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Evaluation of Artemisinin Contents as Affected by Soil and Water Management Strategies under Gravity-Drip Irrigation System in Samaru, Nigeria

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Research Article

Abstract

Malaria has been among the dangerous diseases not only in Nigeria but Africa as a whole. Artemisia crop has an artemisinin, which is a strong anti- malaria drug. However, despite its importance in curing this disease, it is only produced under rain-fed but hardly produced under irrigation in Nigeria. The experiment consisted of three levels of irrigation water application at 100, 80, and 60% ETo (reference evapotranspiration); two mulch levels (rice straw mulch and no mulch) giving a total number of six treatments, replicated three times, totaling eighteen treatments laid in Randomized Complete Block Design (RCBD). The soil moisture was monitored throughout the crop growing season with access tubes installed at different incremental depths of 0-20 cm, 20-40 cm and 40-60 cm below the soil surface. The artemisinin content was determined in the Faculty of Pharmaceutical Sciences, Ahmadu Bello University, Zaria. The artemisinin content obtained ranges from 0.27 % w/w to 1.84 % w/w. The least artemisinin content was obtained from the treatment with irrigation at 60% ETo with no mulch. While the highest value was obtained with irrigation at 100% ETo with rice straw mulch. The artemisinin content of artemisia annua is affected by water stress. Irrigating the crop fully results in higher artemisinin content of artemisia annua followed by 20 % deficit. The least artemisinin content of artemisia annua was obtained at much water stress of 40 %. The study, recommends a full irrigation could be practiced for effective production of artemisia crop under drip irrigation. However, up to 40 % irrigation water deficit could be applied in areas of high water scarcity. Moreover, since rice straw is cost effective, it is recommended for use as mulching material for the cultivation of artemisia crop under irrigation.

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Artemisia; artemisinin; irrigation; soil and water management

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1. Introduction

Water scarcity at a global scale is increasing, making it perplexing to achieve sustainable agricultural production (Habibu *et al.,* 2020; Dolan, *et al.,* 2021). Agricultural water scarcity is projected to increase in more than 80 % of the world's countries by the year 2050 (Liu *et al*., 2022; Haruna *et al.,* 2023; Onwuegbunam *et al*., 2023). This coupled with the increasing population, climate change impacts and competition from other sectors, puts food security at stake (FAO, *et al.,* 2022). The primary goal of agricultural research in the 20th century was to maximize crop output, but, in more recent years, the emphasis has switched to maximizing the use of natural resources (Geerts and Raes, 2009). One of the most important resources for crop production is water, and agricultural sector is the main consumer of water, accounting for 70% of total water usage (FAO, 2011). In many regions of the world, there is already a severe water shortage (Forouzani and Karami, 2011), particularly in those where irrigation water has been overused (Chai *et al.,* 2016).

Most farmers in underdeveloped nations like Nigeria engage in rain-fed agriculture, which results in low production and consequently low revenue. Irrigated agriculture has been a component of adaptation methods to offset the consequences of climate change in various locations, including the Guinea, Sudan, and Sahel Savannah regions. Hand pumps, wells, canal water, and rainfall were the main sources of irrigation water supply. These techniques have had serious problems such as under and over-irrigation, which result in leaching and loss of the soil's nutrient contents (Suresh *et al.*, 2014).

Artemisia annua L., also known as sweet wormwood, is an annual shrub native to China that may also thrive in a variety of subtropical and temperate climates. It has been effectively used to treat malaria in China for more than 2000 years. (Dewer, 2010). The artemisia plant produces artemisinin, a potent anti-malarial medication. In Nigeria, however, it is only produced under rain fed conditions and rarely under irrigation, despite its significance in the treatment of this disease.

One of the most hazardous diseases, not just in Nigeria but throughout Africa and other regions, is malaria. One of the deadliest parasites in the world, the malaria parasite Plasmodium falciparum is responsible for over a million fatalities annually. Sub-Saharan Africa accounts for 90% of cases, 85% of which involve children under five. Low productivity in rain-fed agriculture leads to low income. Additionally, it is not yet known whether the crop may be impacted by water stress due to the country's worrying water shortage, particularly in the northern region. As a result, this study assessed the artemisinin content using drip irrigation while also considering soil and water management practices. Mulch and irrigation are regarded among the possibilities for increasing crop production while reducing water use for irrigation at the field level. This will allow for the discharge of excess water for purposes other than agriculture (Igbadun and Oiganji, 2012). Water is applied efficiently and gradually, drop by drop, at a single point or grid of points on or just below the soil's surface close to a plant's root zone. This technique is popular because it makes it possible to handle fertilizer and water both effectively (Rajurkar *et al*., 2012).

2. Materials and Methods

2.1 Experimental Site

The field experiment was carried out during the dry season at the Ahmadu Bello University's Institute for Agricultural Research (I.A.R.) Irrigation Field in Zaria, Kaduna state. According to Maniyunda et al. (2020), it is situated in Nigeria's Northern Guinea Savanna Ecological Zone in latitude 11° 11' N, longitude 7° 38' E (shown in Figure 1) and 686 m above mean sea level.

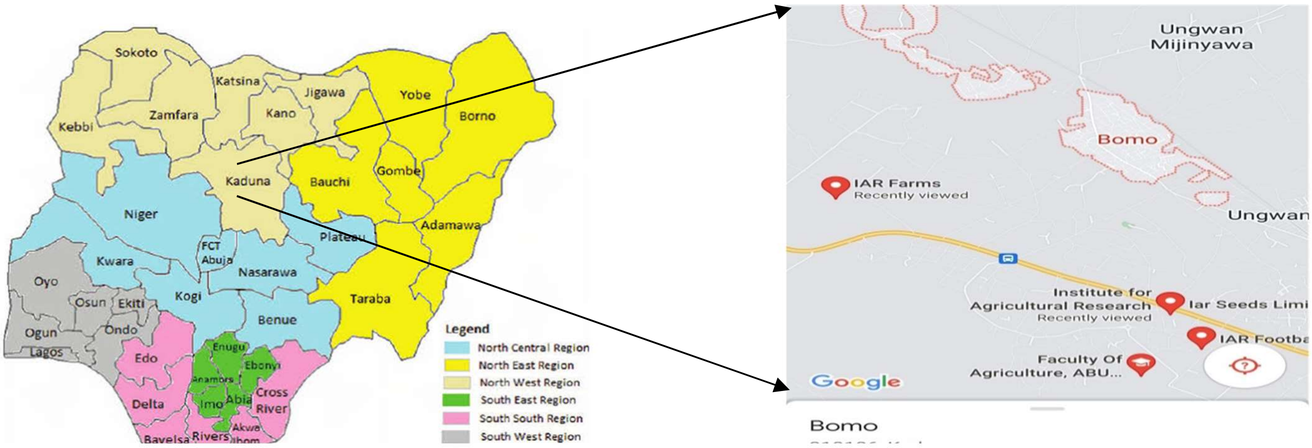

Figure 1: Figure 1: Location of the Study Area

2.2 Analyzing Soil Data

Measurement stations within the study area were randomly chosen for sampling prior to planting. For the purpose of determining the soil's bulk density, moisture content, and texture in a lab, soil samples were taken at intervals of 0–15, 15–30, 30-4, and 45–60cm below the soil surface.

2.3 Field Operations

To increase the soil's ability for infiltration, water retention, and soil aeration, the field was harrowed. A drip watering system was used to transplant the experimental crop, Artemisia to an area that was 1 m by 1 m after it had been grown in a nursery for six weeks. The field was pegged and then irrigated to field capacity. In order to conserve soil moisture, mulching was also done using a randomized complete block design.

The artemisinin content was quantified at the Faculty of Pharmaceutical Sciences, Ahmadu Bello University, Zaria Using high-performance liquid chromatography (HPLC) with the following procedural steps: preparations of extracts, standard stock solutions, calibration curve and HPLC procedure. (Lapkin, et al. 2009).

2.5 Soil Moisture Measurement

Depleted moisture from soil using a theta probe moisture meter, at incremental depths of 60, 40, and 20 cm were calculated. By putting the instrument through access tubes that were previously placed in each hole, readings were taken in-situ, and the values were recorded.

2.6 Developing Experiments

The experiment consists of two components: mulching (no mulch, and rice straw mulch,) and three levels of irrigation (100, 80, and 60% of ETo (reference evapotranspiration)), which results in six treatments duplicated three times totaling 18 plots,. These two components are shown in Table 1. The Randomized Complete Block Design (RCBD) was used to lay out the treatments.

Table: Treatment Description at the Experimental Plots

S/N	Treatments	Description
1.	1_{100}+RM	irrigation at 100 % ETo with rice straw mulch
2.	1_{100}+NM	irrigation at 100 % ETo with no mulch
3.	1_{80}+RM	irrigation at 80 % ETo with rice straw mulch
4.	1_{80}+NM	irrigation at 80 % ETo with no mulch
5.	1_{60}+RM	irrigation at 60 % ETo with rice straw mulch
6.	1_{60}+NM	irrigation at 60 % ETo with no mulch

2.7 Design of a Drip System

Two sets of plastic tanks each with a capacity of 3000 liters were mounted on a stanchion and utilized as the construction materials for the gravity drip irrigation configuration (Figure 2). Each stanchion rises 3.2 m above the surrounding terrain. 1.25" (one and a quarter inch) sub-mainline pipes, 0.25" (one-quarter inch) laterals, and mainline pipes with diameters of 2" (two inches) and 1.5" (one and a half inches) are attached. This drip kit was set up in the field, spanning a 2500 m2 area with lateral lengths of 25 m and sub-main lengths of 100 m. The water was transferred from the main canal to the plastic storage tanks using a two-inch centrifugal pump.

Figure 2: Layout of Experimental Plots

2.8 Determination of Emission Characteristics of Drip System

To assess the homogeneity of the drip irrigation components, a methodology similar to that described by Merriam and Keller (1978), Vermeiren and Jobling (1986), and Oyebode et al. (2011) was utilized. As a result, four emitters were chosen for each lateral at four separate points along its length: at the start, at the 1/4 and 1/2 mark, and at the finish. A pressure gauge that was mounted along the submains just before the filter was used to measure the operating pressures for each test. The volume of the water released from the emitters over a 5-minute period was calculated using a graduated measuring cylinder. These facts helped determine the average flow for each emitter and, thus, the average emission rates. Equation 1 (Keller and Karmeli, 1974).

$$EU = \frac{q_{25}}{\bar{q}} \times 100 \tag{1}$$

The coefficient of variation of the emitter flow (CVq) was calculated by (2) (Bralts and Kesner, 1983).

$$CV_q = \frac{Sd(q)}{\bar{q}} \times 100 \tag{2}$$

Similarly, using (3) the emitter flow variation (q_{var}) was calculated (Wu and Gitlin, 1983; Agriinfo, 2018; Solomon, 2000).

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \times 100 \tag{3}$$

Where, EU: Emission uniformity (%), q25: the 25% of emitters with the lowest flow (l/h) on average discharge; Sd(q): typical deviation of the emitters' discharge (l/h); $\bar{q}$: average discharge of all the emitters (l/h); equation 4 was used to calculate the emitter discharge (4).

$$a = \sqrt{\frac{\sum(\times i - \upsilon)^2}{N}} \tag{4}$$

Where a is the emitter discharge deviation, N is the number of the emitter discharge, X_i is the each value from population, υ is the emitter discharge means, q_{max} is the maximum emitter discharge along the line (l/h), and q_{min} is the minimum emitter discharge along the line (l/h).

2.9 Water Application Calculation for Irrigation

The amount of water applied (Q_i) per irrigation was calculated as a function of the study region's periodic reference evapotranspiration (ETo, mm) and the soil sample's drip-wetted area (Adw, m^2). Hence: Equation 5 was used to determine the area, and Q_i is the amount of water to be applied per irrigation (l), and Adw is the drip-wetted area (m^2). Hence,

$$Q_i = A_{dw} \times ET_o \tag{5}$$

Where Q_i is the amount of water to be applied per irrigation (l), A_{dw} is the drip wetted area (m^2) the area was determine using (6).

$$A_{dw} = \frac{\pi d^2}{4} \tag{6}$$

According to Algharibi *et al.* (2013), the depth of irrigation water applied, dn, was taken into account as a function of the reference evapotranspiration (ETo) for the research region. The estimated daily or monthly reference evapotranspiration (ETo) is measured in millimeters.

By dividing the net irrigation depth by the system application efficiency (drip emission uniformity), the gross irrigation depth, d_g, was calculated.

$$d_g = \frac{d_n}{E_a} \tag{7}$$

Where the d_g is the gross irrigation needs in centimeters, E_a is the net irrigation requirement, %, and d_n is the irrigation application efficiency, cm.

According to an expected proportion of the wetted area relative to the total irrigated area, which depends on emitter discharge, spacing, and soil type, the volume of water (m^3) corresponding to dg was computed (Karmeli and Peri, 1972)

2.10 Adopted Irrigation scheduling

According to earlier studies (Amans *et al.,* 2010), irrigation intervals were set at seven days per irrigation circle, and the volume of water applied was determined by reference evapotranspiration data for the study area. Thus, (8) was used to calculate the amount of water applied each irrigation:

$$V_i = A_{dw} * 7 * ET_o \tag{8}$$

Where V_i is the irrigation volume (m^3) , Ad_w is the drip wetted area (m^2), ET_o is reference evapotranspiration (mm).

2.11 Determination of Irrigation Running Time

The drip irrigation running time (time taken to apply the required amount of water) used in administering water according to the Kumari *et al.* (2014): treatments were determined as;

$$T_{drip}=\frac{N_p V}{N_e Q \times EU} \tag{9}$$

Where T_{drip} is the Drip Irrigation time (hours), N_p is the Number of plants served by one lateral, V is the volume of water applied per plant in drip irrigation system (litre), N_e is the number of emitters in one lateral, Q is the average emitter discharge (litre/hr), EU is the Emission uniformity (fraction).

3. Results and Discussion

3.1 Hydraulic Performance of Gravity Drip Irrigation System

Because of its excellent and high consistency, the drip irrigation method has been the most widely utilized irrigation technique worldwide. With this technique, water is transferred from the pipe network to the plant through emitters and distributed to the field using pipes. The primary issue is the decrease in pressures and discharge distribution across the network as a result of the volume of pressure losses between the lateral's head and end. The discharge distribution of emitters; the pressure drops in pipes could affects the flow rate of water through the emitters. Coefficient of variation (CV); an increase in pressure drop may cause higher variation in discharge rates leading to a higher CV. And uniformity; as pressure drop increases, the uniformity of water application could negatively be impacted.

3.1.1 Uniformity of Emission

The drip irrigation system's uniform emission distribution is crucial for irrigation water management and could be the foundation for both crop productivity and the most effective use of available water resources. As a result, the higher the value of emission uniformity, the more it might be used as a foundation for maximum water use efficiency and agricultural yield (Kumari *et al.,* 2018). According to Table 2, the average emission uniformity in this investigation ranged from 93 % to 74 %. The ageing of the drip lines, which affects emitter discharge and emission uniformity, may be the cause of the lower-than-expected emission uniformity of 95% reported by Bralt *et al.* (1987). This further supported the results of Ramalan *et al.* (2010). And Kumari *et al.* (2018). Reported general ratings of emission uniformity 80 to 90% are considered as good.

3.1.2 Coefficient of variation and emitter flow variation

The coefficient of variation average is 17.67 % and the emitter flow variation average is 18. 68% as presented in Table 2. Therefore, increase in emitter flow variation could be an indication of greater magnitude between lowest and highest emission rate. Jensen (1983) Reported, in drip irrigation, the variation average should not exceed 20 %. it could be observed, emitter discharge decreasing linearly with the operating pressure from 6.15 l/hr to 6.10 l/hr and 2.36 kpa to 2.10 respectively, this could be due to elevation of the field which could be influence of gravitational force and also, the distance from the main to the different junction. The distance from the main to the different junction could also be another reason for the decrease in pressure and emitter discharge.

Table 2: Emitter Discharge, Coefficient of Variation and Emission Uniformity at Different Operating Pressures Levels

Junction	Emitter Discharge (l/h)	Operating Pressure (kPa)	Coefficient of Variation (%)	Emission Uniformity (%)	Emitter flow Variation (%)
J1	6.15	2.36	16	93	18.32
J2	6.14	2.36	15	89	21.20
J5	6.14	2.24	18	74	16.21
J6	6.13	2.20	17	75	20.00
J9	6.11	2.15	20	90	16.32
J10	6.10	2.10	20	80	20.00

From Figure 2, the relationship between the operating pressure and the emitter discharge, is expressed as:
$Q= 0.1625*H^{0.4132}$
Where Q is the emitter flow rate (l/hr) and H is the operating pressure (kPa). The coefficient of determination (r^2) obtained to be 0.8905, and was considered good, it showed that, the expression is appropriate in describing the relationship between the discharge and the operating pressure of the emitters. The emitter discharge values coefficient (ke) and the emitter discharge exponent (x) of drip system evaluated were found to be 0.1625 and 0.4132 respectively. The emitter is classified as PC (laminar flow regime; smooth and steady flow) because it had an emitter exponent value less than 0.5 based on Braud and Soon (1980).

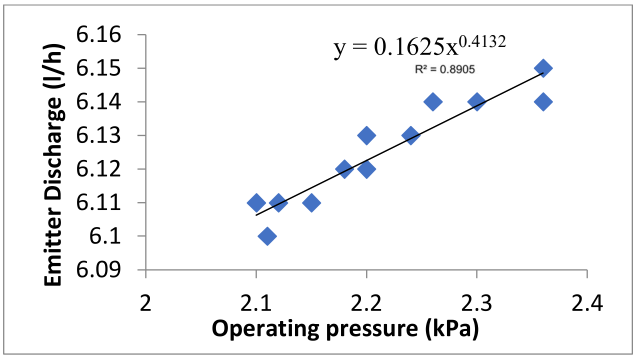

Figure 3: Means of Measured emitter Discharge Rates at different Pressure

3.2: Irrigation Water use and Water Applied

Table 3 showed the variation of irrigation water application volume during the dry season for the tested crop. It is observed that, the irrigation water applied decreased with increase in deficit irrigation from 3461.17 to 2021.76. However, for each treatment, higher water was applied when the plots were not covered with mulching material. The decreasing pattern of water applied as a result of deficit irrigation was expected, because deficit irrigation is to reduce the amount of water in the soil for the crop to use without or with minimum ill effect on the economic quality and quantity. In addition, mulching conserves moisture thereby reducing the rate of evaporation of water hence, less required amount by the crop.
Further, crop water use was noticed to be less for each water application level when the field was covered by the straw mulch thereby minimizing the rate of water use by the crop. This is also a good strategy, particularly in areas of water stress. The saved water could be diverted for other uses without harmful effects on the crop.

Table 3: Irrigation Water Applied and Water used (liters) for Artemisia Annua

S/N	Treatment	Water applied	Water use
1	1_{100}RM	3401.42	2854.05
2	1_{100}NM	3461.17	3326.283
3	1_{80}RM	2695.68	2135.23
4	1_{80}NM	2776.75	2585.17
5	1_{60}RM	2021.76	1551.88
6	1_{60}NM	2111.64	1931.93

3.3 Effect of Irrigation Levels and Mulch and on Artemisinin Content

The artemisinin content of artemisia annua is affected by water stress as presented in Table 4. Irrigating the crop fully results in higher artemisinin content of artemisia annua followed by 20% deficit. The least artemisinin content of artemisia annua was obtained at much water stress of 40%. Further, the artemisinin content of artemisia annua increases with mulching as presented in Table 5. Higher artemisinin content of artemisia annua was obtained when the crop field was mulched with rice straw under full irrigation. The least artemisinin content was when the crop was stressed due to higher deficit and high rate of evaporation for non-mulched plot. Furthermore, rain-fed cultivation of Artemisia hybrid variety initiated by 1994 had resulted in giving higher yields than the wild plants: up to 2.5 tons of dry leaf per ha with 1.0–1.5% artemisinin content depending on growing conditions. (Dewer, 2010). In this study, artemisinin content of 1.84% w/w. This also could be as a result of the growing conditions. This is also in line with findings of (Chen, S., et al. 2021). Reported that temperature, humidity and light intensity significantly influenced artemisinin accumulation. Understanding this relationship helps optimize cultivation conditions and identify suitable regions for A. annua.

Table 4: Effect of Irrigation Levels, Mulch Type and Nutrient Application on Artemisinin Content of Artemisia Annua

Treatment	Artemisinin content (% w/w)
Irrigation level (I) (%)	
100	0.49a
80	0.42b
60	0.33c
SEt	0.02
Mulch (M)	
Rice Straw	0.46a
No mulch	0.33b
SEt	0.01

Table 5: Mulch level and Nutrient Application Interaction on Artemisinin Content of Artemisia Annua

Mulch	Irrigation level (%)		
	100	80	60
No Mulch	5.99d	5.81e	4.85f
Rice Straw	7.83a	7.32b	6.20c
SEt	0.30		

4. Conclusion

The artemisinin content of artemisia annua is affected by water stress. Irrigating the crop fully results in higher artemisinin content of artemisia annua followed by 20 % deficit. The least artemisinin content was obtained at much water stress of 40 %. Further, the artemisinin content increases with mulching. Higher artemisinin content of artemisia annua was obtained when the crop field was mulched with rice straw. The study therefore, recommends a full irrigation could be practiced for effective production of artemisia crop under drip irrigation. However, up to 40 % irrigation water deficit could be applied in areas of high water scarcity. Since rice straw is cost effective, it is recommended for use as mulching material for the cultivation of artemisia crop under irrigation. The study recommends that a full irrigation should be practiced for effective production of artemisia crop under irrigation. However, up to 40 % irrigation water deficit could be applied in areas of high water scarcity.

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