European Journal of Science, Innovation and Technology
ISSN: 2786-4936
www.ejsit-journal.com
Volume 3 | Number 5 | 2023

Design and Fabrication of Drip Irrigation System Using *Spinacia oleraceae*

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ABSTRACT

The study evaluated the application of drip irrigation on a spinach (*Spinacia oleraceae*) garden by localizing a drip irrigation system. The system was designed to deliver water required by the crop intermittently. The system was constructed exclusively from readily available materials which include one-inch polyvinyl chloride (PVC) Pipes, 1/2-inch flexible hose, drip set, sockets, end cap, tee reducers. The emitter was punched using a drip set hole punch on a 5 m lateral flexible PVC pipe. The result of system's test indicated an efficient outcome with covered area of all drippers as 0.000071 m^2 at a discharge rate of the emitters of 0.5. The overall emitter flow variation was 50%. Lateral discharge (Q_L) was 0.008 l/s, head loss (ΔH) was 458.26 m, statistical uniformity coefficient (SUC) was 50% while application efficiency was 67%. From the evaluations the field test shows that the water application was adequate by irrigating the area situated on the lateral at 0.0000071 m^2. The drip system designed irrigated 0.000071 m^2 of the total 0.00119 ha with 10 spinach crops stand for 10 drippers. Emitter blockage which is a challenge with drip system irrigation was controlled by proper maintenance of the main and lateral lines. The use of this system will enhance the seasonless production of spinach and in turn make agro-business enterprising; ease labour task and the drudgery in farming activities especially in rural communities.

Keywords: Design, Fabrication, Drip Irrigation, Construction, Installation

INTRODUCTION

Irrigation is the artificial application of water to the soil to enhance the production of crops and to facilitate agricultural practices (like seed bed preparation and harvesting) by changing the condition of the soil (Zakari et al., 2013). Overtime, there have been a need for a growing economy to push for self-sustainability and this has necessitated the introduction of irrigation as a method to boost agro-business. Irrigation is a mechanized tool that comes into play as one of the means of improving total volume or reliability of agricultural production by managing water for the crop (Pei et al., 2023). Many factors serve to limit crop growth; soil type, nutrient content and climate but water has been found to be the principal yield-limiting factor (Harby & Hans, 2013). Irrigation generally is the application of controlled amount of water to plants at needed interval at a given time. In many areas of the world, the amount of rainfall is not adequate to meet the moisture requirements of crops. Hence, successful crop production often requires adequate provision for irrigation (Idama & Ekruyota, 2021). Irrigation plays a key role in the performance of agriculture, which increases income growth. A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and ensure the economic vitality of the region.

Drip irrigation sometimes called trickle irrigation (Zakari et al., 2013) works by dripping water slowly and directly into the soil from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plants so that only part

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of the soil in which the roots grow is wetted, unlike surface and sprinkler irrigation which involves wetting the entire soil profile. Drip irrigation limits the water supplied for consumptive use of the plant by maintaining minimum soil moisture which is equal to the field capacity. The system permits the fine control on the application of moisture and nutrients at stated frequencies (Idama & Ekruyota 2021).

The unique characteristic of drip irrigation is the partial wetting of the soil surface. Droplets of water flow out from the dripper directly to the soil surface and infiltrate into the soil. Through capillary force, the water flow in all directions, but downward flow is increased by the force of gravity. The wetted soil volume is increased while water content is gradually reduced towards the margins. Within the wetted soil volume there is a good balance between water and air and therefore an excellent aeration, a high level of water availability to plant. An optimal and efficient water and nutrient uptake by plant roots (Amresh, 2017).

Agriculture is an important area that has greatly impacted on the livelihood of the country's population today. The problem of deterioration in the production of food grains, limited water resource, declining soil health has led to the introduction of a drip irrigation system (Galande, 2012). Also, the increasing water demands from industrial and urban settlements have further reduced the quantity and quality of agricultural water use (Belay et al., 2022). Drip irrigation remains an aspect of agricultural process that most farmers are ignorant about especially in our region (the Niger Delta). The need to irrigate farms/gardens by a method that is accessible, available, cost efficient and requires low labour and energy inputs has led to the design and fabrication of a drip irrigation system (Hamidatu et al., 2021). The use of this system will surely help in alleviating poverty and easing labour task and drudgery in farming activities especially in rural communities.

Hence the aim of this study is to design and fabricate an economical drip irrigation system that will have efficient water delivered to plants root zone through unclogged emitters on the lateral line and in the right amounts with respect to time. This study is centered on designing a "stand alone" surface drip irrigation system that will transport water at lower rates, through flexible supply tubing, distribution tubing and applying it with emitters on individual and narrow planting areas like trees, shrubs, vines, vegetables, flower beds and plant containers/pots, etc. (Mohsin et al., 2021).

BRIEF OVERVIEW OF SPINACH

Spinach also known as "Round leaf Spinage" is a staple of the early American vegetable garden, it is a relatively quick-growing vegetable and easy to maintain. Spinach is in the classification system Family "*Amaranthaceae*" and *Spinacia oleraceae*. It is within the family of leafy green vegetables, referred to as "greens" or "potherbs". Spinach ranges in colour from light to dark green and comes in two general types; the crinkle leaf variety and the smooth leaf variety, although there are varieties that contain characters of both, known as "semi-Savoy Spinach" (Mohsin et al., 2021).

Cultivation: Spinach is always raised from seeds and grown better when planted in drills rather than broadcast (Hema et al., 2017). This green does best in rich soil and partial shade. Full sun will cause the plant to run to seed prematurely, so the amount of sunlight available to the plant is very important, and as a result, spinach is always grown as a spring or fall crop; a vegetable with shallow root depth (6-12″) and low water need. This is unique, given that generally speaking, very few vegetables will grow satisfactorily in partial shade (Hamidatu et al., 2021).

Table 1: Water losses under various irrigation approach

Approach of Irrigation	Normal climate (%)	Hot climate (%)
Surface	30 to 45	35 to 40
Gate pipe	15 to 20	20 to 25
Sprinkler	6 to 9	10 to 20
Drip	1 to 2	2 to 3

Source: Saksena (1993)

MATERIALS AND METHODS

The Study Area

This study was conducted in Rivers State University Nkpolu Oroworukwo Port Harcourt on a selected area of 0.00119 ha which lies South of the Niger Delta within Latitudes 6.98^0 E and Longitudes 4.79^{0}N. Port Harcourt is an industrialized cosmopolitan city located in the heart of the Niger Delta; characterized by a humid tropical climate with 70% of the annual rainfall spread between April August, while 22% is between September to November; the mean annual rainfall pattern for Port Harcourt is 2,500 mm. This follows both relatively dry and humidity of 85% season with a mean temperature (daily minimum and maximum) of about 23^{o}C and 31.5^{o}C respectively. The soil type is ultisol (USDA classification) with a sandy loam texture (Ayotamuno et al., 2000; Ubong et al., 2015).

Design Data

The data below were employed in the design and fabrication of the drip irrigation system.

Table 2: Materials used for the design

S/No	Parameters	Value/Unit
i	Area of land	17mx0.7m = (0.00119ha)
ii	Size of tank	3000l
iii	Internal diameter of mainline (PVC)	0.0254m
iv	Internal diameter of lateral line (LDPE)	0.0127m
v	Total length of main line	11.89m
vi	Total length of lateral line	4.6m
vii	Soil type	Sandy loam
viii	Total number of drippers (emitters)	10
ix	Diameter of drippers	0.003m
x	Time per drip	One second
xi	Number of drip /second	One drip
xii	Drippers spacing	0.03m
xiii	Height of surface tank	1m above ground
xiv	Number of spinaches	10

Layout of the Drip Irrigation System

The designed was a surface drip irrigation system with a 3000 litres water tank, mounted to a stand at a height of 1 m above the ground based on the recommendation of FAO (2000). The drip system consists of PVC main line, lateral and dripper. The main line receives water directly from the water tank, also the laterals are connected with main line and all drippers are in line with the laterals. The drip lateral line tubing has an emitter spacing of 0.03 m so that each emitter supplies water to a single plant. Water was filled to a small-scale drip irrigation tank with water pump and 0.0381 m^3 (3.81 litres) amount of water was released to the spinach field as water requirement.

Analysis of Design and Results

The data given above were used to determine the size of materials needed for the fabrication of the drip irrigation system and the analysis of the data can be derived as thus:

Area covered by a single dripper per plant

$$A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 \quad (1)$$

$$A = \pi \left(\frac{0.003}{2}\right)^2$$

$$\mathrm{A} = 0.0000071\mathrm{m}^2$$

Area covered by all drippers

$$= 0.0000071m^2 \times 10\ drippers = 0.000071m^2$$

Discharge rate of the drippers

$$Q_d = {}^{1drop}/_{Sec} \quad (2)$$

But 20,000 drops = 1litre

$$Q_d = \frac{1}{20000} = 0.00005\frac{l}{s}$$

Emitter flow variation (Q_V)

$$Q_V = \frac{(Q_{max} - Q_{min})}{Q_{max}} \times 100 \quad (3)$$

Let maximum flow rate = 2 drops = 0.0001 l/s
Let minimum flow rate = 1 drop = 0.00005 l/s

$$Q_V = \left(\frac{0.0001 - 0.00005}{0.0001}\right)100$$

$$Q_V = 0.5 \times 100 = 50\%$$

Lateral discharge (Q_L)

$$Q_L = \frac{lateral\ lenght \times Emitter\ discharge}{Emitter\ spacing} \quad (4)$$

$$Q_L = \frac{4.6 \times 0.00005}{0.03}$$

$$Q_L = 0.008\frac{l}{s}$$

Basic hydraulics of drip irrigation system

Evaluation of head loss in a drip irrigation line:

$$\Delta\mathrm{H} = 15.27\left(\frac{\mathrm{Q}^{1.852}}{\mathrm{D}^{4.871}}\right)\mathrm{L} \quad (5)$$

Where, ΔH =Energy drop by friction (m); Q = Total Discharge in the pipe (lit/sec); D = Inside diameter of pipe (cm); L = Length of the pipe section (m) (Musa & Egharevba, 2009)

$$\Delta H = 5.35\left(\frac{Q^{1.852}}{D^{4.871}}\right)L$$

$$\Delta H = 5.35\left(\frac{0.0005^{1.852}}{0.0127^{4.871}}\right)4.6$$

$$\Delta H = 5.35\left(\frac{1.083 \times 10^{-8}}{0.0127 \times 10^{-10}}\right)4.6$$

$$\Delta H = 5.35(18.66)4.6 = 458.26m$$

Statistical uniformity coefficient (SUC)

$$SUC = 100 \times (1 - Q_V) \text{ (6)}$$
$$SU = 100 \times (1 - 0.5)$$
$$SU = 100 \times 0.5 = 50\%$$

Application efficiency

$$Ea = \left(\frac{Qmin}{Qavg}\right) 100 \text{ (7) (Jack \& David, 1974)}$$

Where, Ea =application efficiency (%); $Qmin$ = minimum emitter flow rate (l/h); $Qavg$ = average emitter flow rate (l/h); Let average flow rate be 1.5 drops per second

$$\therefore \frac{1.5}{20000} = 0.000075 \frac{l}{s}$$
$$E_a = \left(\frac{0.00005}{0.000075}\right) 100$$
$$E_a = 66.7 \times 100 = 67\%$$

DISCUSSION

The evaluation test of the drip irrigation was highlighted using parameters in Table 2 employed to generate the results obtained from the established equations. Area covered by all drippers as 0.000071 m^2 at a discharge rate of the emitters of 0.5. The overall emitter flow variation was 50%. Lateral discharge (Q_L) was 0.008 l/s, head loss (ΔH) was 458.26 m, SUC was 50% while application efficiency was 67%. From the evaluations the field test shows that the water application was adequate by irrigating the area situated on the lateral at 0.0000071 m^2. The drip system designed irrigated 0.000071 m^2 of the 0.00119 ha with 10 spinach crops stand for the 10 drippers. The field efficiency of the irrigated area was generally low. This may be attributed to high moisture content of the area during the season as there were cases of oversaturation of the plots.

CONCLUSION

This study sought to employ some elementary parameters such as emitter flow variation, lateral discharge, head loss, statistical uniformity coefficient, application efficiency and the evaluations from Table 2 to make possible drip irrigation of a spinach (*Spinacia oleraceae*) garden. Field efficiency of the drip irrigation was evaluated to determine the efficiency of the delivery of irrigated water required for the vegetable crop intermittently. The research has addressed the challenges faced by farmers both at higher and local level particularly the problem of high cost in importing the drip irrigation systems components. Emitter blockage which is the common problem with drip system of irrigation was controlled by adequate maintenance of the main and lateral lines. The implementation of this system will surely help in alleviating poverty and easing labour task and drudgery in farming activities especially in rural communities and above all curb the challenge of seasonal crop production. Therefore, it can be inferred that gravity drip irrigation system has been designed, constructed and installed using available local materials.

ACKNOWLEDGEMENTS

The authors thank the Department of Agricultural and Environmental Engineering laboratory, Faculty of Engineering, Rivers State University, Port-Harcourt, Rivers State and my Supervisor for their support of this work.

COMPETING INTERESTS

Authors have declared that there is no conflicting interest associated in the course of research.

AUTHORS' CONTRIBUTIONS

Ntesat, U.B.: Analysed and interpreted the data; wrote the paper. Nweke, B.: Conceived and designed the experiment. Ozero, B.O.: Contributed the needed local materials, finance and demonstrated the experiments in the field.

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