PERFORMANCE EVALUATION OF BAMBOO (*Oxytenanthera abyssinica*) LOW- COST MICRO IRRIGATION LATERAL SYSTEM

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ABSTRACT

The objective of the study was to develop construction techniques and determine the application uniformities of a bamboo low-cost micro irrigation lateral system. Fresh bamboo stalks were sorted, dried and bored. The system's three 4 m long laterals made of bamboo tube with an average internal diameter of 1.7 mm were connected to a bamboo mainline pipe with an average diameter of 3 mm which receives water from the plastic reservoir. The mean flow rate of 5.91 litres per hour through about 1.9 mm diameter emitters falls within the acceptable discharge range for micro irrigation systems. A systems performance assessment based on standards for micro- irrigation systems was carried out. Average discharge variations, coefficient of manufacturing variation, emission uniformity, Christiansen coefficient of uniformity and distribution efficiency were 30%, 9.8%, 73%, 92% and 88%, respectively from the 1.9 mm emitter orifice fall within the recommended values for micro-irrigation systems. Method of orificing and cleansing of emitters should be improved upon, so as to reduce the flow rate variations in the emitters.

Keywords: bamboo (*Oxytenanthera abyssinica)*, micro irrigation system, application uniformity.

1. INTRODUCTION

Water for irrigation is no longer as abundant, particularly in north eastern Nigeria, as most people thought it was. Due to the extreme climatic irregularities in this region, the initial problem that the farmer needs to solve is that of providing water to his crops. Effective management of soil and scarce water resources in semi-arid settings is critical for improving crop productivity (Kizito *et. al*., 2007). Therefore, there is a need to replace the more wasteful surface irrigation and even sprinkler methods by more efficient systems that minimize loss of water (Adeniji, 1991). One way to achieve this objective is to use micro or trickle irrigation system which can drastically reduce the irrigation water requirements without necessarily decreasing their yields. However, the high investment cost and technological requirements of conventional micro/trickle irrigation is a limiting factor in its application, especially in the developing countries. To overcome this, bamboo and other locally available materials are being considered as micro irrigation components in this work. Bamboo belongs to a unique group of gigantic grasses of the family Poeceae or Graminae. Bamboo is a versatile fast growing species which has been described as segmented and complex subterranean system (Janssen, 2000). It attains its full length in 2 to 3 months and its maturity in 2 to 3 years. Bamboos can grow at sea level to as high as 3000 meters above sea level and they are well adapted to growing in plains, hilly and high altitude mountain regions and in most soil types except desert, marsh and alkaline soils (Ahmad, 2000).

Micro irrigation is the slow, even application of low-pressure water to soil and plants using plastic tubing's, called emitters, placed near the plants' root zone. It is a water saving alternative to sprinkler or furrow methods of irrigation. It can be used for most crops with either high or low water demands (Shock, 2006) and can drastically reduce the irrigation water requirements of the crop without decreasing the yield.

The uniformity of water application is of major concern in drip irrigation system design procedures. It is typically used as a primary measure of the potential performance of the system. Therefore the main objective of the study is to develop construction techniques and to determine the application uniformities of a bamboo low-cost micro irrigation lateral system.

2. MATERIALS AND METHODS

2.1 The bamboo micro irrigation layout

Fresh bamboo stalks were sorted, dried and bored. The excessive tapered portions were discarded to make the pipe uniform. The bamboo culms were vice to work bench and drilled with selected drilling bits attached to an iron rod. For long bamboo, this was done by pushing the iron first from one end then removing it and pushing it in through the other end. The bored bamboos were cut into required sizes using a hacksaw. Internal diameters of the bamboo were measured using vernier calliper at the entrance and exit of the pipe.

Water flows into the drip (micro) lines from a plastic reservoir 120 *l* capacity placed 2m above the ground supported by a wooden stand made with 2 × 2 timbers. It is a gravity system that is adapted to take advantage of the benefits of the micro irrigation method without requiring an expensive water pressure system. Gate valve was placed at the outlet of the plastic reservoir to control flow. The system's three 4 m long laterals made of bamboo tube with an average internal diameter of 1.7 mm were connected to a bamboo mainline pipe with an average diameter of 3 mm which receives water from the plastic reservoir. Twenty seven (27) emitter openings were installed (trial) and these numbers can irrigate a small vegetable field of 3 m by 1.5 metre. The system can be shifted to irrigate an area of 18 m^2 or can be modified to irrigate a larger area. Largely because the rubber joint was most leak-proof and imparted least head loss, all joints were made using rubber bands. An ordinary 'mosquito net' wire mesh (1 mm diameter) was placed at the gate valve to serve as a filter in order to prevent blockages of the micro openings. The arrangement of the drip kit is shown in Figure-1. The experiment was conducted at Agricultural Engineering Farm, University of Maiduguri, Maiduguri.

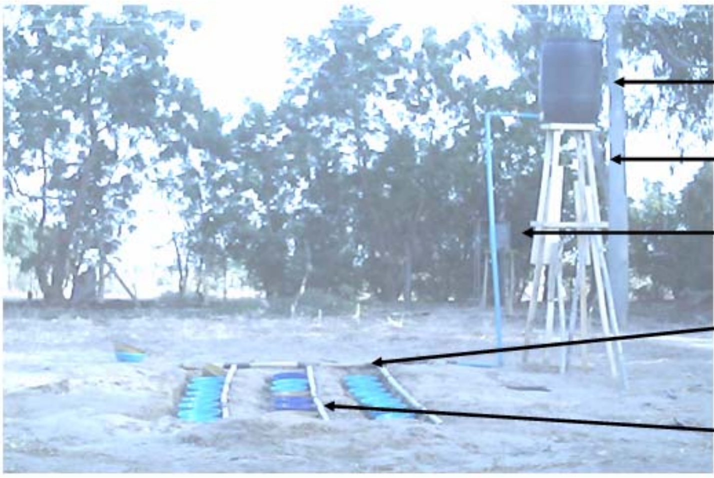

Figure-1. Bamboo micro irrigation system arrangement.

2.2 Emitter installation

Emitters of various sizes were installed on the bamboo pipe laterals at spacing of 30 cm. The emitters were installed by:

i Marking off points for drilling using a biro and a 30 cm ruler to measure spacing.
ii Using nails of 25, 35 and 51 mm length with corresponding diameters of 1.5, 2.2 and 2.8 mms, respectively to punch the orifice emitters.

2.3 Emitter flow measurement

After installation of emitters, water was allowed to flow through for about 40 minutes in order to achieve a fairly constant flow. Small plastic containers were placed beneath each micro opening in order to measure the volume of water collected using a graduated cylinder. The time taken to fill the cylinder was recorded. Discharges recorded at various emitter openings were used in evaluating the system performance parameters.

2.4 Maintenance

Emitter clogging caused by physical, chemical or biological material was the biggest maintenance problem of the micro-irrigation system. Emitters were maintained by periodic checking of the filtering devices. Openings were cleared of clogging by the use of ordinary needles of various sizes. Joints were checked for leakages and tightened.

2.5 Systems performance in terms of uniformity of water flow

Micro irrigation laterals are designed to maintain an acceptable variation in discharges along their length. According to Murray - Rust and Snellen (1993), the performance of an irrigation system is represented by its measured levels of achievement in terms of one or several parameters chosen as indicators of the systems goal. The system goal in this case is to supply each plant with the calculated water requirement at the same delivery rate. The most widely accepted hydraulic performance parameters for assessing micro-irrigation systems vis-à-vis parity in water distribution are; Emitter flow rate variation (q_{var}), Discharge coefficient of variation (Cvq), Christiansen′s coefficient of uniformity (CUC), Emission uniformity (EU) and Distribution uniformity (DU). These are given respectively by:

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \times 100 \quad \text{.........................} \quad (1)$$

where

q_{max} = maximum emitter flow
q_{min} = minimum emitter flow

$$Cvq = \frac{S}{q_a} \times 100 \quad \text{..............................} \quad (2)$$

where

Cvq = Discharge coefficient of variation in percentage
S = Standard deviation of the emitter discharges
q_a = average flow rate

$$CU = 100\left(1.0 - \sum x \big/ nm\right) \quad \text{.........................} \quad (3)$$

where, according to Keller *et al*., (2001)

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CU = coefficient of uniformity developed by Christiansen, %
z = individual depth of catch observations from uniformity test, mm
x = |z - m| =absolute deviation of the individual observations from the mean, mm
m = (∑z)/n=mean depth of observations, mm
n = number of observations

Distribution efficiency (DU) was computed from the following equations (Keller *et al*., 2001).

$$DU = 100 - 1.27\ Cv \quad (4)$$

where

Du = distribution efficiency in %
Cv = Discharge coefficient of variation
According to James (1988), Emission uniformity could be calculated from:

$$EU = 100\left(1.0 - \frac{1.27}{\sqrt{Ne}}Cv\right)\frac{Q_{min}}{Q_{av}} \quad (5)$$

EU = the design emission uniformity, %
Ne = number of emitters per plant
Cv= discharge coefficient of variation
Q_{min} = minimum emitter discharge, l/hour
Q_{av} = average emitter discharge, l/hour

The performance parameters were compared with the ASAE (1985) standards for classifying manufacturers coefficients of variation and design Emission Uniformity (EU) ranges as shown in Tables 1 and 2, respectively.

Table-1. Recommended ranges of manufacturers coefficients of variation.

Emitter type	C_v range	Classification
Point source	<0.05 0.05 to 0.10 0.10 to 0.15 >0.15	Good Average Marginal Unacceptable
Line source	<0.10 0.10 to 0.120 > 0.20	Good Average Marginal to unacceptable

Source: ASAE (1985)

Table-2. Recommended ranges of design emission uniformity (EU).

Emitter type	Topography	EU range for arid areas
Point source on permanent crops	Uniform Steep or undulating	90 to 95 85 to 90
Point source on permanent or semipermenant crops	Uniform Steep or undulating	85 to 90 80 to 90
Line source on annual row crops	Uniform Steep or undulating	80 to 90 70 to 85

Source: ASAE (1985)

3. RESULTS AND DISCUSSIONS

3.1 Systems performance parameters of the micro irrigation system

The hydraulic characteristics of an irrigation system eventually translate to observable system performance parameters which are of more direct implication to crop growth and yield. The performance of an irrigation system is represented by the measured level of achievement in terms of one or several parameters chosen as indicators of the system′s goal. The system′s goal is to provide relatively high water application uniformities and thus provide the potential for high irrigation efficiency. A low-cost micro kit arrangement operating at 2 meter head, having three, 4 m long bamboo laterals with 1.5 mm, 2.2 mm and 2.8 mm diameter orifice outlets respectively spaced at 0.30 m intervals. The mean values of flow rate were 4.01, 7.86 and 22.64 l/hr for the 1.5mm, 2.2mm and 2.8 mm diameter orifices respectively. Flow rates of 4.01 and 7.86 l/hr are acceptable for micro irrigation systems. However, flow rate of 22.64 l/hr from the 2.8mm diameter orifice outlet is considered higher than desired when compared with the acceptable range of flow rates (0.2 - 12l/hr) from emitters (Sijali, 2001).

Table-3 shows the hydraulic performance parameters of the low-cost micro-irrigation system. From the table, measured mean Cvq of 14.0 and 4.8% values at the 2 emitter openings (1.5 mm and 2.2 mm) with mean flow rates of 4 l/hr and 7.8 l/hr, respectively fall within the ASAE (1985) recommended range for point source emitters (0 - 0.15) as shown in Table- 1. However, mean Cvq value of 22% from the 2.8 mm diameter orifice outlet discharging water at mean value of 22 l/hour does not fall within the acceptable ASAE (1985) limits. Discharge coefficient of variation (Cvq) describes the quality of the processes used to manufacture emission devices. Lower Cvq values obtained from the 2 levels of the emitter openings (1.5 mm and 2.2 mm diameters) indicate high precision in punching of the orifice outlets. This shows that the device can be safely used in low-cost micro irrigation systems.

Values of emitter flow rate variations (q_{var}) are generally higher for all the emitter openings. In drip irrigation design, an emitter flow variation of less than 20 percent (about 40% pressure variation) is considered satisfactory for lateral line. Recognizing yet-to-be solved problem of the removal of the nodal plates (partitions) of the bamboo stem, the flow rate variations from the 2.2 mm diameter emitter orifice of 20-24% are considered acceptable for this low cost micro-irrigation system at this stage. Discharge variations in this micro system arrangement can be attributed to differential clogging of orifice emitters, problems in punching holes that are of the same size and pressure head differences among others. Higher values of discharge variations (q_{var}) signify that clogging and variability in punching uniform orifice outlets are the strongest factors affecting the system's performance.

Table-3. System performance parameters (values in percentage).

Orifice diameter (mm)	**Day No.**	**Performance parameters** (%)				
		q (var)	**Cv** (q)	**EU**	**CUC**	**DU**
1.5	1 2 3	37 38 39.7	12.7 14 15.4	66 63 60	90 87 86	84 82 81
	AV	38	14	63	88	82
2.2	1 2 3	20 22 24.4	4 4.7 5.8	85 80 79.6	97 97 95.6	95 94 92.6
	AV	22	4.8	82	96.4	94
2.8	1 2 3	48 53 59.3	19 22.5 25	48 45 36.5	83 79.5 77.4	75 71 68
	AV	53	22	43	80	71

Legend
q (var) = Discharge variation; CV (of) = Discharge coeff. of variations
CUC = Christiansen uniformity coefficient; EU = Emission uniformity
DU = Distribution uniformity.

General performances of the system are acceptable for the micro system arrangement operating with 2.2 mm diameter orifice emitter. Because of the small diameters of the 1.5 mm emitter orifice and relatively coarse filtered water used, clogging was inevitable, thereby giving high discharge variations. On the other hand, the 2 inch nail used for punching the 2.8 mm diameter orifice emitter is big enough thus, cracking the bamboo, and paving way for increased diameters in some outlets, thereby increasing the discharge resulting in higher emitter flow rate variation.

A more general criterion, called Emission Uniformity (EU), which depends on water temperature and the manufacturer's coefficient of variation, has been developed for evaluating trickle lateral design and emission selection. Average EU values of 63, 82 and 43% obtained for the three orifice emitters of 1.5, 2.2 and 2.8 mm respectively did not fall within the recommended acceptable limit of 85% for conventional systems in arid regions. However, EU value recorded for the first day of the trial for the 2.2 mm diameter emitter fell within the recommended range for the conventional micro systems.

From the Table, average Christiansen Uniformity Coefficient (CUC) values of 88 and 96.4% obtained from the 1.5 and 2.2 mm orifice emitters respectively are considerably satisfactory for conventional micro systems. Mean CUC value of 80% obtained from the 2.8 mm orifice emitter is low. Data on uniformity coefficient are useful as a basis for selecting combination of spacing, discharge, emitter size and operating pressure to obtain high values of irrigation efficiency at specified operating pressure. Lower uniformities imply that some areas of the field receive less water than others resulting in salt concentration in some areas.

DU is general criterion used for evaluating low-cost micro irrigation systems. DU values obtained fall within tolerance limit for low-cost micro irrigation systems serving small plots as outlined by Keller *et al.*, (2001). However, values obtained from the 2.2 mm diameter emitter openings were excellent (94 - 96%) and therefore highly recommended.

Comparing the results obtained with that of Mofoke *et al.*, (2004) where he used hospital medical infusion set as drip emitters; q_{var}, Cvq and CUC uniformity values were low for all the emitter openings except the discharge coefficient of variation and Christiansen Coefficient of Uniformity mean values from the 2.2 mm emitter orifice, where higher uniformity values were observed.

4. CONCLUSIONS

With this global phenomenon of water scarcity, orifice emitter of 1.5 mm diameter discharging water at about 4 l/hr is good as it gave mean values of 14, 88 and 82% for Cvq, CUC and DU respectively. However, where water is not a limiting factor, the micro system arrangement using 2.2 mm diameter emitter orifice discharging water at an average value of about 7.8 l/hr having the best uniformity coefficients, is highly recommended.

Generally, there is a decrease in the system performance indicators with time from all the 3 levels of emitter openings. This can be attributed to emitter clogging. However, the clogging condition of the system is not severe enough to attract stringent corrective measures. Therefore, in order to achieve a fairly constant uniform flow rate, orifices are to be cleaned periodically.

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