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Calibration and Evaluation of Improvised Drip Irrigation Equipment

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Abstract

Low-income farmers in developing countries hardly afford irrigation equipment and systems, they resort to buying poly vinyle chloride (PVC) pipes as improvised equipment and install in farms mostly for vegetable irrigation. This study focused on the calibration and performance evaluation of improvised drip irrigation systems, using poly vinyl chloride (PVC), un plasticized polyvinyl chloride (UPVC) and infusion set materials. Soil parameters from the experimental plot were found to be silty clay loam, Soil structure – blocky; bulk density-1.32g/cm^3 and mean moisture content 6.57%. The medi-emitter calibration ranged from 0-35mm at 5mm intervals. There was no flow at 0, 5, and 10mm graduation points of discharge. Minimum and maximum flow occurred at 20 and 35mm graduation, while at 15mm, water flow occurred in droplets. Flow rates from 15, 20, 25, 30 and 35mm were found to be, 1.47x10^{-6}m^3/s, 2.53x10^{-8}m^3/s, 2.53x10^{-6}m^3/s, 2.81x10^{-6}m^3/s and 3.85x10^{-6}m^3/s respectively. The efficiency of the improvised irrigation system was evaluated by raising cucumber vegetable crop on the experimental plot for a period of seventy days, with total water volume of 2063.502liters. The performance of the medi-emitter and drip system were evaluated based on; the length of tube, thickness of tube, thickness of slip connector, drip chamber thickness, spike thickness, length of slide clamp, diameters of PVC pipes as well as hydraulic Parameters and crop yield. The components dimensions before calibration and after ultilization, showed no significant effect on the efficiency and performance of the improvised drip system. The experimental crop yielded 95% performance of crop. It is recommended that, due to the continuous exposure of improvised materials (PVC, UPVC and infusion sets) in the field to environmental conditions, the equipment can be efficiently used for two to three years for irrigation.

***Keywords:* Improvised, Calibration, Drip irrigation, Medi-emitter, Experimental,**

1. INTRODUCTION

Irrigation is a mechanization tool that comes into play as one of the means of improving total volume or reliability of agricultural development by managing water for crop production [1]. World population currently growing at a rate of about 1.5% [2], is intensifying pressure on our natural resources especially water. The world trend in irrigation is such that the total irrigated area was 311 million hectares (ha)[3].

Globally agriculture makes use of available water accounting for about 70% of all uses. In places where agriculture is the main activity as in India and Africa, 90% of water is used for agriculture entailing use of irrigation. It has been found that because of temporal and spatial variations potential, usable water is small in supply [4]. Predictions showed that by the year 2025, about 35% of the world population may face water shortages [2]. Most recommended strategies to avert an impending water crisis emphasis increased efficiency from the irrigation sub-sector, and one way of achieving this, is for farmers to switch over from the traditional flooding method of irrigation to the highly efficient drip system. Regrettably, the cost of conventional drip systems deters their adoption by peasant farmers who command the agricultural sector of developing countries. Consequently, only about 1% of the total irrigated land world-wide is currently under drip irrigation [5] .

In Nigeria, the agricultural sector accounts for nearly 15% of the GDP, yet agricultural productivity is on the decline while population increases. About 90% of the country's food is produced by small-scale farmers cultivating tiny plots of land who depend on rainfall than irrigation systems [6]. The Government through Millennium Development Goals (MDGs) joined other UN countries to adopt technological proposition for irrigation as a means to improve food supply with the available water and a way to bring more land under cultivation[7].

Nigerian land mass is 92.4 million ha [8], out of which 82million ha is arable but only 34 million ha are utilized [9,10], and out of this between 4.0 to 4.5 million ha (approximately 4.5 to 5.0% of the land) are suitable for irrigated agriculture but only 1.1 million ha can be supported fully by the water available, the remaining 3.4 million ha are flood plains. Olden surface irrigation methods are still in use which results into water wastage resulting in low yield.

The concept of affordable Micro-irrigation systems has been identified as a commensurate drip technology for low-income farmers. These systems equally possess potentials for efficient agricultural water use and researched with much success [11-14].

The pertinent predicament for the low-income farmers or subsistence farmers is that the irrigation systems equipments are not affordable, because they are expensive. In Nigeria, most farmers who engage in irrigation farming(mostly vegetable crops) using sprinkler or drip irrigation systems resort to buying poly vinyle chloride (PVC) pipes as improvised equipments because standard irrigation pipes are not affordable.

The objective of this study was to set up a micro-irrigation system using PVC pipes with disposable infusion set (Medi-emitter) as drip irrigation; to calibrate and evaluate the performance of the system and monitor the hydraulic deliveries within the study period. And to verify, if the environmental conditions affect the PVC pipes expansivity and medi-emitter dripping performance and evaluate the systems performance on the water requirement and yield on Cucumber vegetable crop.

2.0 MATERIALS AND METHODS

2.1 Study Area

Makurdi is the capital city of Benue state Nigeria. It lies between latitudes 7^0 45'and 7^0 52'N of the equator and longitude 8^0 35' and 8^0 41'E of Greenwich meridian, in the Northern Guinea Savannah agro-ecological zone, where river Benue passes through, referred to as Benue valley. The valley is highly agriculturally productive as home to highest producers of variety of crops such as cassava, soybean, guinea corn, yams, sesame, rice and groundnuts for the country [15]. No form of irrigation is ongoing in the area despite the available water resources (streams and river Benue tributaries).

The climate in Makurdi is referred to as a local steppe climate within the humid zone with little seasonal temperature variation throughout the year. Two major seasons do exist, the rainy season between April and October and the dry season between November and March [16,17]. The temperature averages 27.58°C while average annual rainfall is 690 mm in August and September, with an average of 260 mm. The least amount of rainfall occurs in March, with an average of 10 mm and the temperatures are highest in March, at about 35.85°C with the lowest occurring in January, with 26.6 °C[15;18].

2.2 Experimental Site and Materials Used

The study was carried out in an experimental plot in the Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Benue State. Water was sourced from a 1000 litres tank to the farm through an installed water network systems.

The materials used for the study were classified into two parts; the materials for land preparation, measurement, soil test, (Table 1) and those used for Irrigation and result recordings (Table 2).

Table 1: Materials Used for Land Preparation Measurement and Soil Test

S/N	Materials	Uses
1	Vernier Caliper	Measures internal and external diameter of pipes line
2	Measuring Cylinder	Measures the volume of liquid (water).
3	Funnel	Guide/direct water into the graduated cylinder/Conical flask.
4	Soldering Iron	For perforations on the laterals PVC pipes
5	Soil Moisture Content Test Instruments	
	Weigh Scale	Obtain mass of soil samples
	Cans	Collect soil sample.
	Oven	Dry soil samples.
6	Bulk Density Test Instrument; Set of sieves, sieve shaker, weigh balance, brush, mortal/piston	Determine the soil's bulk density.

7	Evaporative pan	Carrying-out Evapo-transpiration test
8	Recordable Rain-gauge	Records rainfall amount in(mm)
9	Hack- saw	Cut PVC pipes into design sizes
10	Gum (PVC Solvent)	Joining PVC pipes
11	Improved Variety of Cucumber seeds	Used for Performance Analysis (study)

Table 2: Materials Used for Water Conveyance

Materials	Description	Uses
Water Tank	1000 Litres capacity	Store water used for Irrigation.
Main Line	2.54cm (1 inch) thickness of PVC pipes	Supplies water to the sub –mains from the tank (water source)
Sub-Main Lines	1.90cm (3/4 inch) thickness of PVC pipes	Connected to the Main and delivers water to the laterals
Laterals	1.27cm (1/2 inch) thickness of PVC pipes of 900cm in length.	Supplies water to the medi-emitter (DIS)
Couplers	Tees, sockets, elbows, stopper and end-caps; made of UPVC	Direct where pipes travel and how the flow of the water in the pipes travel.
Disposable Infusion Sets, (DIS)(medi-emitter)	Improvised material, made of Plastics	Emits water in droplets during Irrigation

2.2.1 Determination of site soil and hydro characteristics

Soil characteristics of the study site are directly influenced by relief, decomposition of parent material, climate, timing and organism. Loamy soils can encompass a variety of infiltration speeds [19-20]. Soil constituents and characteristics of the site soil were done to determined; Particle size distribution, the field capacity (FC) of the soil, Permanent wilting point (PWP), density, Available moisture content (percentage %), Moisture Content (%).

Hydro characteristics that affect irrigation systems were also determined in the areas of; Evapo-transpiration (consumptive use), Net Irrigation Requirement (NIR), Gross Irrigation Requirement (GIR), Irrigation interval/frequency, Irrigation interval (It), Irrigation period (Ip), Drip set capacity, Pressure variation of the system, Head losses computations and Linear calibration of the medi-emitter and amount of water applied.

2.2.2 Experimental set up

In irrigation design consideration [21], the mains, sub-mains and laterals pipes specifically design for drip irrigation withstands saline irrigation water and it is not easily affected by chemical fertilizers [22], but all the pipes use in the experiment and the improvised medi-emitters are made of PVC (Poly vinyle chloride) materials, laid and couple according to standards[23-26]. The experimental plot covered an area of $16m^2$, with a systematic water conveyance layout for (Fig.1). The improvised medi-emitters[27] (Fig.2) were fixed into the pipes with specifications as shown in Table (2), with the spike (water outlet) directly on each plant head (Plate 1).

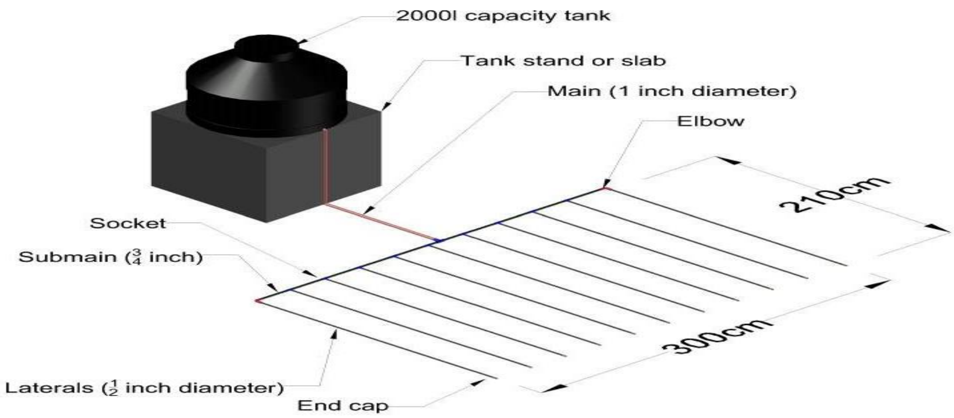

Figure 1: Side view of design drip system set

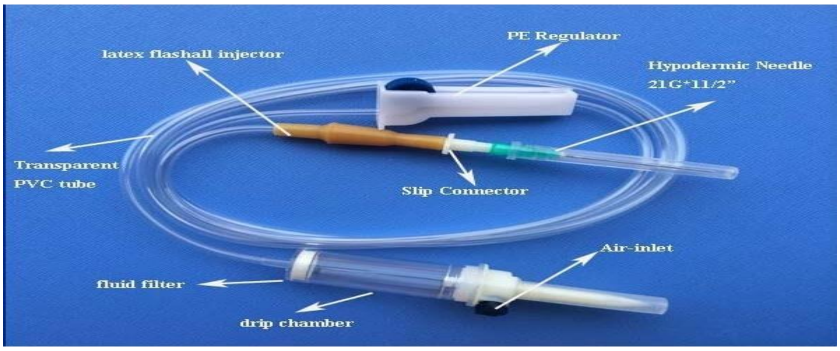

Figure 2: Disposable infusion set, DIS (Medi-emitter). Source: Arshine (2021)

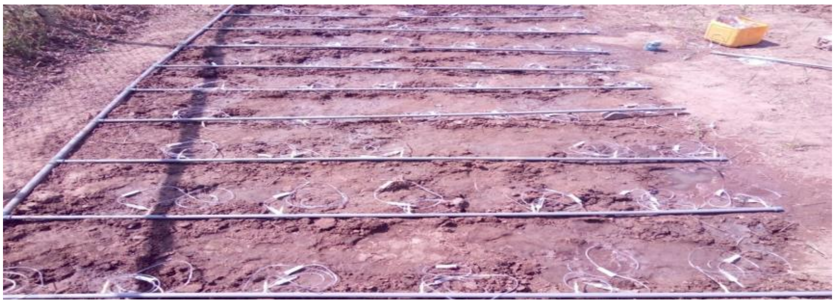

Plate 1: Experimental set-up of PVC pipes and medi-emitters

The Set up Farm Gravity Irrigation System was checked by determining the flow rate discharge from the emitters, measured and calculated using emission uniformity while the results were compared with micro irrigation uniformity classification standard based on American Society of Agricultural Engineers [28-30], and the installation was demonstrated on Cucumber vegetable crop cultivation.The following realtionships are used to determine and analyzed the experimental set up.

i. Test for emission efficiency of the set up was determined from the formula:

$$\text{Emission Uniformity (\%)} = \frac{Avg.discharge\ rate\ of\ the\ 25\%\ sampled\ emitter\ with\ the\ least\ discharge}{Avg.dicharge\ rate\ of\ all\ sampled\ emmiters} \text{ x } 100 \quad 1$$

ii. Crop consumptive use:

The consumptive use of water at growth stage of crop and reference transpiration (ETo) [12], and determine using the relation:

ETo = K pan × E pan 2

Where: ETo : reference crop evapo-transpiration; K pan: pan coefficient;

iii. Net Irrigation Requirement (NIR):

The net depth of irrigation was determined from Readily Available Water (RAW).

RAW = (MAD) AW 3

Where: RAW = Readily available water (mm), MAD = Maximum allowable deficiency, and AW = Available water.

$$RAW = \frac{(MAD)X(\,Drz)x\,(FC-PWP)X\,(P)}{100} \quad 4$$

Where Drz = effecting rooting depth of cucumber, FC = Average field capacity (%)

Pwp = Permanent wilting point (%)

iv. Gross Irrigation Requirement (GIR):

The gross irrigation requirement is the total amount of water applied throughout irrigation.

$$GIR = \frac{RAW}{FE} \quad 5$$

Where;

GIR =Gross irrigation requirement; RAW (=NIR) = Net irrigation requirement and

FE =Field efficiency of the system.

v. Irrigation interval/frequency:

This is the number of days between irrigations during periods without rainfall.

The design irrigation frequency = Net depth of irrigation/Transpiration rate of Cucumber vegetable crop.

$$T = Et \text{ x } \frac{Ps}{85} \quad 6$$

Where, T = average transpiration rate of the water leaf (mm/day), Ps = area shaded by the crop as a percentage of the total area (%), ET = conventionally accepted consumptive use rate of the crop (mm/day).

vi. Irrigation period (Ip):

Irrigation period is the number of days that can be allowed for applying irrigation to a given designed area during the peak consumptive use period of the crop irrigated[31].

$$Ip = \frac{(Mb-MI) X\ FC\ X\ bd)}{(100\ X\ Cu)} \quad 7$$

Where: Ip = irrigation period (days), Mb = moisture content at the start of irrigation (%), and Ml = moisture content in the root zone at the lower limit of moisture depletion (%) FC and bd is bulk density. Cu = consumptive use (mm/day).

Area of Experimental Field = Length x Width 8

For Experimental area;

volume of water required (q) = Effective wetted area of experimental field x GIR. 9

Actual irrigation periods maximum discharge per lateral line:

$$Q = volume/time = \frac{q}{t} \quad 10$$

Where: Q = quantity of water discharge; q = discharge rate; t = time taken to discharge the water

vii. Pressure Variation of the System:

The total energy drop by friction for lateral can be expressed as [32]:

$$H = 5.35\ x\ \frac{Q^{1.852}}{D^{4.871}}\ x\ L \quad 11$$

Where: H = total energy drop by friction at the end of lateral (m), Q = total discharge at the inlet of lateral.

The discharge equation for the emitter is given as [31]:

$$Q = 1.41P^{0.5} \quad 12$$

Where Q = Emitter discharge (L/hr) = 2.80 l/hr, P = Operating Pressure (m)

viii. Main-line head loss

The head loss due to friction in poly-vinyl pipes 28.93mm internal diameter of 5000mm length is computed from the following procedures [33].

$$Q= AV \quad 13$$

Where; Q= discharge m^3/sec, A= Cross sectional area (m^2),V= Velocity of flow (m/s)

The type of flow through the pipe is determined from Reynolds number, which is given by; $Re= \frac{Vd}{v}$ 14

Where; V= Velocity of flow, d= diameter of pipe, v = kinematic viscosity of water

$$Head\ loss = h_f = \frac{4 \times f \times l \times v^2}{2gd} \quad 15$$

Where; f= frictional factor, l = length of pipe, v = pipe velocity, g = acceleration due to gravity
d = diameter of the pipe.

ix. Minor loss computation

There is a loss of head in pipe-fitting, bends and at pipe entry. The head loss in pipe fittings in form of head loss due to sudden contraction is often expressed by the formula [33]:

$$H_f = \frac{kv^2}{2g} \quad 16$$

K = fitting loss co-efficient (Sharp pipe entry = 0.5); V = velocity at V^2

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3. RESULTS AND DISCUSSIONS

3.1 Results

Soil properties of the experimental site were determined through laboratory standard methods and procedures. The soil properties of grain size/sieve analysis and soil moisture content determined are recorded in Tables 3; while bulk density, soil texture, soil colour and soil structure are recorded in Table 4. The total amount of water taken up by crop for tissue building, transpiration or, unavoidable evaporation of soil moisture, snow (crop consumptive use of water by the cucumber crop) which is a reference of crop evapo-transpiration, was carried out and results were recorded in Table 5.

The average discharge rates of the sampled medi-emitters according to the valves and distances from the water source are presented in Table 6. The wetting depth ranged from 0.1m to 1.5m and the average wetting circumference

Table 3: Soil Moisture Content of the Experimental Site

Replicates	M_1(g)	M_2(g)	M_3(g)	$M_2 – M_3$ (g)	$M_3 – M_1$(g)	(M_2-M_3)/(M_3-x M_1) 100/1(%)
A1	62.6	292.4	277.7	14.7	215.1	6.83
A2	16.5	124.8	117.8	7	101.3	6.91
A3	63.3	284.0	268.8	15.2	205.5	7.397
B1	63.6	278.6	267.6	11	204	5.39
B2	62.1	287.5	275.5	12	213.4	5.62
B3	62.5	257.0	246.5	10.5	184	5.71
C1	61.5	302.3	285.9	16.4	224.4	7.31
C2	61.5	263.3	250.2	13.1	188.7	6.94
C3	16.9	146.1	137.6	8.5	120.7	7.04
Average						**6.57**

Table 4: Results of Soil Physical Parametres

S/No	Parametres	Results
1	Soil Colour	Brown
2	Soil Structure	Blocky
3	Bulk Density	1.32g/cm^3
4	Moisture Content	6.57%
5	Soil Texture	Silty Clay Loam
6	Percentage of Soil Constituents	Sand 10% Silt 60% Clay 30%

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Table 5: Evapo-transpiration Rate at the Experimental Site

Days	Time (pm)	Reading (mm)	Evaporation Rate (mm)
1st	2:45	105.52	-
2nd	2:45	99.08	6.44
3rd	2:44	95.21	3.87
4th	2:46	89.02	6.19
5th	2:34	85.35	3.67
6th	2:57	79.15	6.20
7th	2:40	73.87	5.28
8th	2:35	68.56	5.31
Average ET			5.28

Table 6: Discharge Rates ($x10^{-8}$) (m^3/s) of Sampled Medi-Emitters at 20 mm Calibration

Control Valves	1	2	3	4	5	6	7	8	9	10
Head Lateral (closest to water source)	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
Middle Lateral	2.53	2.53	2.50	2.53	2.51	2.50	2.53	2.52	2.53	2.53
End Lateral (farthest from the water source)	2.50	2.49	2.52	2.52	2.51	2.53	2.49	2.53	2.49	2.51

was 60 cm. The 25 % discharge rates of all sampled medi emitters was used to test the efficiency of emission (emission uniformity) of the ten control valves. Table (7) presents the average emission uniformity for the ten control valves calculated using the relations:

25% of least sampled emitters = $\frac{10 \, x \, 25}{100}$ = 2.5

The infusion sets which served as emitters/drippers were calibrated linearly at different intervals of the flow regulator, the result is as shown in Table 8. The performance evaluation of the improvised material for the drip irrigation PVC pipes of different sizes internal and external diameters were taken before and after use with a venier caliper (Table 9), as well as average collated parameter of the on-field infusion set components lengths and diameters before and after use (Table 10).

Table 7: Average Emission Uniformity (%) of the Medi-emitters from the ten control Valves

	Control Valves									
	1	2	3	4	5	6	7	8	9	10

Emission Uniformity (%)	79.7	84	86	89	86	86.4	89.6	83	85.7	83.2

Table 8: Water Discharge of the Calibrated Medi-Emitter (Disposable Infusion Set)

Graduations	Starting Time (AM)	Stopping Time	Discharge Time	Volume Discharge(ml)	Evaluation
0	-*	-*	-*	0	No flow
5	-	-	-	0	No flow
10	-	-	-	0	No flow
15	7:17:05	5:24:05PM	11hrs, 7min	1000	Droplets
20	7:01:05	7:12:23AM	11min, 18secs	1000	Min. flow
25	6:34:09	6:40:45AM	6min, 36secs	1000	flow occur
30	6:27:20	6:33:16AM	5mins, 56secs	1000	flow occur
35	6:11:10	6:15:30AM	4mins, 20secs	1000	Max. Flow

-* No Flow

Table 9: External and Internal Diametres of PVC Pipes before and after Use

	Initial Reading(mm)		Final Reading(mm)		Difference in Diametres(mm)		
Pipes	**Internal Diameter (D_1)**	**External Diameter (D_2)**	**Internal Diameter (D_3)**	**External Diameter (D_4)**	**Internal (D_3-D_1)**	**External (D_4-D_2)**	**Remark**
Main-line	28.93	32.23	29. 08	32.48	0.15	0.25	Negligible
Sub-main	21.64	25.28	22.92	25.40	1.28	0.12	Negligible
Laterals	16.49	20.09	16.60	20.32	0.11	0.23	Negligible

Table 10: Field Performance of Medi-Emitter (Disposable Infusion Set)

Components	Initial Reading(r_1)	Final Reading(r_2)	Difference (r_2-r_1)	Remark
Length of Tube	150cm	150.67cm	0.67cm	Elongated
Thickness of Tube	3.90mm	3.82mm	- 0.08mm	Contracted
Slip Connector Thickness	4.12mm	4.12mm	0.00mm	No Effect
Drip Chamber	15.60mm	15.30mm	- 0.30mm	Contracted

Thickness				
Spike Thickness	4.50mm	4.50mm	0.00mm	No Effect
Length of Slide Clamp	5cm	5cm	0.00cm	No Effect

3.2 Discussion

3.2.1 Linear calibration of improvised emitter

The disposable infusion set (Medi-emitter) was calibrated at intervals of 5mm using the slide clamp of the infusion set and ranges from 0 –35 mm. Each graduation was calibrated such that

their flow-rates were determined on the known length of the graduated flow regulator of disposable infusion set to obtain the discharge or flow rate (volume/time; m^3/sec) at each points (0, 5,10, 15, 20, 25, 30, 35; mm). Open channels have zero atmospheric (atm) pressure[33], therefore, the flow-rates of the infusion sets were calculated through a laboratory experiment using the open channel method, graduated cylinder, beaker and a stop-watch at each set of graduations (calibration).

There was no flow for 0, 5 and 10mm graduation; 35mm graduation had the maximum flow of 1000 ml for 5 minutes, 56 seconds, while 15mm graduation flow occurred in droplets. However, since infiltration depends on soil types, the medi-emitters were set at 20mm graduation before installation and application on the field. The adopted graduation was to mitigate water losses that may occur through seepage.

3.2.2 Drip system evaluation

(a) PVC pipes

As part of the specific objectives, the environmental conditions such as sunlight (temperature), relative humidity, wind, etc, effects were verified to check whether or not PVC pipes and medi-emitter were subjected to expansivity or contraction during and after utilization (Irrigation).

Pipes internal and external diametre readings were taken before installation and after utilization using a digital venier caliper and the result is as presented in (Table 9) (Figs., 3 - 6).The differences in the internal and external diametres of main-line, sub-main line and laterals were found to be 0.15, 1.28 and 0.11mm for internal diameters and 0.25, 0.12, and 0.23 mm for external diametres respectively. The expansions in the PVC pipes were insignificant. This inconsequential increment in pipes diameters did not affect the efficient use and performance of the drip system during irrigation.

(b) Medi -Emitter

The Performance of the improvised infusion sets were evaluated on the basis of its ability to withstand deformation during utilization after subjection to environmental conditions on the field. The Medi-emiter succeeded in ensuring good pressure distribbution, uniform water application and provision of sufficient moisture (water) for the plants within the crop root zone (adequate wetting depth) and good infiltration, which results in better yield of the cucumber vegetable crops[34].

K pan varies between 0.35 (humid low) and 0.85 (High humidity), Average K pan = 0.70.

The average wetting circumference of 60cm is large enough for production of leafy and vegetables[16].

ET_O 5.28mm/day was multiplied by crop factor value (K_C) for each stage of the crop as shown in the Table 11 above. These results were used to draw out an irrigation schedule for the study.

MAD for leafy vegetables = 0.5 [31,35], with an effective rooting depth of cucumber (0.6 -1.5m) at 60 cm (Drz); P = area wetted as a percent of the total area = 40%. From equation (4),

RAW = $\frac{0.5 \ x \ 0.6 \ x \ (11.7-3.7) x \ 40}{100}$ = 9.6 mm

FE =Field efficiency of the system(equation 5), (For drip irrigation system, application efficiency = 80%)

= 9.6 mm x $\frac{80}{100}$ = 7.68 mm

Irrigation interval/frequency (eqn 6).

Taking Ps = 40 % and ET (Cucumber) = 5.3 mm/ day (from field ET Test),

T = 5.3x 40/85 = 2.49 ~ 2.5 (mm/day).

Therefore**,** Irrigation interval (It**)** = $\frac{9.6mm}{2.5mm}$ x /day = 3.84 ≃ 4 days, which is the maximum irrigation interval that would not stress the Cucumber crop excessively.

Irrigation period (Ip): From equation (7);

Mb = 0.75, Ml = 0.625, For FC = 11.7%, dz = 600 mm, Cu =5.30 mm/day, bd = 1.32g/cm^3

Ip = $\frac{(0.75-0.625) \ x \ 11.7 \ x \ 600 \ x \ 1.32)}{(100 \ x \ 5.30)}$ = 2.2 ≃ 2days

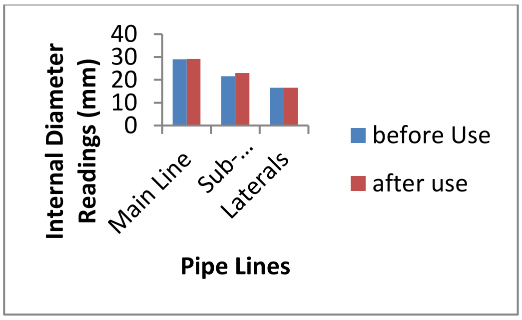

Figure 3: Comparing expansivity of internal diameter across pipes

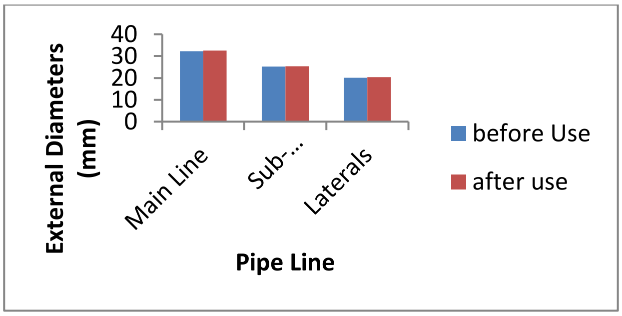

Figure 4: Comparing expansivity of external diameters of pipes

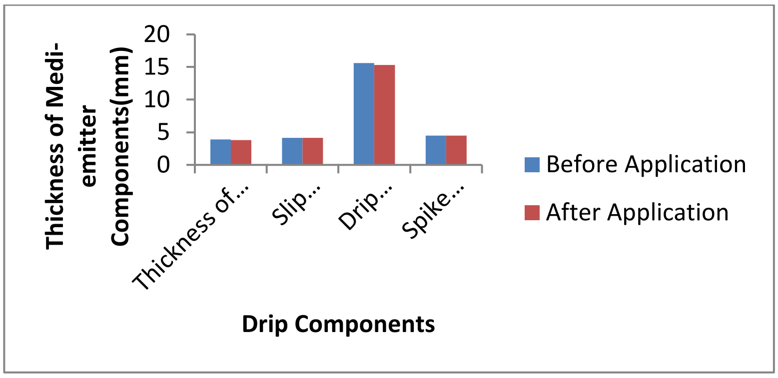

Figure 5: Medi-emitter components thickness performance evaluation

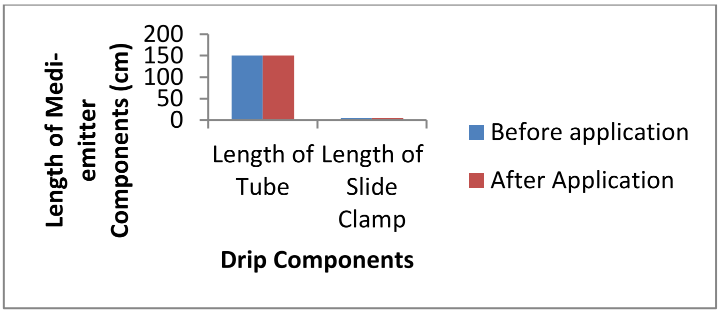

Figure 6: Medi-emitter components length performance evaluation

Area of Experimental Field (equation8) = Length = 4 m x 2.1 m = 8.2 m^2

Taking 40% of the entire experimental field area to be wetted by the medi-emitters, then the effective wetted area per head = wetted area (%) x Area of experimental field;

= 0.4 x 8.2 = 3.28m^2

For Experimental area, volume of water required (q) = Effective wetted area of experimental field x GIR (eqn 8):

= 3.28 x 0.012 = 0.03936 m^3

Volume of Water = Gross application depth x area = 39.36 $\simeq$ 40 liters

Various actual irrigation periods of 24hrs, 48hrs and 72hrs were tried after which 24hrs was chosen for the design because it gave maximum discharge per lateral line(equation 9).

Q = volume/time = $\frac{q}{t}$ = $\frac{0.03936(m^3)}{24(hrs)}$ = 0.00164m^3 = 1.64 l/hr

q = 0.03936(m^3)/48 (hrs) = 0.00082 m^3/hrs = 0.82 l/hr

q = 0.03936(m^3)/72 (hrs) = 0.000547 m^3/hrs = 0.55 l/hr

For each lateral the discharge q = 0.000456 l/sec.

The 60 medi-emitters were spaced 35 cm along the lateral line. For 60 medi-emitters, the discharge rate, q = 1.64 l/hr

Therefore, for 1 medi-emitter = $\frac{1.64}{60}$ = 0.027 l/h

Each lateral line contains 6 medi-emitters with a total flow rate of 0.164 l/hr

Main line discharge rate = 1.64 l/hr x 10 = 16.4 l/hr

Drip set capacity: In this design, the area of the garden irrigated: 8.4 m^2 (4m x 2.1m).

Therefore, amount of water required per irrigation = area of the garden x gross irrigation depth = 4m x 2.1 x 9.6 = 400cm x 210cm x 0.96cm = 80,640cm^3 = 0.8064 x10^2 litres.

Pressure Variation of the System (Eqn 10):

From design and results, D = 1.649 cm, L = 2.1m, Q = 0.000456 l/sec

Therefore, $H = 5.35 \times \frac{0.000456^{1.852}}{1.649^{4.871}} \times 2.1 = 6.38\times10^{-7}$ m

The discharge for the emitter was obtained from equation (12), where Q = Emitter discharge (L/hr) = 2.80 l/hr, P = Operating Pressure (m)

Therefore, $P^{0.5} = 2.80/1.41$, $P = (2.4561)^2 = 0.6032$m = He(head loss in the lateral

Main-line head loss: Using equation (12), where Q= 18.306 Lit/day = 5.085 x $10^{-6}m^3$/sec, D = 28.93mm = 0.02893m

$$V = \frac{4Q}{\pi d^2} = \frac{4\times5.085\times10^{-6}}{3.142\times0.02893\times0.02893} = 7.53 \times 10^{-3} \text{ m/s.}$$

The type of flow through the pipe is determined from Reynolds number relationship (eqn 14);

Where: v = kinematic viscosity of water = $1.14\times 10^{-6}m^2/s$, therefore;

$$Re = \frac{7.53\times10^{-3}\times0.02893}{1.14\times10^{-6}} = 191.09.$$

But the flow is said to be laminar, if only $Re < 2000$. Since 191.09 is less than 2000, the flow of water through 28.93 internal diameter Main-line pipe is Laminar.

Thus, the value of frictional factor (f) is obtained from the relation [32] as:

$$f = \frac{0.0791}{Re^{\frac{1}{4}}} = \frac{0.0791}{191^{\frac{1}{4}}} = 0.0213$$

Head loss (h_f) was calculated from equation (15), therefore;

$$h_f = \frac{4\times f\times l\times v^2}{2gd} = \frac{4\times0.0213\times5\times7.53\times10^{-3})^2}{2\times9.81\times0.02893} = 0.005645\text{m} = 5.65\text{mm.}$$

Sub-main Line Head Loss: Head loss due to friction in poly-vinyl pipes of 21.64mm internal diameter, 4000mm length was computed using equation (13), where; Q= 18.306 Lit/day = 5.085 x $10^{-6}m^3$/sec, d = 21.64mm = 0.02164m

$$V = \frac{4Q}{\pi d^2} = \frac{4\times5.085\times10^{-6}}{3.142\times0.02164\times0.02164} = 3.8 \times 10^{-3} \text{ m/s.}$$

The type of flow through the pipe also using $Re = \frac{Vd}{v}$ = $Re = \frac{13.8\times10^{-3}\times0.02164}{1.14\times10^{-6}} = 261.96$.

For the value of Reynolds number (Re) to be 261.96, which is less than 2000, then flow of water through 21.64 internal diameter sub-main-line pipe is also Laminar. Thus, the value of frictional factor (f) is also obtained from the relation:

$f = \frac{0.0791}{Re^{\frac{1}{4}}}$ = $0.01966m$

Head loss = $h_f = \frac{4\times f\times l\times v^2}{2gd} = \frac{4\times 0.01966\times 4\times(13.8\times 10^{-3})^2}{2\times 9.81\times 0.02164}$ = 0.000141m = 0.141mm.

Head loss of laterals: Head loss due to friction in poly-vinyl pipes 16.49mm internal diameter of 2100 mm length is computed using the equation 13procedures, where:

Q = 18.306 Lit/day = 5.085 x 10^{-6}m^3/sec, d = 16.49mm = 0.01649m, therefore;

V = $\frac{4Q}{\pi d^2} = \frac{4\times 5.085\times 10^{-6}}{3.142\times 0.01649\times 0.01649}$ = 23.81 x 10^{-3} m/s.

The type of flow through the pipe from: Re = $\frac{Vd}{v}$ = 344.41

Since 344.41 is less than 2000, the flow of water through 16.49 internal diameter lateral pipes is laminar. Thus, frictional factor (f):

$f = \frac{0.0791}{Re^{\frac{1}{4}}}$ = 0.01836

Head loss = $h_f = \frac{4\times f\times l\times v^2}{2gd} = \frac{4\times 0.01836\times 2.1\times(23.81\times 10^{-3})^2}{2\times 9.81\times 0.01649}$ = 0.00027m = 0.27mm.

Minor loss computation: The head loss in pipe fittings due to sudden bends and contractions were computed using the formula in equation (16) for the following areas:

(a) The head loss due to sharp entry into 21.64mm internal diameter pipe (sub-main) of length 4000mm from a main-line of 28.93mm internal diameter pipe of 5000mm length.

$h_f = \frac{k(v_2)^2}{2g} = \frac{0.5\times(13.8\times 10^{-3})^2}{2\times 9.81}$ = 4.8532 x 10^{-6}m

(b) The head loss due to sharp entry into 16.49mm internal diameter Lateral pipes of length 2100mm from a sub-main line of 21.64mm thick pipe (internal diameter) of 4000 mm length is calculated as:

$h_f = \frac{k(v_2)^2}{2g} = \frac{0.5\times(23.81\times 10^{-3})^2}{2\times 9.81}$ = 1.445 x 10^{-5}m

(c) Head loss due to T-junction 90^0 fitting between the sub-main line and the laterals is given below:

$h_f = \frac{k(v_2)^2}{2g}$ where k = 1.8 (tee-Junction)

$h_f = \frac{1.8\times(23.81\times 10^{-3})^2}{2\times 9.81}$ = 2.89 x 10^{-2}m.

(c) Flow rates of Medi-emitter

Flow rates of medi-emitters were determined using laboratory equipment, such as 1000 ml graduated transparent cylinder, cornical flask and a stop-watch. Based on volume quantification of water for the initial stage, 30.05ml of water was discharge at an average of 3 hours, 18 minutes. An average flow rate of 2.525 x 10^{-8} m^3/s was obtained by the medi-emitters, through-out irrigation period of cucumber vegetable crop.

(d) Discharge rates and emission uniformity

All the medi- emitters had approximately the same discharge rates. The little difference could be possibly due to pressure loss (head loss) as a result of distance from source of water. Variation recorded in the uniformity of emitter flow rate may have resulted from clogging, leakage or improper flushing, wearing of emitter components as they were adjusted several times in order to arrive at a desired flow rate in line with observation [36].This problem of clogging could be handled by periodic cleaning of filters, checking the pressure drop across the filter, checking the holes in the screens, and/or flushing the laterals at least two or three times a year [37].

An improperly managed filter station can waste water and threaten a drip system's fitness and accuracy[38], and this can result in low yield or total crop failure. The discharge rates from the different control valves having almost the same value (uniform) irrespective of time indicates the uniformity of the emitters.

Comparing the emission uniformity results obtained with the standard values [29], shows that the values from this drip Irrigation system falls under good performance standard. This also proved the effectiveness of the system in water management and optimization when water is a limiting factor for crop production.

4. CONCLUSION

The improvised drip irrigation system and medi-emitter calibration achieved a high degree of uniformity of water application throughout the laterals as analyzed. The high water application uniformity shows that the variability among emitters used in this irrigation system is low. The efficiency was evaluated by raising cucumber vegetable crop on an experimental plot. The agronomic performance of the crop yielded an average of four fruits per vine which is equivalent to 95% yield of the fruits harvested.

The technology is affordable, efficient, and durable. It will enable small-scale farmers to efficiently utilize marginal quantity of water, reduction of weed infestation and high cost of energy in lifting water from the wells or reservoirs for efficient irrigation of vegetable crops. It is recommended that:

- The system be introduced to and be adapted by the small scale farmers in Nigeria for water conservation and management.
- Frequent evaluations be carried to identify and correct emitter clogging problems.
- Infusion sets be set at graduation of 15 – 20 mm for efficient and effective use of water by crops and also to combat seepage and medi-emitter clogging problems that may occur from poor percolation or infiltration.
- Infusion set can be use for more than one cropping season, since its subjection to environmental conditions has little or no significant effects on its efficiency.
- Further studies should be done to curb the problems of weeding around the pipe lines.
- More research on how long the system can last in the field and to adopt the method for mechanized farming.

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