining its evapotranspiration rate for irrigation planning and scheduling and also the crop water used to irrigate spinach. So there is need for accurate and consistent measurement of evapotranspiration rate. This can be obtained by using weighing micro-lysimeter method among the several methods used for this purpose. Hence this method has been chose in this project based on its degree of accuracy and consistency.

1.2 Statement of the Problem

Climate change might affect crop water use than it is to project, just what climate will, how severe the change will be and how long the changes will last, obviously environments become warmer and season duration change, crop water need will increase and all plants require water for survival i.e. for growth and cooling purpose. Hence the knowledge of evapotranspiration rate in this region is the fundamental basis for determining the water use for spinach.

1.3 Objectives of the Study

The specific objectives of this study were to:

i. Determine daily crop water use for spinach (Spinacia oleracea), using weighing micro-lysimeter.

ii. Determine the daily and peak evapotranspiration rate for spinach using weighing micro-lysimeter.

1.4 Justification of the Study

Successful crop production depends upon the grower establishing the optimal interplay between numerous, inter-related soil, plant, climatic and economical factors. The availability of soil water is one of the factors that frequently limits plant performance and subsequent crop yield.

With increase in population, all year round consistent cultivation is of great important in order to satisfy self and family sustainability in term of salad crop which widely used in soup and industries. Thus during the dry spells, an appropriate soil water balance must be planned and monitored based on the rate of evapotranspiration and the crop water use for the crop.

1.5 Scope of the Study

In this project, the micro-lysimeter method and water balance equation was used to measure and compute, respectively the crop water use for spinach (Spinacia oleracea).

CHAPTER TWO

2.0 LITERATURE REVIEW

Several methods had been adopted by researchers in of determining evapotranspiration rate of different crops. Although with reference to the project area, few studies have been carried out so far on crops evapotranspiration among such studies are Egbarevba and Mohammed (1999) that presented the annual water requirement of $2.42\mathrm{x}10^3$, $3.214\mathrm{x}10^3$, $3.29\mathrm{x}10^3$ and $4.002\mathrm{x}10^3\mathrm{m}^3$/ha/annum for millet, maize, sorghum and wheat respectively, as computed from modified Penman equation based on reference evapotranspiration (ETr). Also Hand (1963) wrote an article on an electrically weighed lysimeter for measuring evaporation rate. Recently, experimentation on weighing lysimeter was carried out for the measurement of Amaranthus, of consumptive use or crop evapotranspiration (Etc), by George (2002), where a peak consumptive use rate of 7.0mm/day was recorded during the dry season and 6.1mm/day was measured during the rainy season. An article was also published online by John (2009) on testing the precision of a weighable gravitation lysimeter. In practice, the estimation rate for the evapotranspiration for a specific crop requires first calculating potential or reference evapotranspiration and then applying the proper crop coefficients (Kc) to estimate actual crop evapotranspiration (ETa).

2.1 Evapotranspiration

The process known as evapotranspiration (ET) is of the great importance in many disciplines, including irrigation scheduling, and hydrologic and drainage studies.

In a broad definition, the evapotranspiration is a combined process of both evaporation from soil and plant surface and transpiration through plant canopies. In the evapotranspiration process the water is transferred from the soil and plant surfaces into the atmosphere in the form of water vapour. (ABE 343/AE 256, 2003)

- **Potential Evapotranspiration**

The potential evapotranspiration concept was first introduced in the late 1940s and 50s by Penman and it is defined as ''the amount of water transpired in a given time by a short green crop, completely shading the ground, of uniform height and with adequate water status in the soil profile''. (http://edis.ifas.ufl.edu).

- **Reference Crop Evapotranspiration**

The reference evapotranspiration is defined as the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12m (4.72in), a fixed surface resistance of 70secm-1 (70sec, 3.2ft-1) and albedo of 0.23, closely resembling the evapotranspiration from an extentive surface of green grass of uniform height , actively growing, well- water, and completely shading the ground. (Suat & Dorota 2003).

- **Peak period Consumptive Use**

This is defined as the average daily water used rate during a few days of the highest consumptive use of the season.

- **Seasonal Consumptive Use**

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

2.2 Spinach

Spinach (Spinacia oleracea) is a member of the Chenopodiocese (Goosefoot family), which also includes Swiss Chord and Beefs .Spinach is a low growing fleshly leaved annual that forms a heavy rosette of either smooth or wrinkled leaves. Cultivation of this crop began in Iran around 400AD. The first savoyed leaf variety was introduced into North America in 1828. (Dr. Vitiam & Alana, 2008)

2.2.1 Botany

Spinach performs best on well drained sandy loams or loams high in organic matter. Early and over wintered crops should be planted on soil with good drainage and on that warm up early in the season. Peat soils may also be used for spinach production. In all instance, the soil pH should be between 6 and 6.8. Spinach is not tolerant to acidic soil, therefore it is recommended to have the soil tested on a regular basis.

2.2.2 Climatic Condition

Spinach prefer a cool climate. The minimum temperature for seed germination is $2^{O}C$ with a maximum germination temperature of $30^{O}C$ and an optimum range of 7 to $20^{O}C$. Young plants can withstand temperature as low as $9^{O}C$ .Best crop growth occurs at 15 to $20^{O}C$ with a minimum temperature of $5^{O}C$ and a maximum of $30^{O}C$. Spinach bolts rapidly when days are both long and hot. Bolting refers to the premature production of a seed stalk and renders the product unmarketable. Selecting varieties resistant to bolting will be reduce the problem (Piccinni et al., 2009).

2.2.3 Varieties

Spinach varieties are classified by leaf types, and there are three types grown in Nova Scotia; savoy (wrinkled), semi-savoy and flat. Savoy and semi- savoy are used for fresh markets, while smooth (flat) types are used for baby spinach (Texas, 2006).

2.2.4 Cultivation

In Nova Scotia the spinach crop is direct seeded as the soil can be worked in early April all the way through to August. For continuous supply of the market, seedling every 10-14days is recommended. However, from May to July, seeding intervals gradually shorten to 5-7days and from July-August seeding intervals equal 7-10days in length.

Spinach is commonly sown into rows spaced 20-30cm apart. In recent years, growers have experiment with spinach being grown in rows 5cm apart and seed spaced 5cm apart in the row. Spinach is seeded on raised beds with 10-20rows in the bed. A bed that is raised a few centimetres will aid in air and water drainage. (Dr. Vitiam & Alana, 2008)

Spinach requires a regular supply of moisture since it is a shallow rooted crop and should receive 25mm of water every five days from rainfall or irrigation. The first five days of plant growth (germination and seedling emergence) are very moisture dependant and require 5mm-12mm of the water. Sprinkler irrigation is used on spinach production in Nova Scotia.

For baby spinach market commercial growers have been experimenting with seeding in rows spaced 5cm apart and seeds spaced 1-15cm apart in the rows 2-5rows of spinach are grown on raised beds which could be 50-100cm wide.ays from rainfall or irrigation (Allen et al., 1998).

2.2.5 Crop Management

2.2.6 Irrigation

Spinach requires a regular supply of moisture since it is shallow rooted crop and should receive 25mm of water every five days from rainfall or irrigation. The first five days plant growth (germination and seedling emergence) are very moisture dependant and require 5mm – 12mm of water. Sprinkler irrigation is used on spinach production in Nova Scotia (Texas, 2001).

Table 2.1: Botanical Family of Spinach

Botanical family	Vegetable crops
Asteraceae	Lettuce, Endive, Artichoke, Radicchio
Alliaceae	Leeks, Garlic, Onion
Chenopodiaceae	Spinach, Swiss Chard, Beets
Brassicaceae	Broccoli, Cauliflower, Bruseels, Sprouts, Cabbage, Kale, Turnip, Kohl, Rabi Radish
Curbitaceae	Winter Squash, Summer Squash, Watermelons, Muskmelons, Cucumbers, Pumpkins
Poaceac	Sweet Corn
Fabaceac	Beans, Peas, Peanuts
Solanaceac	Tomato, Eggplant, Peppers, Potatoes
Apiacaec	Carrots, Parsleys, Parsnip, Fennel

Source: Wikipedia, (2008).

By rotating crops that leave a high amount of residue in the soil, soil fertility can be enhanced naturally. Crop rotation can also improve soil structure by altering deep-rooted and shallow-rooted plants.

Crop rotation play a key role in crop productions by aiding in the suppression of diseases, insect and weeds. Crop within the plan family tend to be susceptible to the same pests therefore rotation of non suspectible crops for several years allow will plant material to decompose pest cycles to become broken. Without the presence of susceptible plant materials, the number of disease and pest organisms will begins to diminish (Wikipedia, 2008).

Crop rotation aids in weed control because the growth habit of the crop differs, which causes a decrease in weeds ability to compete for a space. Tillage practices and timing are different for each group resulting in a weeds ability to permanently establish.

Due to disease pressure, (refer to the pest management section of this guide) it is best not in plant spinach more than once every three to four years. This crop has shallow roots that will not help to improve soil structure or aeration. Spinach seeds require a finely manicured seed bed therefore previous crop residues would severely hinder crop establishment. Spinach should not follow red beets or Swiss chard in the rotation (WSUCE, 2000).

2.3 Water Requirements of Crops

The term "Water requirements" may be defined as the quantity of water, regardless of its source, required by a crop from the time it is sown to the time it is harvested. This depends on variations on climates, soil types, method of cultivation and useful rainfall. Water requirement includes the losses due to evapotranspiration (ET) or consumptive use (CU) plus the losses during the application of irrigation water (Unavoidable losses) and the quantity of water required for special operations such as land preparation, transplanting, leaching, etc.

This may be formulated as

$$WR = ET \text{ or } CU + \text{application losses} + \text{special needs}$$

OR

$$WR = IR + ER + S$$

Where

WR = Water Requirement

ET = Evapotranspiration

CU = Consumptive use of consumptive

ER = Effective Rainfall

S = Soil profile contributions

IR = Field irrigation requirement of crop

2.4 Measurement and Estimation of Evapotranspiration

Evapotranspiration can be measured by direct measurement and estimated by empirical methods and Micro-meterological methods (climatological data).

2.5 Lysimeter Method

The term "lysimeter" was derived from the Greek words "lysis" and "metron" meaning dissolving and measuring, respectively. The term is thus applicable to any device utilized for studying the rate, amount ant composition of percolation water through a porous medium. Indeed, many definitions refer to "instruments or devices that contain soil and receive natural rainfall or irrigation and are provided with an arrangement for collecting and measuring the percolate". Percolation is an important phase of the hydrologic cycle; it recharges groundwater and discharges into streams.

For Mcllroy and Angus, (1963), a lysimeter consists of "a block of soil, together with vegetation, if any, enclosed in a suitable container and exposed in natural surroundings to permit determination of any one term of the hydrologic equation when the others are known". Similarly Tanner (1967) lysimeter refers to a "device in which a volume of soil, which may be planted to vegetation, is located in a container to isolate it hydrologically from the surrounding soil in order to assess or control various terms of the water balance equation". Mainly there are two types of lysimeters which are Weighing and Non Weighing Lysimeters:

- **Weighing Lysimeter:** In weighing lysimeters the change of weight (corrected for precipitation, irrigation and drainage) provides a direct and accurate measurement of the change of water content (ΔW). The complicated and expensive weighing mechanisms make application limited, however,

In the case of non weighing lysimeters other means are used to determine ΔW such as soil sampling, tensiometers, electro-resistance blocks or neutron probes. Only the application of neutron probes allows accurate and measurements of soil moisture changes

In most cases, however, the water budget is determined over the period between two drainage occurrences. Directly after drainage is completed. The soil mass contains a well-defined soil moisture content. So-called "Field capacity". After an adequate rain or irrigation, depleted water (ΔW) is compensated and the soil moisture content is supposedly again at field capacity after drainage ceases. ΔW then becomes negligible and evapotranspiration can then be determined directly by:

$$ET = P + I - D \qquad (2.1)$$

Evapotranspiration values are thus averages over the time periods between drainage occurrences. Evapotranspiration errors may, occur, however due to some differences in moisture content after drainage.

In the case of compensation lysimeters, where a constant water table is maintained, depleted moisture (ΔW) results in a drop in the water level which is often compensated and replenished by an automatic devices. Here evapotranspiration measurement can be carried out over short periods.

In continuously draining lysimeters with daily irrigation, soil moisture content is more or less constant, consequently the change in moisture storages becomes negligible and $\Delta W = 0$.

- **Non- Weighing Lysimeter:** This enable us to determine evapotranspiration for a given period of time by deducing the drainage water collected from the total water input. In the case of weighing lysimeter, the evapotranspiration and the drainage components can be determined simultaneously and independently.

In non weighing lysimeter, there is no weighing devices for measuring change in soil moisture; so various techniques such as Neutron scattering, Gravimetric sampling, Electrical resistance, Soil matric potential etc are used to determined ΔS.

Non weighing lysimeter currently providing valuable data range in sizes from large area, deep, monolith lysimeters at Coshocton, Ohio USA to the small area shallow lysimeter constructed from oil drums (George, 2002).

The Coshocton lysimeter are used for Eta and the oil-drum type. Similarly, the water table Lysimeter in 1950 has been widely employed for ETp measurement; the water required to maintain the water table at a given depth is metered to give ETp

2.6 Lysimeter Area

In referring to the lysimeter area, a distinction can be made between:

- The lysimeter's soil area defined as the soil surface within the lysimeter on which a crop is planted
- The total lysimeter area are defined as the lysimeter soil area plus the wall thickness area
- The "effective area defined" as a fictive field area with an evapotranspiration equal to the evapotranspiration recorded in the lysimeter.

  The greater the difference between the effective area and lysimeter's soil area, the greater the magnitude of error, especially under advective conditions.

Penman (1963) estimated that the solar energy absorbed by a small lysimeter of 60 cm diameter is doubled when the lysimeter plants are 15cm taller than the surrounding plants.

Samie and de Villele (1970), using two years average figures, concluded that lysimeters of 0.27m^2 and 2m^2 overestimate evapotranspiration from a 5m^2 lysimeter by 27percent and 8percent, respectively. The recommended that the minimum lysimeter area for potential evapotranspiration measurements should be 2 m^2.

Sarraf, Vink and Aboukhaled (1969) reported an overestimation in the order of 10 percent for 0.27 m^{2}lysimeters as compared using monthly evapotranspiration data. When using 10-day evapotranspiration data differences became as high as 17percent. Deviation among small lysimeters were rather high on 10-day and even monthly basis. As a result, the small unit of 0.27m^2 which were quite common in Lebanon, were replaced by 4m^2 lysimeters. Monthly evapotranspiration values from 4m^2 lysimeters (drainage) were in excellent agreement with those of the 16m^2 precision weighing lysimeter; differences ranged between 1 and 2 percent. Thompson and Boyce (1971) found good agreement between sugarcane water use values from three 3.70m^2 precision lysimeters and a 405m plastic lined drainage lysimeter.

While 4m^2 was found adequate for high density plants (grass, wheat, onions, vegetables), for broadly spaced crops such as bananas, a much larger lysimeter (50m^2) was used to accommodate sufficient plants (Sarraf and Bovee 1973).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Location

The study was conducted at the Federal University of Technology Minna, Gidan kwano campus, Niger State. Minna lies on the latitude of 09^{0} 34^{1}E and longitude $06^{0}28^{1}$E.Niger State lies in the semi-arid zone and has two distinct seasons, the wet and the dry seasons, respectively. The wet season start in April and end 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 with mean annual relative humidity of 59%.

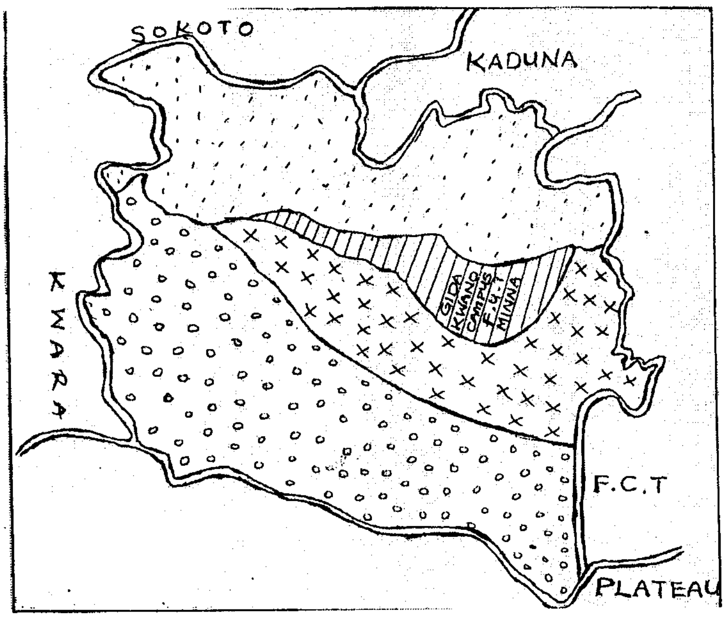

Fig. 3.1. Map of Niger state.

3.2 Lysimeter Construction

A set of 3- weighing micro lysimeter were used to determine the crop evapotranspiration(ETc) and reference evapotranspiration(ETo) for Spinach. A metal steel sheet of 16guage was cut into 500mm by 200mm to construct the four sides of the lysimeter with an angle iron of 200mm to brace each sides of the metal sheet. An angle iron of 200mm by 200mm was used as the four stands, beneath the four sides of the metal steel sheet was an angle iron of 500mm by 500mm welded horizontally, above it was a plywood of 490mm by 490mm seated on angle iron with an opening of 12mm by 12mm at the center for percolating water to drain into the measuring cylinder. On the plywood was a tyre tube filled with water and a flexible tube fixed on its valve that display increase and decrease in height of water. On the tyre tube was another plywood of the same dimension drilled with a hole of 12mm, on the plywood was a bucket filled with soil of 20kg and at one side of the lysimeter was an angle iron of 1500mm welded as vertical post which hold a meter rule of 750mm attached firmly with flexible tube placed for easy reading.

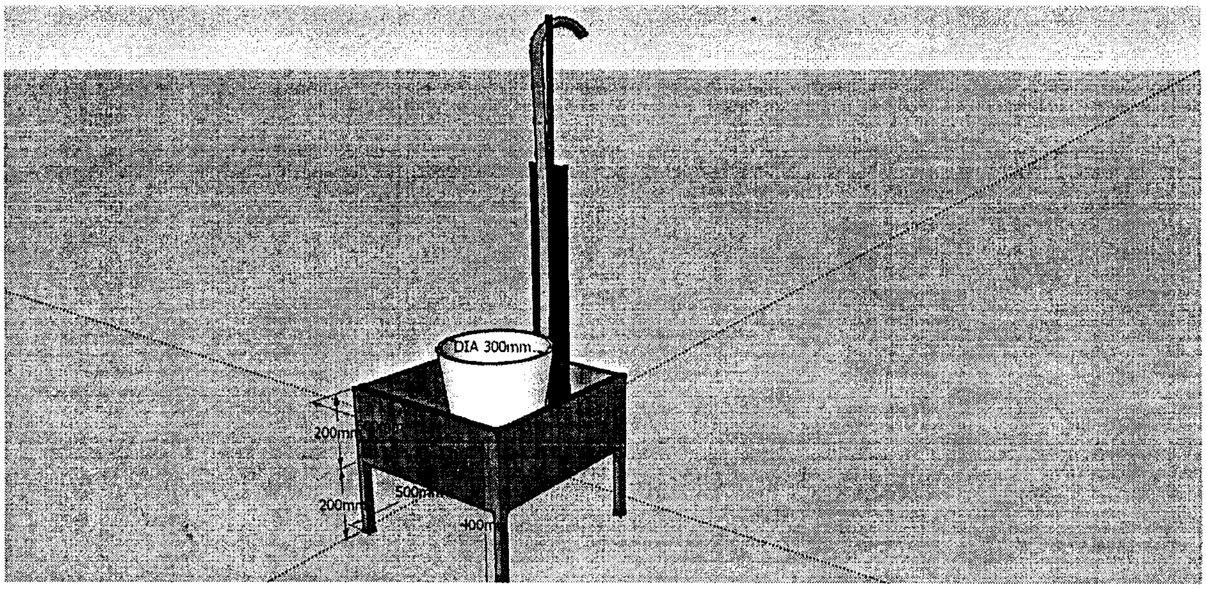

Fig 3.2 Sketch of a micro weighing lysimeter

3.3 Lysimeter Installation

A foundation of depth 500mm,width of 800mm and length of 2800mm was dug in order for the lysimeter to be installed inside for the purpose of this experimentation. Figure 3.1.Dug of foundation for the lysimeter setup. Before the lysimeter pot was filled with soil for its agronomic purpose, different weight of stone was weighed using digital weighing balance and was put inside the lysimeter pot to determine a difference in height of water in manometer tube and a relationship of $W= 0.006*H - 12.81$, $R^2 = 0.95$ was gotten from the graph of weight against height. Weight was in kg and the height in mm. Table 3.0.Table and graph of different weight and height gotten. The inside of the bucket was casted, and was allowed to drain for a day, a wire net was placed on it and on the net was a small quantity of a sandy soil placed to allow easy infiltration, then on it was a desired bulk density of loamy sandy soil say 20kg filled into the bucket. The bucket was then saturated and allowed to drain for two days to achieve field capacity, the drainage bottle was emptied and initial meter rule reading was recorded and noted before every rainfall.

3.4 Cultivation of Spinach

Considering the agronomic botany of Spinach, rainfall was used as a source of irrigation and the moisture level of soil was observed. Spinach was planted on the 29th of July 2011 early in the morning and it took 8days for Spinach to start germination, it vegetative stage end on the 11th of September 2011, with the fruiting stage starting immediately and end its maturity on 22nd of September 2011. N.P.K fertilizer was applied to the crop in order to gain nutrient required for its proper growth. The soil was well tilth at regular interval of a week (i.e. the plowing of land in preparation for a growing crop) in order to provide a conducive medium for plant growth by facilitating aeration for easy water infiltration. The weeding of the lysimeter pot and the surrounding environment was carried out every two weeks to prevent insect from attacking the crop.

3.5 Data Collection

Every day, whether there is rainfall or not, readings were taken from the lysimeters, rainfall was measured and recorded immediately from the rainguage (if there was rainfall). The rainguage was installed closed to the lysimeter setup, also the drainage water of the plant was measured and recorded at an interval of three days and change in height of the water in the manometer tube was recorded daily as well. The difference between the first reading and final reading represent the depth of rainfall on the crop.

3.6 Computation of Consumptive Water Use

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

$$\text{Input} - \text{Output} = \pm \Delta W \qquad (3.1)$$

$$P + I - (Ro + Dr + ET) = \pm \Delta W \qquad (3.2)$$

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:

$$ET = P + I - D \pm \Delta W \qquad (3.3)$$

Precipitation (P) and irrigation (I) can be directly measured by convectional 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 $W=0.006*H -12.81, R^2 = 0.95$. The water balance equation is re-write to be $Et = P - Dr - (W_{i+1}-W_i)*Cf$.

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:

$\text{Density}(kg/m^3) = \frac{Mass\ (kg)}{Volume\ (m^3)}$

$\text{Volume}(m^3) = \frac{Mass\ (kg)}{Density\ (kg/m^3)}$

Diameter of the pot =30cm.

$\text{Surface area} = \pi \frac{d^2}{4}$

$\frac{3.142 * (0.3)2}{4} = 0.071m^2$

$\text{Depth} = \frac{Volume\ (m^3)}{Surface\ area\ of\ pot\ (m^2)}$

$\text{Depth}(m) = \frac{1000}{0.071} = 14084.5m$

Converting meter(m) to millimetre(mm)

$\frac{14084}{1000} = 14.1mm$

Therefore the conventional factor is 14.1mm

Therefore Water balance equation:

$Et = P - Dr - (W_{i+1} - W_i) * 14.1.$

Et = 18.50-12-(15.51-15.51)*14.1

Etc = 6.5mm/day

3.7 Computation of Reference Evapotranspiration (Eto).

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

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

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

Table 3.0. For different weight (kg) and height (mm)

Height (mm)	Weight (kg)
230.00	.04
240.00	.24
241.00	.44
246.00	.67
250.00	.89
254.00	1.12
256.00	1.35
259.00	1.57
261.00	1.79
264.00	2.02
277.00	2.25

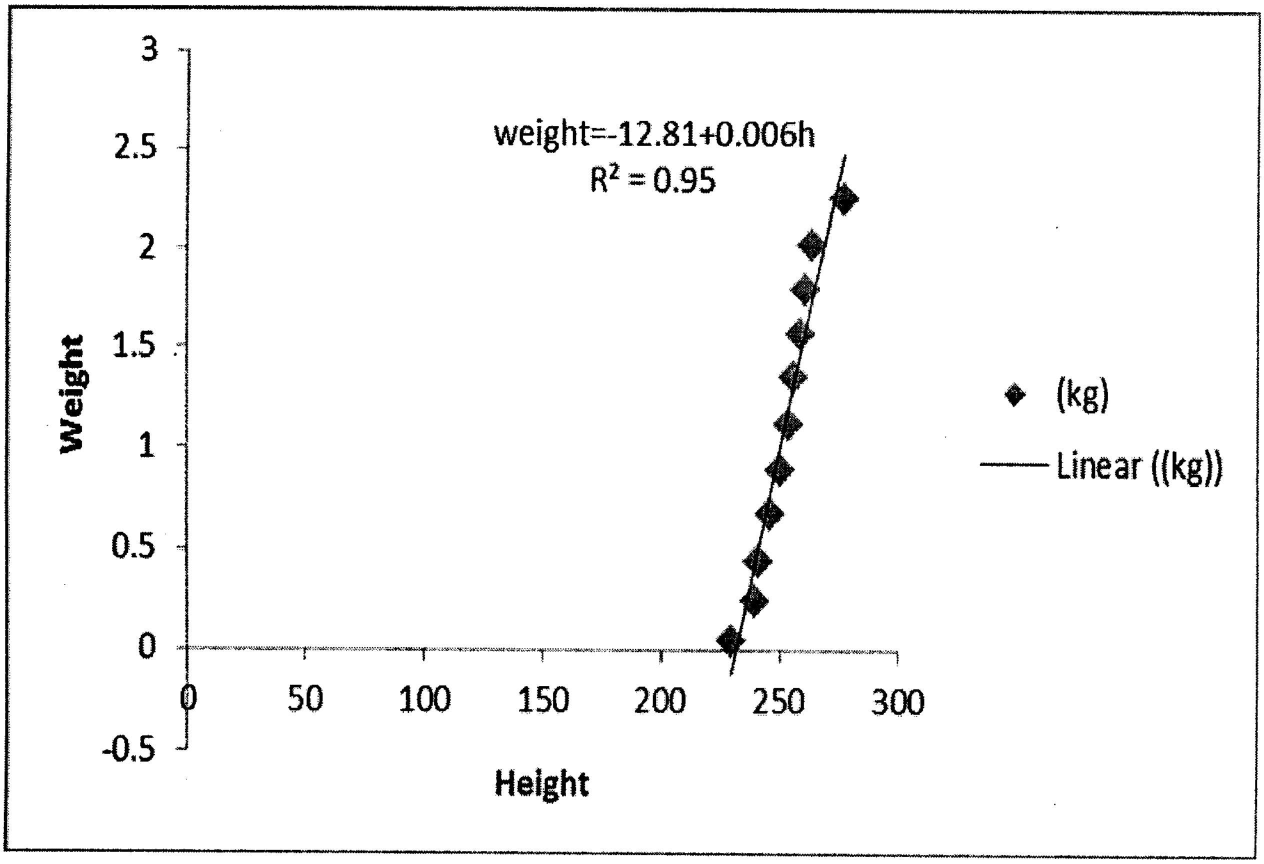

Fig 3.3 Graph of different weight (kg) and height (mm)

Plate 3.1: Dug out foundation for Lysimeter set up

Plate.3.2: Set up of micro weighing lysimeter.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Result

The result of height, weight, rainfall, drainage, evapotranspiration and reference evapotranspiration is presented below in Table 4.1

TABLE 4.1: Height, weight, rainfall, drainage, crop evapotranspiration and reference evapotranspiration for Spinach.

DATE	HEIGHT	WEIGHT	RAINFALL	DRAINAGE	ET	Eto
28/7/2011			18.5			
29/7/2011	472	15.51				
30/7/2011	470	15.39				
31/7/2011	471	15.45				
1/8/2011	472	15.51	25	12	6.5	0.013
2/8/2011	412	11.91				
3/8/2011	384	10.23				
4/8/2011	409	11.73		10	17.538	0.0063
5/8/2011	380	9.99	8			
6/8/2011	335	7.29				
7/8/2011	340	7.59		5	-9.23	0.01
8/8/2011	336	7.35				
9/8/2011	334	7.23	27			
10/8/2011	345	7.89		20	-2.306	0.007
11/8/2011	326	6.75				
12/8/2011	290	4.59				
13/8/2011	322	6.51	19	24	22.458	0.012
14/8/2011	300	5.19				
15/8/2011	260	2.79				
16/8/2011	267	3.21		12	20.536	0.016
17/8/2011	284	4.23	23			
18/8/2011	253	2.37				
19/8/2011	245	1.89		10.2	19.568	0.016
20/8/2011	246	1.95				
21/8/2011	225	0.69	28			
22/8/2011	202	-0.69		20.2	27.258	0.014

23/8/2011	200	-0.81				
24/8/2011	197	-0.99	11			
25/8/2011	180	-2.01		10	15.382	0.015
26/8/2011	186	-1.65	34			
27/8/2011	179	-2.07				
28/8/2011	170	-2.61		27	14.614	0.014
29/8/2011	168	-2.73				
30/8/2011	165	-2.91	27			
31/8/2011	157	-3.39		12	21.768	0.012
1/9/2011	150	-3.81				
2/9/2011	153	-3.63	9			
3/9/2011	154	-3.57		0	8.154	0.011
4/9/2011	150	-3.81				
5/9/2011	155	-3.51				
6/9/2011	150	-3.81		0	12.384	0.012
7/9/2011	157	-3.39				
8/9/2011	140	-4.41	16			
9/9/2011	130	-5.01		0	24.46	0.015
10/9/2011	139	-4.47				
11/9/2011	130	-5.01	4			
12/9/2011	134	-4.77		0	0.616	0.016
13/9/2011	129	-5.07				
14/9/2011	130	-5.01				
15/9/2011	133	-4.83	41	5	-0.154	0.013
16/9/2011	123	-5.43				
17/9/2011	119	-5.67				
18/9/2011	130	-5.01		12	23.078	0.015
19/9/2011	135	-4.71				
20/9/2011	140	-4.41				
21/9/2011	141	-4.35	32	20	5.772	0.021
22/9/2011	143	-4.23				

4.2.0 Discussion of results

The result of the project experimentation are discussed in relation to: Precipitation, Drainage, Evapotranspiration and Crop yield.

4.2.1 Precipitation

From the experiment carried out on Spinach by using micro weighing lysimeter shows that amount of rainfall that fell affect the growth rate of the crop (Spinach) and rate of crop evapotranspiration(ET) for interval of three days. From Table 4.1 the highest rainfall was on 15/09/2011 and crop evapotranspiration(ET) rate for the rainfall with 41mm for that of 18/09/2011 and 21/09/2011, respectively were 23.07mm/day and 5.77mm/day and the evapotranspiration rate(ET) of 4mm rainfall was 0.616mm/day and (-0.754)mm/day, respectively.

4.2.2 Drainage

From the experiment carried out on the micro weighing lysimeter, the drainage water collected varies from three days interval depending on the amount of water retained in the soil. When the soil moisture is very high, the drainage water is also very high and when the soil moisture is low the drainage water is also very low. From Table 4.1, it was found that the higher the drainage the lower the crop evapotranspitation(Et).

4.2.3 Evapotranspiration (Eto)

From the experiment carried out on the micro weighing lysimeter, the rainfall, drainage , moisture content and environmental conditions such as (relative humidity sunshine radiation, wind velocity, etc.) affects the evapotranspiration value of the crop. Increase drainage lead to decrease in evapotranspiration rate of the crop and vice versa.

Furthermore, excessive increase in evapotranspiration value is due to :

1. Lysimeter pot are in isolation
2. The use of micro lysimeters
3. Low atmospheric humidity
4. High wind velocity
5. The lysimeter are not represented in a field condition.

4.2.4 Crop Yield

Spinach crop has 3-different stages, these includes:

1. Vegetative stage: from sowing to complete vegetative cover. Plate 4.1
2. Flowering stage: from starting flowering to starting of fruiting. Plate 4.2
3. Fruiting stage: from fruiting to maturity stage. Plate 4.3

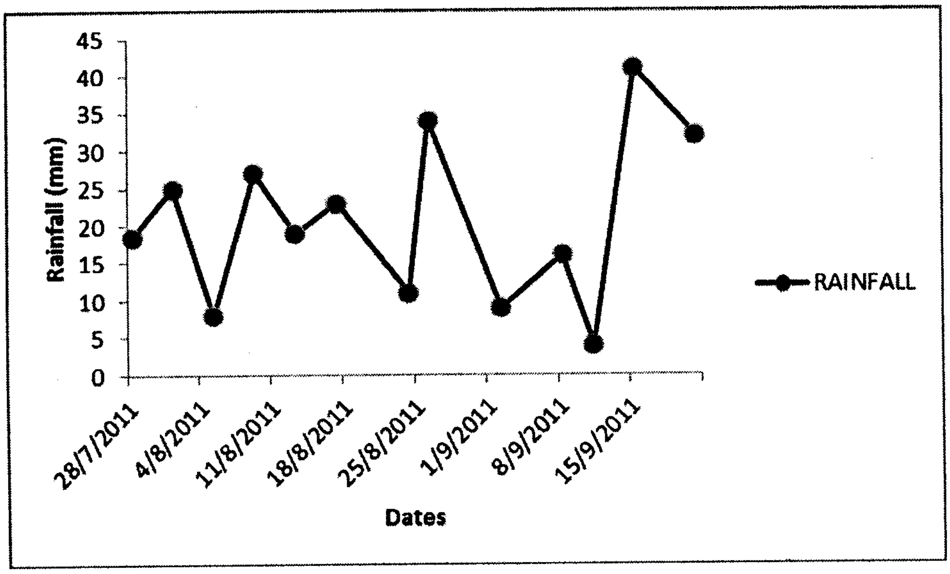

Fig. 4.1. Daily rainfall for the study period

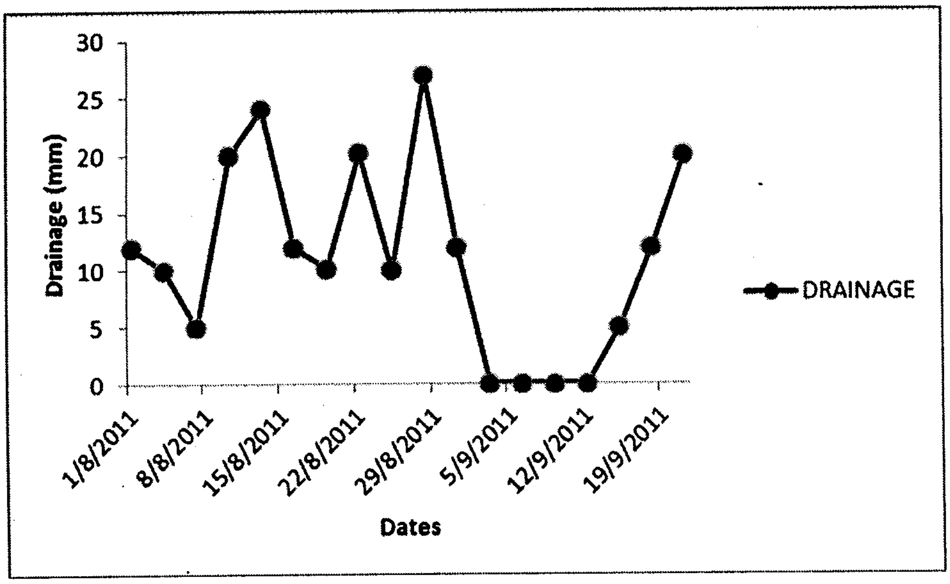

Fig. 4.2. Daily drainage for the study period

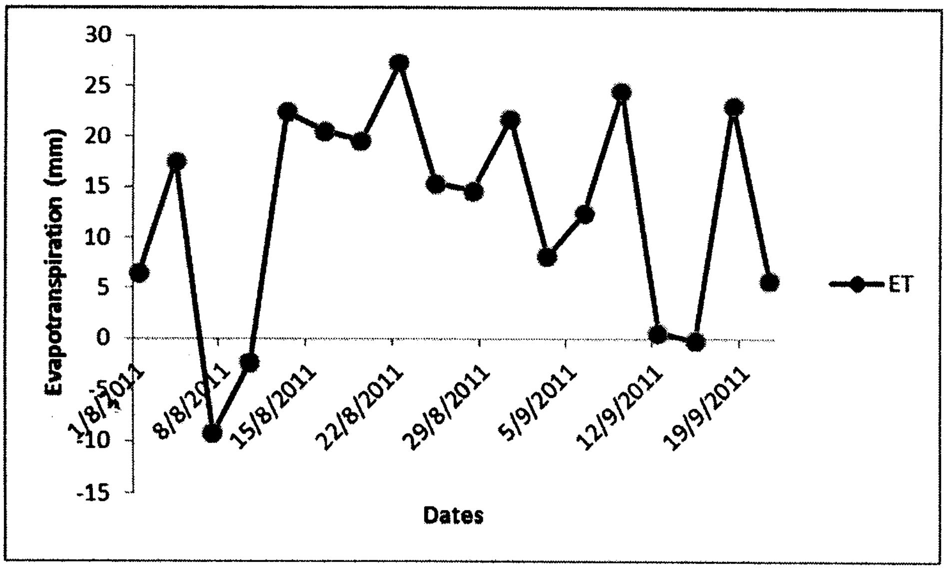

Fig. 4.3. Daily evapotranspiration for the study period.

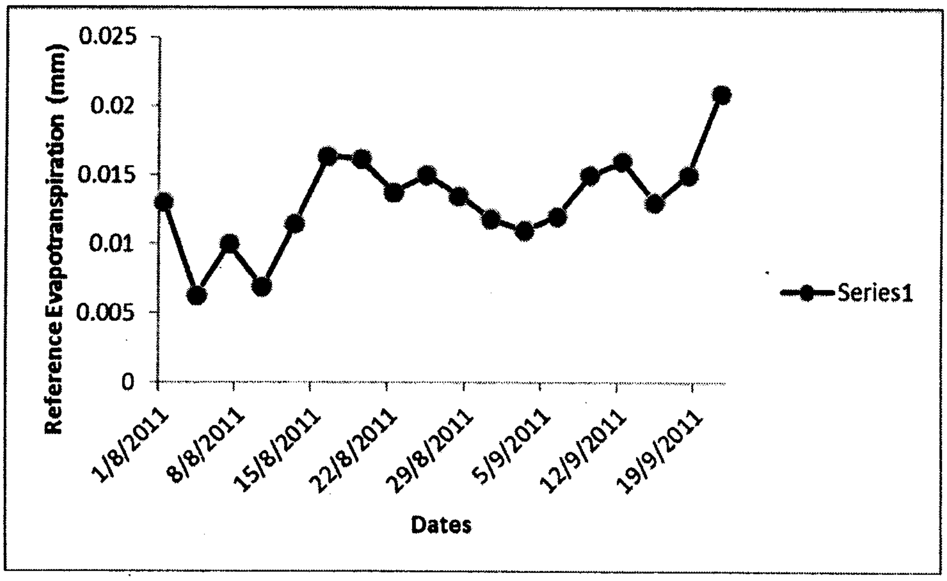

Fig. 4.4. Daily reference evapotranspiration for the study period

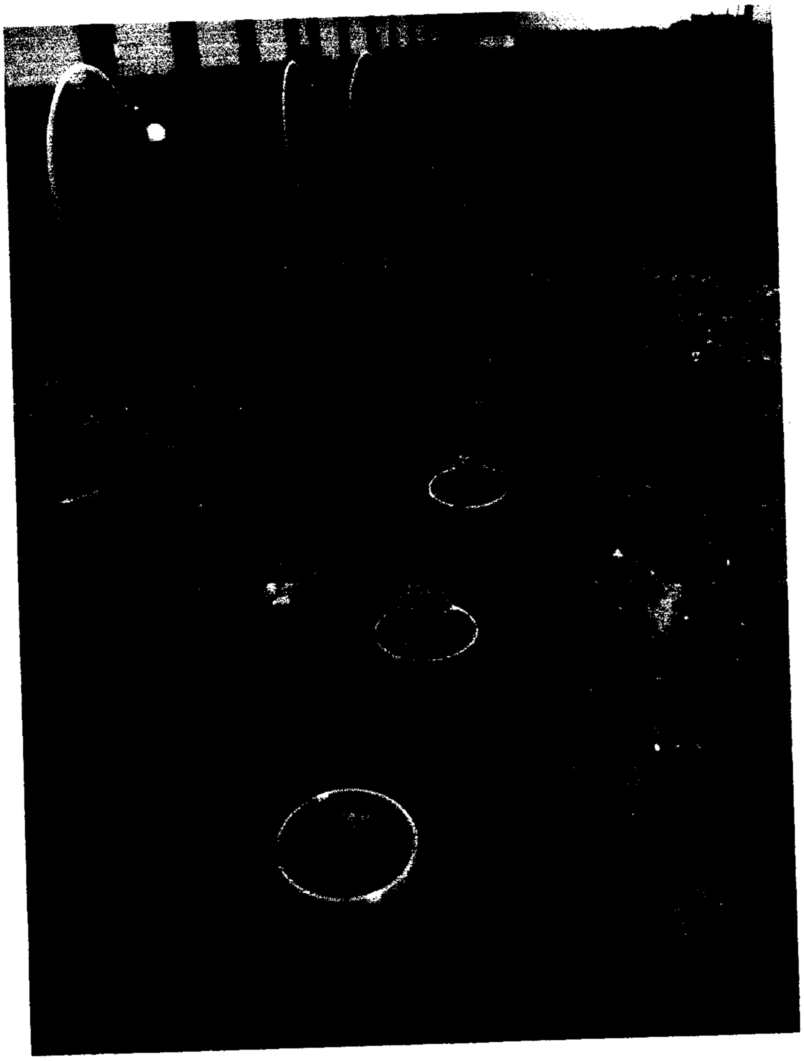

Plate 4.1: Vegetative Stage of Spinach

Plate 4.2: Flowering stage of Spinach

Plate 4.3: Maturity stage of Spinach

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Conclusion

Agricultural practices and management of lysimeters and of the surrounding or fields affects spinach growth and crop evapotranspiration. During the experiment, rainfall occurring on a lysimeter bearing spinach plant caused yellowing of foliage due to the lack of aeration, delay in growth and lowered evapotranspiration. There was a difference in the condition of the crop within the lysimeter as a result of lysimeter size with respect to the surrounding and the crop in the outside condition benefit from better control of plant population, water, fertilizer and pesticide applications.

Hence, the highest and minimum values of rainfall with their corresponding crop evapotranspiration rates for the period of study were 41 mm and 4 mm and 23.1mm/day and 5.8mm/day, respectively. Increase drainage lead to decrease in evapotranspiration rate of the crop and vice versa and the drainage water collected varies from three days interval depending on the amount of water retained in the soil. If the water supply does not meet the limit, it may result to some effect that may be harmful to the spinach plant inhibiting its growth. Micro weighing lysimeter are suitable provide plant growth was representative and the root development in the lysimeter need not be identical to that outside, but must not restrict representative vegetative growth.

5.1 Recommendation.

For future purpose and work relative to this project the recommendation that I proposed are as follows.

1. The lysimeter should be large and deep to reduce boundary effects and to avoid restricting root development.
2. Lysimeter area must be cleaned and well protected from weeds, insects, pests and animals.
3. Regular irrigation schedule must be carried out in order to achieve better result under dry season cropping.
4. Ensure the quality of the irrigation water used is good enough so as not to introduce salt hazards to both the soil and crop.
5. The soil should be tilled from time to time in order to provide aeration and enhance infiltration of water into the soil.

REFERENCES

ABE 343/AE 256. (2003). Evapotranspiration Handbook. Agricultural and Biological Department, Florida. Visit the EDIS website at http://edis.ifas.ufl.edu.

Allen, R.G., Pereira, L.S., Raes, O. & Smith, M. (1998). Crop evaporation; guidelines for computing crop water requirement. In: Proceedings of the irrigation and Drainage paper No. 56. Food and Agricultural Organization, united Nations Rome, Italy.

Dr. Vitiam, Z. & Alana, R. (Consultant). (2008, April). Vegetable crop production guide for Nova scotia. Atlantic provinces Agricultural services coordinating committe

Egharevba, N.A. and Mohammed, B. (1999). Evapotranspiration of selected cereals in Niger State. Proceeding of the 21st Ann. Conf. of the Nig. Soc. Of Engrs. Fed. Poly Bauchi, Nigeria pp 76-80.

George, S. (2002). Measurement of consumptive use of Amaranthus crop. Final year project at Dept. of Agric. Engineering FUT Minna.

Hand, D.W. (1963). An Electrically weighed Lysimeter for measuring evaporation rates. ISHS. Acta Horticulturae 7: Symposium on the Techniques of Experimentation in Green houses.

John, W. & Sons, Inc. (2009, Mars. 9). Testing the precision of a weighable gravitation lysimeter. Department of Soil Physics, Lysimeter station, Dortstrabe 55, 39615 Fakenberg, Germany.

Mcllroy, I.C. and Angus. (1963). The Aspendale multiple weighed Lysimeter installation. Div. Meteorol. Physics paper No. 14 CSIRO, Australia. 27p

Michael, A.M. (1998). Irrigation Theory and Practices Vikas Pub.House New Delhi. pp448-582

Penman, H.L. (1963). Vegetation and Hydrology. Tech. Communication No. 53. Commonwealth Bureau of Soils, England. 124p

Piccinni, G.K., Jonghan, M., Thomas, L., Daniel (2009). Determination of crop coefficient (Kc) for irrigation management of crops. 1619 Garner Field Road, Uvalde Texas 78801.

Samie, C. & De Villele, (1970). Methods of Techniques and the measure of evaporation and evatranspiration potential. Technique elude of the factors physical of the Biosphere, INRA, France. Pp. 258-266

Sarraf, S. and Bovee, A.C.J, (1973). Evapotranspiration and the banamier. Magon Series Tech. No. 20, IRA, Liban 18p.

Sarraf, S., Vink, N and Aboukhaled, A. (1969). Evaporation, evapotranspiration potential of coefficient pich corrige. Magon series sci. No. 32, IRA, Liban. 29p

Sturttevant lewis, E. (2009). Note on Edible Plants, Bibilio Bazzar, LLC Pg. 4

Suat, I. & Dorola, H.Z. (2003). Definitions of Evatranspiration. Professors, (IFAS), Florida, Gainesville, Fl 32611.

Tanner, C.B. (1967). Measurement of evapotranspiration. In: Irrigation of Agricultural lands. Amer. Soc. Agron. 11:534-574.

Texas Agricultural statistics. (2006). United States Department of Agriculture – National Agricultural statistics service (online). Available at www.nass.usda.gov/tv (verified 24 October 27).

Texas Water Development Board. (2001). Report 347. Surveys of irrigation in Texas 1958, 1964, 1969, 1979, 1984, 1989, 1994, and 2000.

Thompson, G.D & Boyce, J.B, (1971). Comparison of Measured ET of Sugar cane from Large and small lysimeters. Proc. South African Sugar Tech. Association. Pp. 169-177

University of Florida. (2006, November). Spinach production in Florida. Retrieved from http://edis.ifas.edu/pdffiles/cv/cv13300.pdf.

Washington State University Cooperative Extension. (2000). Vegetable crop rotation. Retrieved from www.hortnnet.co.nz/publications/guides/fertmanual/vege2.htm

Wikipedia. (2008, February). Crop Rotation. Retrieved from http://en.wikipedia.org/wiks/crop rotation.

APPENDICES

TABLE I 1: Mean Monthly Radiation And Radiation Factor Of Minna, Nigeria [2010].

TABLE I 2: Mean monthly Relative Humidity Minna, Nigeria [2002-2010].

TABLE I 3: Daily Wind Velocity Of Minna, Nigeria [2011].

TABLE I 4: Mean Daily Temperature Of Minna, Nigeria [2011].

TABLE I 5: Daily Temperature Of Minna, Nigeria [2011].

TABLE I 1: 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

TABLE I 2: Mean monthly Relative Humidity Minna, Nigeria [2002-2010].

MONTHS	MEAN MINIMUM R.H (%)	MEAN MAXIMUM R.H (%)
January	20.03	59.06
February	15.5	51.37
March	18.37	66.87
April	29.5	84.12
May	54.25	91.25
June	65.75	93.75
July	71.37	96.38
August	75.62	96.5
September	75.35	87.5
October	60.9	96.5
November	34.5	75.5
December	23	70

TABLE I 3: 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

TABLE I 4: Mean Daily Temperature Of Minna, Nigeria [2011].

Jan	Feb	Mar	April	May	Jun	July	Aug	Sep
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

TABLE I 5: Daily Temperature Of Minna, Nigeria [2011].

Jan Tmax,Tmin	Feb Tmax,Tmin	May Tmax,Tmin	Mar Tmax,Tmin	June Tmax,Tmin	July Tmax,Tmin	Aug Tmax,Tmin	Sep Tmax,Tn
34,20	37,22	36,27	40,23	26,22	30,21	30,25	28,22
33,19	39,23	39,25	40,24	31,21	30,24	31,23	30,28
34,21	39,22	39,25	39,26	32,24	28,19	32,27	31,29
35,20	38,24	39,25	39,24	32,23	30,22	31,29	32,26
33,19	38,22	38,25	39,25	33,24	31,23	30,28	30,25
35,18	37,23	37,27	37,25	31,23	31,23	30,28	29,26
35,17	40,22	38,27	38,28	31,25	28,23	28,25	31,26
36,19	40,21	40,26	39,27	30,22	30,23	28,21	30,25
35,18	37,22	38,28	39,27	33,24	29,22	29,26	32,28
36,18	39,23	38,28	38,24	31,24	30,22	30,28	29,24
35,20	37,22	38,28	39,27	29,23	39,22	29,24	33,29
35,22	37,23	38,26	39,26	32,25	30,23	31,27	28,22
35,23	37,24	38,25	38,27	30,22	29,23	28,24	30,26
36,22	38,25	37,27	38,25	33,24	31,23	32,29	29,24
37,21	36,24	38,28	38,26	33,22	32,24	27,21	31,28
35,23	39,24	36,24	38,24	31,22	30,22	30,22	33,29
36,24	36,27	32,24	39,24	31,25	30,23	27,23	28,26
35,22	39,26	36,26	40,27	30,21	27,24	31,27	29,24
37,23	40,26	35,23	42,27	31,25	28,22	32,25	30,28
36,23	37,25	33,25	39,27	31,21	30,23	28,24	31,26
36,21	38,27	37,26	30,27	29,23	30,22	29,21	33,24
34,24	38,25	35,27	38,27	30,22	29,23	28,22	29,21
35,23	39,25	34,25	38,27	31,24	30,23	31,29	30,28
35,20	40,20	36,24	38,26	27,22	30,23	30,28	31,26
36,22	37,28	34,22	42,29	31,23	32,23	29,22	32,25
36,20	39,27	30,25	39,27	29,22	28,22	31,29	31,27
36,19	39,26	34,22	39,28	32,22	31,23	28,23	28,25
36,23	40,24	30,22	38,26	32,24	29,24	27,21	29,22
34,22	–	29,22	40,25	29,21	32,23	33,24	31,23
35,20	–	33,24	39,25	29,23	31,24	30,28	30,22
37,22	–	33,26	40,25	–	28,24	29,25	–