Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2022, 9(5):53-60

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Determination of Consumptive Water Use of Groundnut Using Weighing Lysimeter

Olotu, Y.[1*], Rodiya A.A.[2], Ibrahim, R.[1], Stephen, A.O.[3], Eleta P.O.[4] & Thomas, B.[3]

[1]Department of Agricultural & Bio-Environmental Engineering, Auchi Polytechnic, Auchi, Nigeria
[2]Department of Agricultural & Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti Nigeria
[3]Department of Civil Engineering Technology, Auchi Polytechnic, Auchi, Nigeria
[4]Department of Agricultural Technology, Auchi Polytechnic, Auchi, Nigeria
Corresponding author: realyahaya@yahoo.com

Abstract The study investigates the use of a weighing lysimeter to periodically estimate groundnut (Arachis Hypogea) water use and crop reference evapotranspiration (ETc). The developed lysimeter consists of a tank, runoff bucket, drainage train, weighing scale, and rain simulator. Groundnut variety (TY491) was planted in the lysimeter tank installed in the field and a 75% germination rate was observed on the fourth day after planting. Lysimeter readings were taken twice daily (7.00 a.m and 4.30 p.m), During the crop germination and establishment periods, the average daily crop water use (CWU) was estimated at 3.0 mm/day, while the CWR increased to 5.4 mm/day at the mid-season and declined to 4.8 mm/day at the end of the season. The comparison of the estimated CWU with the CROPWAT estimation model showed a good relationship with the R^2=0.864 at $P < 0.05$. In conclusion, it is generally observed that weighing lysimeter is suitable to estimate CWU under various climate scenarios with reliable outputs over the study area.

Keywords Weighing lysimeter, Groundnut, Crop water use, CROPWAT estimation model, Germination rate

1. Introduction

Groundnut (Arachis Hypogea) is a major crop grown in the arid and semi-arid zone of Nigeria [1]. The groundnut is one of the major seeds produced in the world belongs to the family Leguminosae. The plant has a high energy value, nutrients and is used to produce a wide range of products derived from the grain, such as peanut butter and natural peanut. [2]. [2] reported that the present annual world production of unshelled and shelled nuts is about 38.2, 1.64 million tons from about 23.8 million ha, respectively. It is either grown for its nut or for its vegetative residue. Recently, the use of groundnut meals is becoming recognized not only as a dietary supplement for children on protein-poor cereal-based diets but also as an effective treatment for children with protein-related malnutrition [2]. Groundnut production is influenced by several environmental factors, especially by moisture stress and temperature as reported by several authors [2; 3; 4].

The groundnut cycles range from 90 to 115 days for early varieties and from 120 to 140 varieties depending on the weather the water requirement range from 500 to 700mm for both cycles [4]. [2] reported that Spanish groundnut cultivars with a growing period of 100-130 days, depending on altitude, are largely grown. Some Valencia cultivars are also grown in the cooler, wetter areas [5;6]. It grows well in environments with average daytime temperatures between 22ºC and 28ºC [7]. An optimum soil temperature for good germination of groundnut is 30ºC. Low temperature at sowing delays germination and increases seed and seeding diseases. Soil test should be done before starting groundnut farming. Groundnut is grown in almost every part of the country and it is best grown on sand-loamy soils with a moderated water holding capacity. The period from sowing to flowering requires 313 GDD (growing degree days) to 360 GDD; depending on the varieties [8].

Groundnut is perfectly grown in well-drained sandy loam or sandy clay warm soils. Deep well-drained soils with a pH of 6.5-7.0, and high fertility are ideal for groundnut. [9] showed that upon correction of soil pH through liming, a substantial increase in the N and P fertilizer use efficiency was achieved. Besides lime, other alternative ameliorants include wood ash [9;10]; animal wastes, and green manures [10]; phosphate and gypsum [11].

One of the major requirements of crops growth is water which is usually supplied through rainfall or irrigation for plants [5;9]. Climate is one of the most important factors determining the crop water requirements needed for unrestricted optimum growth and yield. The demand for water by the crop must be met by the water in the soil via the root system [10]. This research study is focused on determining the consumptive water use for groundnut in order to design and implement effective irrigation scheduling to meet the water requirements for groundnut. Groundnut was chosen for this study because it is the most cultivated crop in the study area (Auchi) with high economic returns and in addition to sensitivity to water deficit.

2. Materials and Methods

2.1. Design consideration

Certain important parameters that were considered in the design and use of the weighing lysimeter include the following: tank size, the durability of the materials, soil type, bulk density of soil in the experimental plot, and root depth. In designing the lysimeter, ease of fabrication, plumbing, simple installation, low maintenance requirement, and low cost were also important considerations. Materials were selected based on availability, quantity, and cost-benefit ratio. Using readily available materials and components helped keep costs down, and a simple design allowed fabrication using common tools. The weighing lysimeter consists of the following components: tank (planted up with vegetable), drainage pipe, and a receiving vessel. These components were installed in the field.

2.2. Lysimeter Components

2.2.1. Soil tank

The weighing lysimeter was made from readily available materials. The tank was a truncated plastic bowl, cylindrical in shape with a surface area of 0.28m². The cylindrical plastic bowl was slightly tampered with at the bottom to allow drainage of water. The receiving vessel was a calibrated bucket (Marek *et al.,* 2006). Sufficient space was made at the bottom to allow the collection of the percolated water and the water collected from the calibrated bucket as drained water from the pipe directly was measured using a measuring cylinder. Pipes were used for the connections from the tampered bottom of the weighing lysimeter tank. The weighing lysimeter tank was filled with the sandy loam soil and a known quantity of water was applied to saturate it. This was to determine the holding capacity of soil in the weighing lysimeter. Groundnut seeds were planted and the agronomic parameters were monitored and recorded in weighing lysimeter until the harvesting period as described by [6].

2.2.2. Lysimeter drain

The drain pipe of polyvinyl chloride (PVC) was fixed to the bottom side of the lysimeter tank with the aid of a threaded joint. This pipe was installed beneath to collect the water percolated from the soil in the tank. This pipe served as a conveyance structure for the percolated water into the receiving vessel. The pipe is a gravity drain system that has a slight fall between the tank and the receiving vessel [8].

2.2.3. Receiving vessel

The drainage pipe was connected to a 5-litre drainage collection unit called the receiving vessel. The receiving vessel is calibrated 5-litre plastic container. From the receiver, the amount of water that infiltrated each event was measured and recorded. The amount of water sprinkled was such that there was percolation each day, although the amount always varied according to the time of the year and weather conditions. Percolated water was recycled to minimized the loss of nutrients

2.3. Assemblage of weighing lysimeter

This was done by marking out the angle bar (frame), plastic bowl, PVC pipes, and hose into the required dimensions with the use of steel tape. The angle bars, pipes, hose, and plastic bowl were cut into their required dimensions. The angle bars were welded to the required length and height. A calibrated bucket was placed at the top flat area while a plastic bowl rested on the one below. The calibrated bucket was perforated at the base and a tap was fixed for easy delivery of water into the plastic bowl that was perforated at the base. Another pipe was fixed for easy delivery of water from the bowl filled with soil into another calibrated bucket. The stand provides support for the weighing lysimeter to withstand soil and water weight as shown in Fig. 1.

Figure 1: Weighing lysimeter during construction

2.4. Site preparation and field layout

Five sets of weighing lysimeters were assembled and used for the study. One out of the five was used as control weighing. Each weighing lysimeter consisted of plastic bowls of 55cm diameter and 40 cm deep which serves as the lysimeter tank where the crops were planted, the weighing system, the runoff, the irrigation system, and the stand (Figs 2a and 2b). The stand carried the irrigation system at the upper part, the weighing lysimeter tank at the middle, and the receiving vessels placed on the ground in an excavated hole for runoff for each of the five systems.

The irrigation system consisted of a plastic bucket of 35cm diameter and 32cm deep which supplied the irrigation water. The irrigation system was placed above the weighing lysimeter tank connected at the bottom side with a rubber hose for irrigation supply for the growth of the crops (Fig. 2a and 2b). The runoff system consisted of a plastic bucket of 15cm diameter and 22 cm deep which serves as the collector. The runoff collector was connected with a rubber hose to an outlet fitting made at the bottom side of the lysimeter tank. The collector was placed at a lower elevation so that the runoff water from the lysimeter tank flows by gravity into the collector. The runoff collector was covered with a lid to prevent rainfall from entering it (Fig. 2a and b).

Figure 2a & 2b: A set of weighing lysimeters during experimentation and crop growth

2.5. Monitoring System

The artificial water application was monitored by noting the time spent on each irrigation and multiplying the same by the flow rate of the system 0.38l/s. By this, the quantity of water applied was determined. Percolated water was recycled in the receiving vessel placed at the adjacent pit through the drainage pipe. The quantity of water collected was always measured and recorded. After recording the percolated water was recycled to minimize loss of nutrients. A rain gauge was installed at the site to catch daily rainfall readings in the case of rainfall since a little part of the study period entered into the rainy season. The project was monitored two times daily morning and evening. Daily climatic datasets were collected. These include temperature, relative humidity, sunshine hours, rainfall, and solar radiation.

2.6. Determination of crop evapotranspiration

Crop evapotranspiration (ET) was calculated using the water balance method equation which is also known as inflow – outflow method as shown in equation (1):

$$\mathrm{ET} = \mathrm{I} + \mathrm{P} \pm \Delta\mathrm{S} \pm \Delta\mathrm{D} \pm \Delta\mathrm{R} \quad (1)$$

Where

ET = Crop evapotranspiration (mm/day)
I = Irrigation (mm)
P = Percolation (mm)
ΔS = Change in Soil Moisture (mm)
ΔD = Change in Precolation (mm)
ΔR = Change in Runoff (mm)

In determining the soil moisture content, the gravimetric method was employed and values were gotten in percentage. From the weighing lysimeter, the crop evapotranspiration was determined by the water balance equation as given equation (1).

2.6.1. Estimation of crop evapotranspiration using climatic data

The models employed here are Blaney-Morin-Nigeria and Hargreaves-Samani [6].

The Blaney-Morin-Nigeria models is of the forms [6]

$$\mathrm{ET} = \mathrm{r_f}[0.45\mathrm{T_a} - 8][\mathrm{H} - \mathrm{R_m}] \quad (2)$$

Where

ET = Evapotranspiration (mm/day)

r_f = Ratio of monthly radiation to annual radiation
Ta = Mean monthly temperature (◦C)
R = Mean monthly relative humidity (%)
H and m are model constants of 520 and 1.31 respectively.

The estimation of ET with Hargreaves – Samani is calculated by the equation (Hargreaves–Samani, 1967).

$$ETo = C(\text{Timed} - 17.78)(\text{Tmax} - \text{Tmin})^{0.5}\ \text{Ra} \quad (3)$$

Where

ETo = The potential evapotranspiration (mm/day)
Tmax = Daily maximum temperature (◦C)
Tmin = Daily mean temperature (◦C)
C = 0.0023
Ra = Water equivalent of the extraterrestrial radiation mm/d

2.6.2 Data Analysis

The data was analysis using Analysis of Variance (ANOVA) and Correlation. Ducan's Least Significant Difference (LSD) was used to determine significant differences among the means.

3. RESULTS AND DISCUSSION

3.1 Irrigation and runoff from the lysimeter apparatus

The water balance parameter (irrigation depth and runoff depth) is shown in Fig. 3. It was observed that peak irrigation amount was obtained in February and the least amount of irrigation was obtained in the middle of December between 16th, 21th, and 26th of December. The depth of irrigation varies from 10.4mm to 90.0 mm.

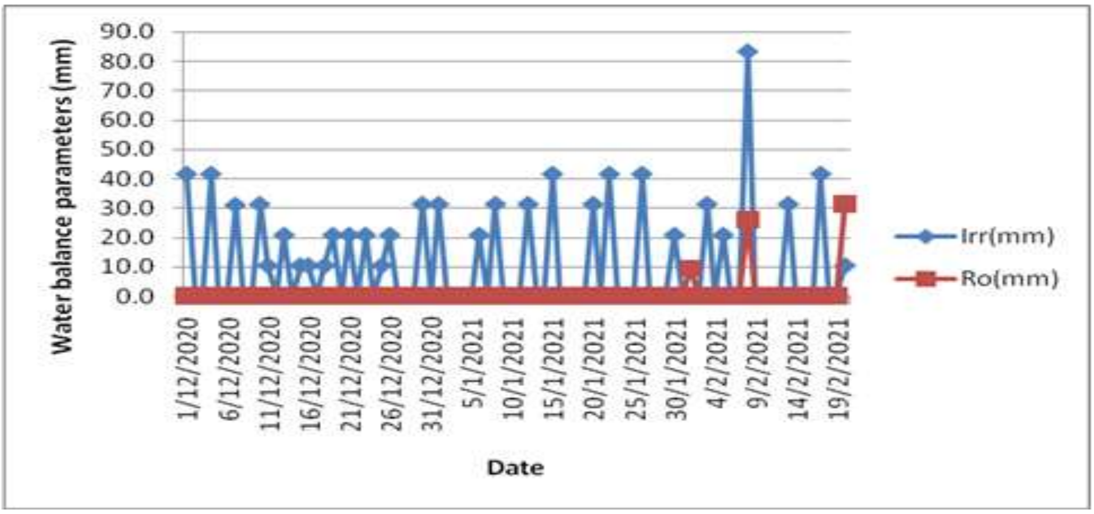


Figure 3: Water balance variables from groundnut weighing lysimeter

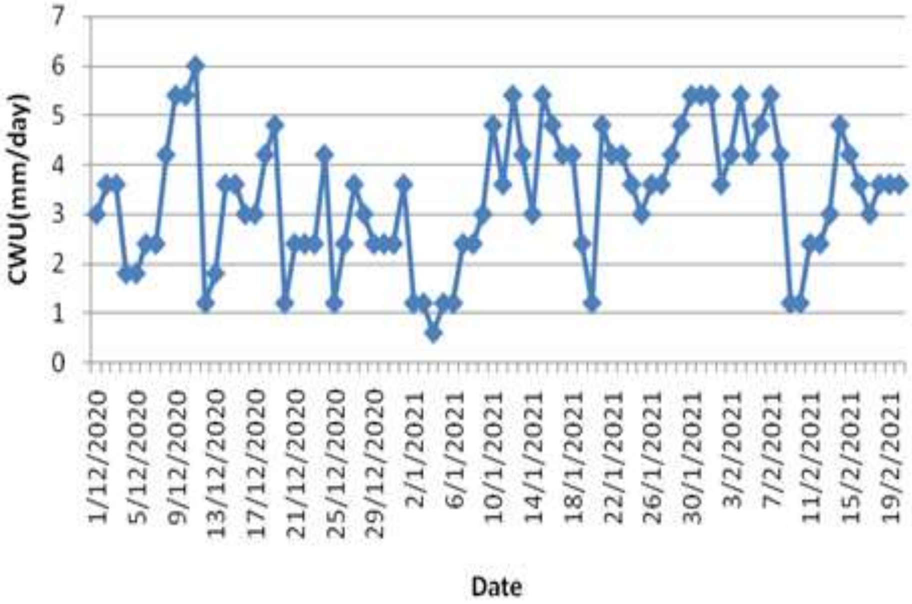
3.2. Crop water use

The result obtained in Fig. 4 shows the trend of daily crop water use (CWU) of groundnut during the growing season. The daily crop water use varied from 0.6mm/day to 5.4mm/day with a seasonal average of 3.6mm/day (Fig. 4a). There was no definite pattern for the daily crop water use with respect to crop age as the value kept rising and falling throughout the crop growing season. This is typical of daily evaporation. Higher evaporation rates were observed on very sunny and cloudless days, while lower evaporation was on cloudy and rainy days. Fig. 4b shows the water use, total irrigation (TI), and runoff for the experimental period (115 days measurement period). The total amount of irrigated water estimated for the period was 143.42mm depth and consumptive water use by groundnut crop was estimated to be 275.4mm for 115 days, the total runoff was 66.7mm for the period. The relationship between irrigation and runoff events for the groundnut lysimeter indicated that the amount of irrigation depth is a function of the irrigation density and duration of irrigation against runoff.

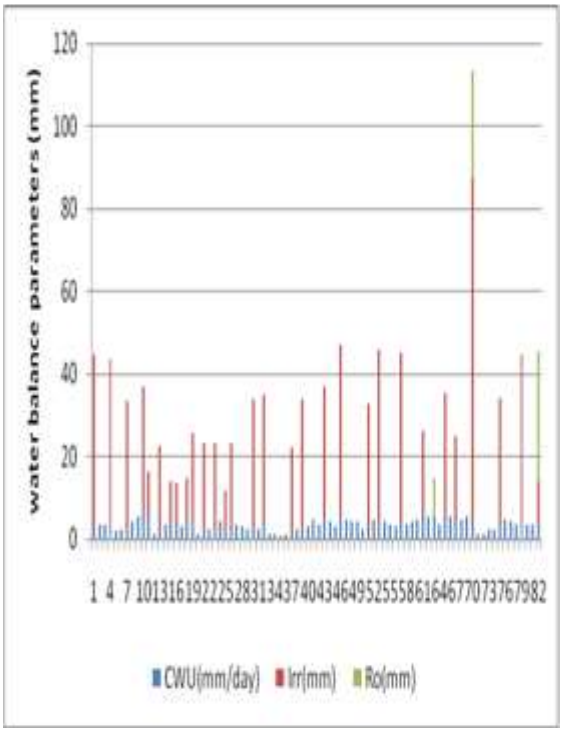
Conversely, under normal conditions runoff would likely occur when the amount of irrigation is high. The result in Fig. 4c showed the behaviour of daily CWU of groundnut under a prevailing ambient temperature.

3.3. Plant phenology

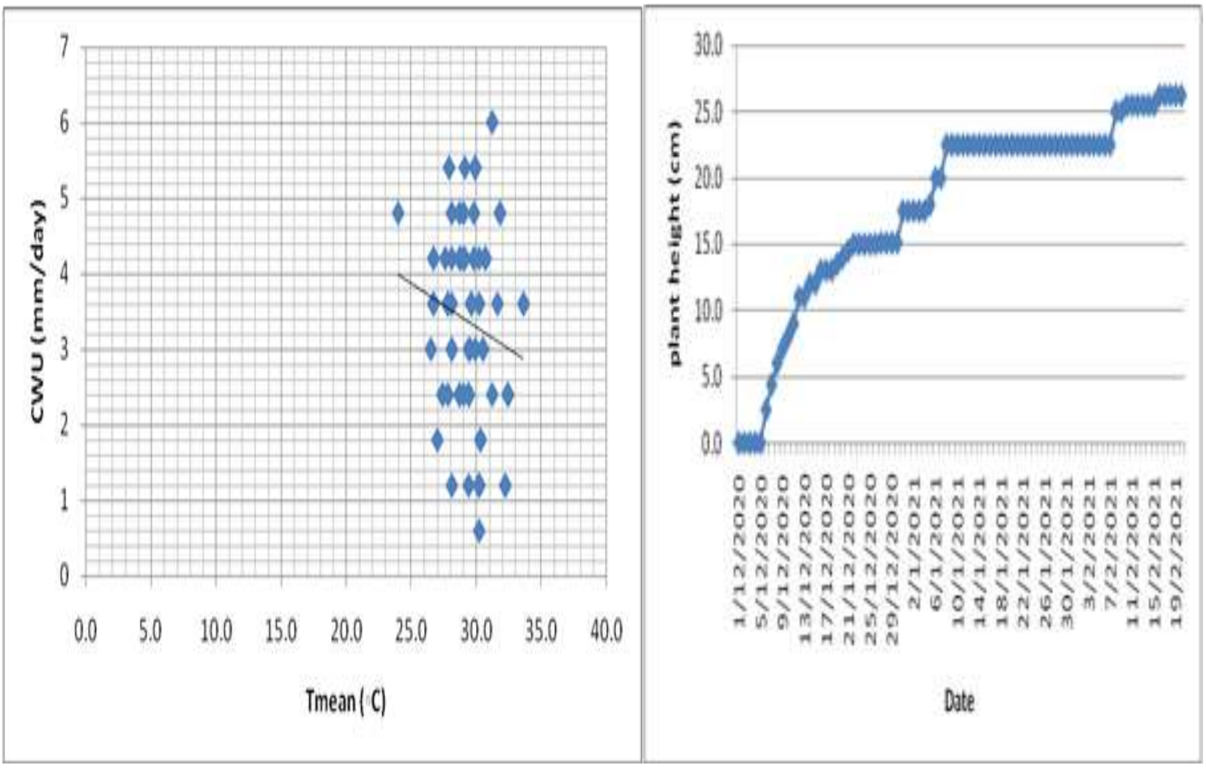
Daily plant height of groundnut crop was measured within the 4-day interval. Fig.4d presents the groundnut phenological development during the growing season. The plant height (Ph) showed a steady increase over the growth cycle. The leaves evolvement in the groundnut was of a high rate. At every shoot, one leaf did emergence, and increments were recorded at 2-4 days intervals. It is observed that the number of leaves of groundnut during the growing period increased progressively. The number of leaves was few during the early stage, but as the days advanced the leaves increased.



(a)



(b)



(c) (d)

Figure 4: Irrigation and runoff measured from the lysimeter (Fig. 1a), Crop water use (Fig. 1b), Measured water balance parameters within 115 DAP (Fig. 1c), Measured plant height (Fig. 1d), and Leaf emergency rate (Fig. 1e)

4. Conclusion

It is important to have a robust knowledge of crop water use under various climatic situations for several crops. This is useful to design an effective and sustainable irrigation scheduling. The overall experimental outcomes for using a weighing lysimeter indicated that the estimated CWU of groundnut was steadily increased from the initial to developmental stage and reduced at the end of maturity stage to harvest period. Hence, the crop stress coefficient (Ks) increased from the crop germination and establishment to the developmental phase. Conversely, to improve groundnut yield, it is important to effectively irrigate the groundnut cultivation during the initial to mid-season crop growing phase for drying season (November to March) farming; and regimented supplementary irrigation is useful during the rainfall period.

References

[1]. Freitas, K. (2005). A major crop grown in the in the arid and semi-arid zone of Nigeria. From temperature, Appl. Eng. Agric., 1, 96–99.

[2]. Ntare, K. (2001). The use of groundnut as a dietary supplement. Appl. Eng. Agric., 1, 100–107.

[3]. Simmonds, L. P. and Williams, J. H. (1989). Population, water use and growth of groundnut maintained on stored water II. Transpiration and evaporation from soil. *Experimental Agriculture*, 25: 63

[4]. Ravindra, V., Nautyal, P. C. and Joshi, Y. C. (1990). Physiological analysis of drought resistance and yield in groundnut. *Tropical Agriculture*, 67: 290 - 296.

[5]. Doorenbos, K.U. and Kassam, T.E. (1979). The groundnut cycles and water requirement. *Experimental Agriculture*, 25(63), pp. 45-60.

[6]. Hargreaves, G. H., and Samani, Z. A. (1985). Reference crop evapotranspiration Humanity Curing a blind spot, *Hydrol. Earth Syst. Sci*., 9, 15– 28.

[7]. Craufurd, P.Q., Prasad, P.V.V., Summerfield, R.J. (2002). Dry matter production and rate of change of harvest index at high temperature in peanut. *Crop Sci*. 42: 146-151.

[8]. Ket D. L. and Wheless, T. G. (1989). The Degree-day requirements for phenological development of peanut. *Agronomy Journal,* 81(1), p. 910-917.

[9]. Mukurumbira, L.M. and Dhliwayo, D.K.C. 1996. Using the Diagnosis and Recommendation Integrated System (DRIS) In Zimbabwe. In Research Results and Network Outputs. Proceedings of the second meeting of the Soil Fertility Network Group, held at Kadoma Ranch Motel, Kadoma, Zimbabwe, 18-21 July 1995. CIMMYT-Zimbabwe, Harare, Zimbabwe. pp. 127-130.

[10]. Ahmad, N., M. Rahim and U. Khan, 2007. Evaluation of different varieties, seed rates and row spacing of Groundnut, planted under agro-ecological conditions of Malakand Division. *J. Interacad*., 9: 178-183.

[11]. Zeyong, X. (1992). Groundnut production and research in East Asia in the 1980s. Proceedings of International Workshop on Groundnut-A Global Perspective, November 25-29, 1991, Patancheru, Andra Pradesh, India, pp: 157-165.