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Hydraulic Characteristics of Medi-Emitter Drip Irrigation System in Jos, Nigeria

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Abstract
The field experiments were carried out at the federal college of forestry farm, Jos- Nigeria, to evaluate the hydraulic characteristics of aMedi-emitter drip irrigation system, constructed with locally sourced materials. A set of Medi-emitter drip system covering an area of 46m² with lateral length of 2.4m and sub-main length of 2.7m was used in the experiment. The overall average Medi-emitter discharge was found to be 1.74L/hr under flow rates best suited for vegetable crops. The average variation of the emitter flow rate of the system was found to be 16.54%, while the distribution uniformity and emission uniformity for the whole system were 94.5 and 97.3% which signified an even distribution of water through the system. It was therefore recommended that the Medi- emitter drip irrigation system should be adopted by farmers within the Northern part of Nigeria for dry season farming so as to boost the economy of peasant farmers.

***Keywords**: Medi-emitter, distribution uniformity, emitter flow rate, emission uniformity*

INTRODUCTION

The rapid increase of the world population and the corresponding demand for extra water by sectors such as industries, municipals and ever growing population among others, are all competing with one another, aggravating the scarcity situation of water (Abedinpour, *et al.,* 2012). Climate change predictions also, inform that by the year 2025 about 35% of the world population may face water shortages due to increasing temperature and decrease in rainfall(Hinrichsen*et al.,* 1998). This worrisome forecast has attracted concerted efforts to speedily institute reliable water management strategies that may prevent water scarcity in the future;one way of achieving this is for farmers to switch over from the traditional flooding method of irrigation to the highly efficient drip system (Mofoke *et al.,* 2006).

The use of drip irrigation system in the middle belt-Nigeria for subsistence farmers is gradually gaining more ground, micro drip irrigation can make the difference between hand and mouth survival (Daniels, 2015). Farmers are less busy on the farm during the dry season, so drip irrigation farming is an alternative to employment and additional sources of income during the period (Annon, 2008). Irrigation farming has increased tremendously because of increased of income during the season (Babatunde, *et al.*, 2008).

Drip irrigate system provide farmers the most efficient way to grow crops in water scarce area, but historically it has been too expensive for small plot farmers. International Development Enterprise (IDE) developed its own design for small farmers by replacing conventional emitter with hole and micro tubes, shifting water distribution line extending to crops, and customizing system layout for small plot (International Development Enterprise, 2004).

Recently, the concept of affordable micro drip irrigation system has been identified as commensurate to drip technology for low income farmers. Regrettably, the cost of

conventional drip systems deters their adoption by peasant farmers who command the agricultural sector of developing countries (Mofoke *et al.,* 2006).One of the primary goals in the design of the drip irrigation system is to have thehydraulic balance which ensures uniform discharge (Shock, 2005). The emitter being an important element of the drip irrigation system, require accurate to achieve uniform discharge.
The medical infusion set is used mainly in hospitals and clinics for transfusion purposes but Mofoke*,et al.,* (2004) reported its satisfactory performance as emitter for a continuous-flow drip irrigation. This was adopted as emitter for the drip system reported herein, here after referred to as "Medi emitter", which operates under flow rates best suited for vegetable crops.The complexity of medical infusion set makes it difficult to maintain precision during its production, as a result of changes in temperature, mould damage and non-uniform mixing of raw materials. These are some of the factors affecting Medi-emitter homogeneity. It is nearly impossible and practically infeasible for any irrigation system to supply exactly the same amount of water to all plants within a field, which may be due to hydraulic variation results from pressure head difference (Mofoke,2006).
Field evaluation of the hydraulic characteristics of the system under local conditions of the study area has not been fully explored (Oiganji, 2016).The uniformity and general performance of micro-irrigation systems are affected by hydraulic design, emitter manufacturer's coefficient of variation, grouping of emitters, and emitter clogging amongst other factors. Therefore, the objective of this work is to evaluate the effectiveness of a medical infusion set as emitter for drip irrigation system.

MATERIALS AND METHODS

Study Area

The experiment was conducted in Federal College of Forestry Jos during 2016 cropping season at the experimental farm, Jos lies at latitude $9^0$56N, and 8^o53E and longitude 9.933^oN and 8.833^oE in the middle belt within the southern Guinea Savannah ecological zone of Nigeria with a mean annual rainfall of 1260mm (Olowolafe and Dung, 2002).

Soil Analysis

Soil sample at 0-15cm depth from study area was taken to Chemical and physical laboratories, Nigerian institute of mining and geo-sciences, Tudun Wada, Jos for analysis. The analysis showed that the soil is sandy loam, pH of 6.30, 0.035% of Nitrogen (N), 2.09% of organic matter (OM), exchangeable bases include 49 ppm of phosphorus (P) 0.1ppm of Na, 1.5ppm of Ca, 0.45ppm of mg, and 20ppm of K, exchangeable acidity 3.5 mMOL/10 of H^+, while the clay, silt and sand were 6.34, 8 and 85.9% respectively.

Experimental Field and Medi-emitter Drip Setup

The experimental field was 0.005ha as shown in Plate 1;the field was divided into plot sizes of 2.7m by 0.6m each. The plots consisted of four drip lines with 10cm Medi-emitter spacing, Medi-emitter was 20cm long, while each plot was 0.5m apart. A set of Medi-emitter drip system covering an area of $46m^2$ with lateral length of 2.4m and sub-main length of 2.7m was used in the study. The drip system consisted of four junctions along the sub-main length (J1 to J4). Each junction had a lateral connected to it, giving a total of four laterals, which was replicated three times to give a total of 12 laterals, each lateral had twenty four (24) evenly spaced Medi-emitters, giving a total of 288 Medi-emitters in the whole system.

Plate 1: Experimental field layout

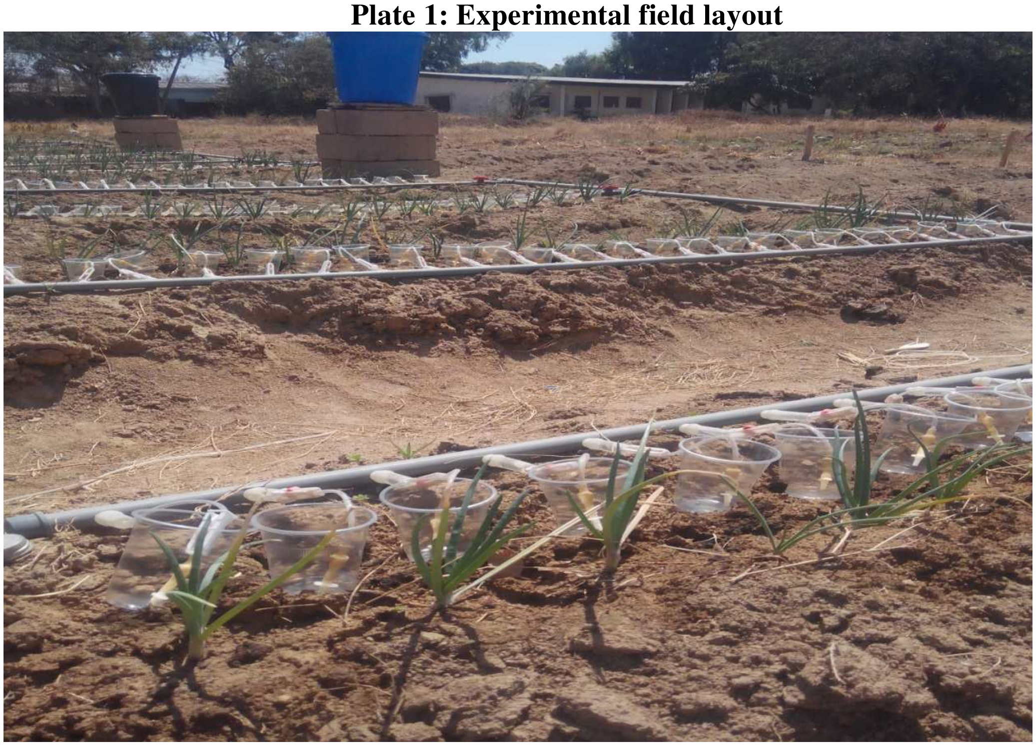

Plate 2: Catch can test for whole plots

An eighty liter (80 liter) capacity poly-vinyl chloride (PVC) container was used as tank on a stand of 0.7m with the use of nine inches blocks, supplied water by gravity to the system as shown in Plate 1. Water was sourced from a nearby borehole 10m away from the experimental field. At the lowest depth of the raised tank a 25mm diameter distributor low density polyethylene pipe was connectedto 5m long main line with a junction at every 0.6m.

Plate 3: Catch can test for one of the junctions

2.4 Medi-Emitter Discharge

The hydraulic performance of the Medi-emitter drip system used in this study were obtained using disposable cups for the catch can test as shown in Plate 2 and 3with respect to the whole junctions and specific junctions in the experimental plots.The emitter flow rate in liter per hour (L/hr) was measured from the individual Medi-emitter with respect to the corresponding distance of the Medi-emitter from the tank was measured. Empirically, the discharge for a specified head and single emitter was calculated as (Oiganji *et al.,* 2015;Oiganji,2016):

$$Q = \frac{V}{t} \qquad (1)$$

Where: Q = single emitter discharge (l/hr)
v = volume of water collected from emitter (l),
t = time of discharge (hr).

The data taken during the field test were discharge from each emitter and the corresponding distance of the emitter from the tank. This was later use to estimate emitter flow rate variation, emission uniformity and distribution uniformity. Each parameter was determined as follows:

Measures of Discharge Uniformity (DU)

Distribution uniformity is an application uniformity term commonly used in evaluating farm irrigation systems. The first requirement for an efficient operation of an irrigation system is the uniform water application, as measured by the discharge uniformity (DU). DU is computed by Eq (2) as given by Merriam *et al.* (1980):

$$DU = \frac{\overline{x_{tq}}}{\bar{x}} \times 100\% \qquad (2)$$

Where:

$\bar{x}$ = Average depth of water received

$\overline{x_{tq}}$ = Average low- quarter depth of water received

Emitter flow variation

Emitter flow variation measures the deviation between the maximum and minimum emitter flow rates (Camp *et al.*, 1997), and is given by Eq (3):

$$q_{av} = \frac{qmax - qmin}{qmax} \times 100\% \qquad (3)$$

where:

$qmax$ – Maximum emitterflow along lateral line, l/hr

$qmin$ = Minimum emitter flow along the lateral, l/hr.

Emission Uniformity

Emission Uniformity is a measure of a dripper's ability to water uniformly over the surface, Michael (1978) recommended that EU values of 94% or more are desirable and in no case should the designed EU be below 90%. Thus, EU can be estimated using Eq (4) as cited by Michael (1978):

$$EU = 100 \left| \frac{q_{LQ}}{q_{mean}} \right| \qquad (4)$$

where:

EU = Emission uniformity (%)

q_{LQ} = Average of the lowest quarter of the observed value (ml)

q_{mean} = Average of discharge values (ml)

RESULTS AND DISCUSSION

Hydraulic Characteristics of the Medi-Emitter

Figure 3.1 to 3.4 shows the Medi-emitter discharge (L/hr) along each drip lateral for the junction J1 to J4. The average flow rates of the Medi-emitters for the whole system was obtained as 1.74 L/hr, the mean flow rates of the emitters in the four (4) junctions when all the junctions were opened were 1.91, 1.64, 1.46 and 1.30 L/hr, respectively as shown in Table 3.1, while the mean flow rates of each junction when others are closed were 1.86, 2.0, 1.95, 1.80 L/hr respectively as shown in Table 3.2. The corresponding distances of J1 to J4 were 1.74, 2.69, 4.6 and 5.61m, respectively.

Emitter flow Variation

The variation of the Medi-emitter flow rate ranged from 16.06 - 16.85% (Table 3.1) when all the junctions were opened and 16.4 -17.7% (Table 3.2) were individual junctions was opened. The average variation of the emitter flow rate of the system was found to be 16.54% which indicates that the arrangement of the drip lines were satisfactory in terms of uniformity of flow from individual emitters. The result agrees with Michael (1978) and Jensen (1983) who stated that in drip irrigation setup the average variation in the discharge rate of individual emitters in the whole field should not exceed 20%.

Table 3.1 Hydraulic characteristic of the Medi-emitter drip system with all the junctions opened.

Junction	Emitter Discharge (L/hr)	Coefficient of variation (%)	Emission Uniformity (%)	Distribution Uniformity (%)	Maximum Emitter Discharge (L/hr)	Minimum Emitter Discharge (L/hr
J1	1.91	16.83	99.46	97.36	2.26	1.60
J2	1.64	16.85	99.04	95.87	2.04	1.41
J3	1.46	16.06	98.93	94.95	1.72	1.30
J4	1.30	16.43	97.00	93.84	1.74	1.10

Table 3.2 Hydraulic characteristic of the Medi-emitter drip system all the junctions were opened.

Junction	Emitter Discharge (L/hr)	Coefficient of variation (%)	Emission Uniformity (%)	Distribution Uniformity (%)	Maximum Emitter Discharge (L/hr)	Minimum Emitter Discharge (L/hr
J1	1.86	17.68	99.74	95.36	2.44	1.49
J2	2.0	15.24	98.32	93.87	2.43	1.43
J3	1.95	16.95	94.27	92.95	2.34	1.60
J4	1.80	16.38	91.34	91.84	2.15	1.46

Distribution and Emission Uniformity

The distribution and emission uniformity of the Medi-emitter drip system were estimated based on Eqs. 2 and 4, respectively. The average distribution uniformity ranged from 91.8 - 97.4%, while the EU varied from 91.3 to 99.5%, respectively as shown in Table 3.1 and 3.2, while the distribution uniformity and emission uniformity for the whole system were 94.5 and 97.3% which signified an even distribution of water through the system, high uniformity implies that all areas of the field received adequate water which will prevent built-up of salt concentration. These results obtained are supported by Oiganji *et al.,* (2015) who stated that a drip system with emission uniformity and distribution of uniformity above 85% is satisfactory. The varied values of the emitter discharge, coefficient of variation, EU and DU at J1-J4, may be due to the lateral distance of the junctions from the tank, as distance since to affect operating pressures of laterals.

Emitter flow rate

Plate 3 shows the Medi-emitter flow rate as affected by lateral distance of the Medi-emitter from the tank at different plots using disposable cup for the catch can test. The overall average Medi-emitter discharge was found to be 1.74L/hr, while the average maximum and minimum discharge rates were 2.14 and 1.42 L/hr, respectively as shown in Table 3.1 and 3.2. Oiganji *et al.,*(2015) reported 0.557 L/hr as overall average dripper in Zaria-Nigeria, while Ramalan et al.,(2010) reported an average dischargein Ethiopia, lowerthan the value reported herein, Mofoke, (2006) reported an emitter flow rate of 533l/hr in Bauchi-Nigeria under a pressure head of 5m with the use of Medi-emitter drip system, which was higher than the value obtained reported herein; differences may be due to: emitter, lateral distance of emitter from tank and height of tank above the ground. Evaluation of the measured emitter flow rates when all the junctions (J1-J4) were opened andwhen specific junctions were opened were observed to be not significant (NS) at $p > 0.05$, when t-test was used for the comparison. It was observed that the variation between discharges at different junctions increases with increase with lateral distance from the tank as shown in Fig. 1-4.

CONCLUSION

The hydraulic characteristics of a Medi-emitter drip irrigation system was constructed and evaluated. The emitter flow rate was significantly influenced by the lateral distance from the tank. The distribution uniformity and emission uniformity for the whole system were 94.5 and 97.3% which signified an even distribution of water through the system.The overall average Medi-emitter discharge was found to be 1.74L/hr under flow rates best suited for vegetable crops. It is therefore recommended that the Medi- emitter drip irrigation system should be adopted by farmers within the Northern part of Nigeria for dry season farming so as to boost the economy of peasant farmers.

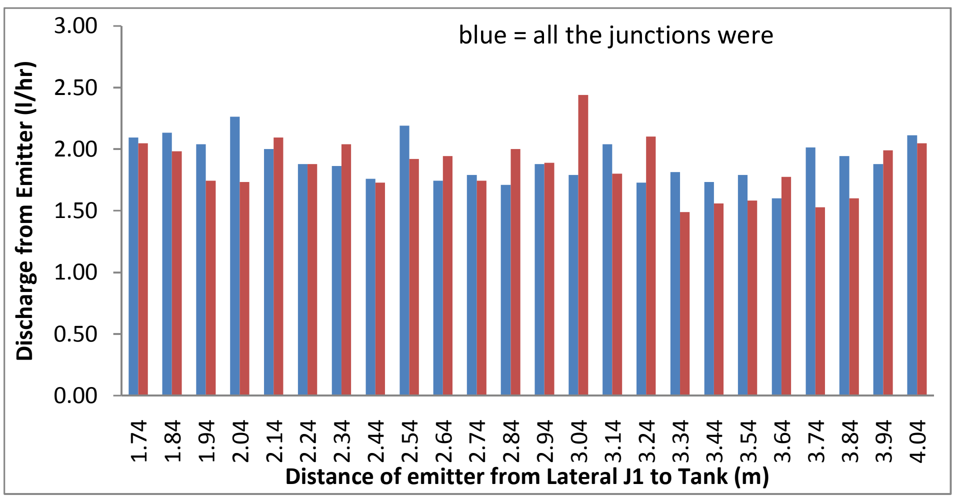

Fig 1 Emitter flow rates at different lateral distances

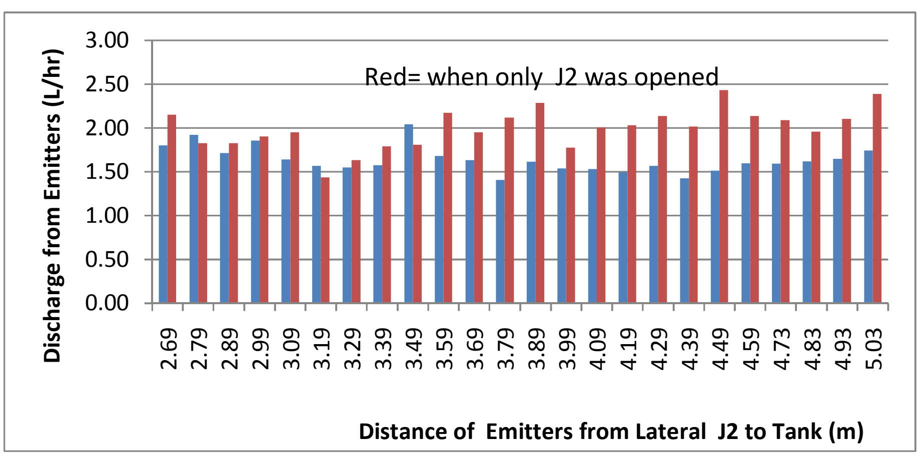

Fig 2 Emitter flow rates at different lateral distances

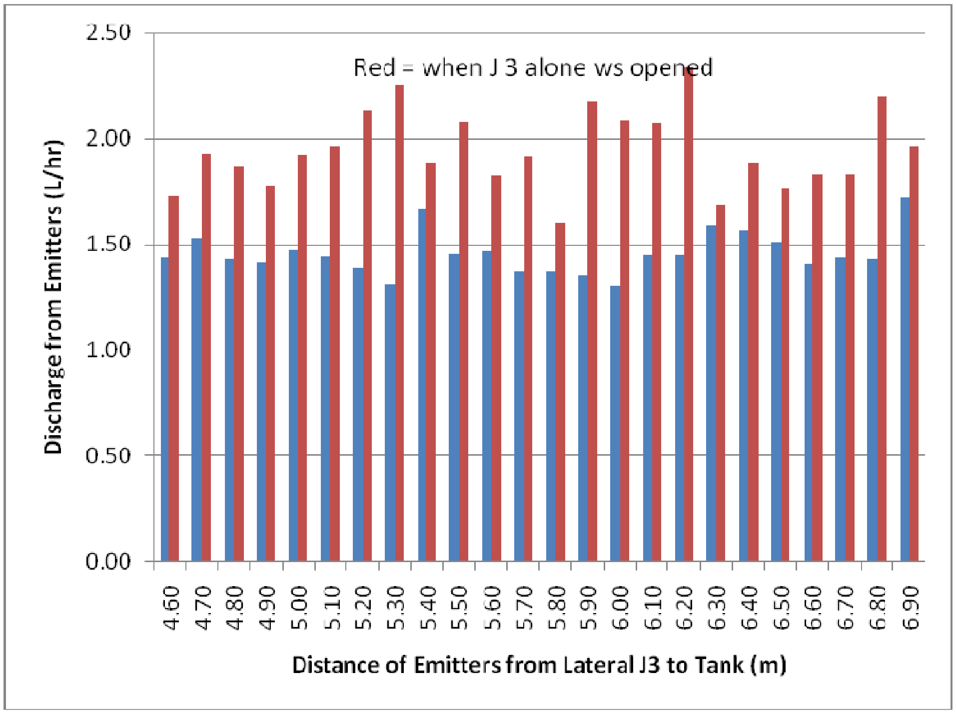

Fig 3 Emitter flow rates at different lateral distances

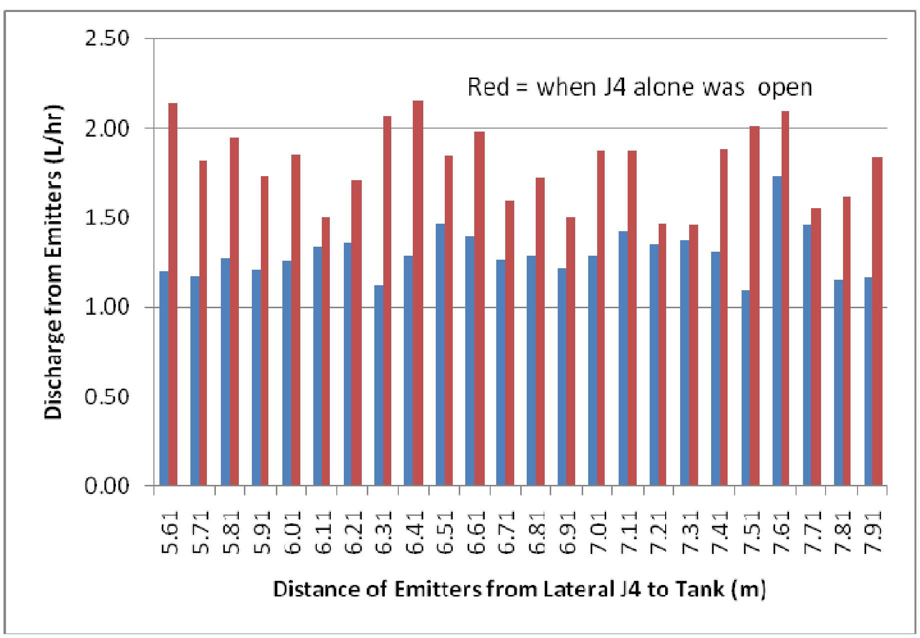

Fig 4 Emitter flow rates at different lateral distances

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