International Journal of Agriculture and Forestry: 2011; 1(1): 9-13
DOI: 10.5923/j.ijaf.20110101.02

Performance Evaluation of Bamboo (*Bambusa Vulgaris, Schrad*)-Pipe and Medi-Emitter in A Gravity-Flow Drip Irrigation System

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Abstract The use of bamboo (*Bambusa vulgaris, Schrad*) in gravity – flow drip irrigation was evaluated at the Teaching and Research Farm, University of Ado Ekiti, Nigeria with leaf amaranth (*Amaranthus cruentus*) as test crop. System involved the use of bamboo as the conveyance structure and medical infusion sets as dripper to deliver water to the field at 10, 15, 20, 25 and 30 drops of water/minute. The variation in discharge ranged from 6.35 to 10.21 percent as the flow rate decreases from 30 to 10 drops of water/minute. The corresponding manufacturer's coefficient of variation ranged from 2.31 to 3.35 percent as the flow rate decreases. Statistical Uniformity Coefficient and Distribution Uniformity varied between 97.21 and 98.33 percent and 96.06 and 97.69 percent respectively as the flow rate increases. There was an increase in plant height on average of 4.85, 12.53, 32.43 and 42.58 cm one, two, three and four weeks after sowing while an optimum yield of 4.13Kg/m^2 was recorded from 15 drops of water/minute. This is a new dimension in affordable drip irrigation technology and an avenue to exploit local and cheap materials whose propagation should be emphasized.

Keywords Bamboo, Medical Infusion Set, Drip Irrigation, Variation, Uniformity, Growth

1. Introduction

Modern irrigation aims at increasing the water use efficiency of production systems through reduced runoff and evaporation losses, reduced leaching of water and contaminants below the root zone and increased yields by providing optimum conditions for plant uptake of water and nutrients (Ivie, 1994; Lamont, 2002). Drip irrigation is an acknowledged technique for achieving high efficiencies in water use of crops by wetting only a limited part of the root zone (Assouline *et al*, 2002). Conventional pipes used for most of the outstanding schemes of drip irrigation are made mainly of polyvinylchloride (PVC) and asbestos-cement, occasionally, while emission devices include point- and line-source emitters that operate either above or below the ground surface at discharge rates of 2 to 8lhr^{-1} (James, 1993; Yanbo and Fipps, 2003). These pipes and emitters are very efficient and adequate but are being imported and so beyond the reach of rural farmers who produce >90% of total agricultural commodities in any year in Nigeria (Nanyang *et al*, 2005). Thus, the search for and use of substitute materials has become inevitable. Bamboo (*Bambusa vulgaris, Schrad*) is one of the nature's gifts to mankind. Its nature as a pipe, with the septum removed, either as a whole or halved has enabled many peasant, average farmers and rural communities to carry out less expensive and less complicated construction of water conveyance schemes for irrigation, drainage and water supply in countries such as Tanzania, Ethiopia, China and Indonesia (Quintans, 1998). The bamboo is used in various forms in Nigeria ranging from pulp and paper to building construction (Onilude, 2005), but its potentials as substitute piping material for irrigation is yet to be established. The medical infusion set is used mainly in hospitals and clinics for transfusion purposes but Mofoke *et al* (2004) reported its satisfactory performance as dripper for a continuous-flow drip irrigation system installed in tomato plots. An evaluation of the operation irrigation systems aims at understanding the adequacy and determining the necessary procedures for improving the performance. Such evaluation should be carried out soon after the system has establishment in the field and periodically repeated. This is because drip irrigation systems sensitive to operational conditions along the time (Keller and Blisner, 1990; Soccol *et al*, 2002). Tests to determine functional attributes are related to resistance and durability therefore, performance evaluation would be best understood through various tests with emitters belonging to a certain piece of equipment composing the irrigation system which represent the gains resulting from different ways of produc-

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Published online at http://journal.sapub.org/ijaf

ing goods and services has become a key issue in the last few decades and can easily applied to irrigation. In irrigation, quality is expressed by some performance parameters, labeled as variation, uniformity, efficiency and adequacy degree (Soccol *et al*, 2002). The emitter's flow of a drip irrigation system is mainly affected by hydraulic dimensions, manufacturing variation, temperature and clogging of emitters (Bralts *et al*, 1981; Bralts and Edward, 1986). If the emitter's flow is turbulent, it is less affected by temperature and if the water taken into the system can be controlled by filters, which are essential for drip irrigation systems, the emitter's variation will only be affected by pressure and manufacturer's variations (Anyoji and Wu, 1994). The overall objective of this work is to evaluate the effectiveness of a bamboo-pipe and medi-emitter drip irrigation system through the determination of discharge variation, coefficient of global variation and emission uniformity and the effect on the growth and yield of *Amaranthus cruentus.*

2. Materials and Methods

The study was carried out on the Teaching Research Farm, University of Ado Ekiti, Southwestern Nigeria. The irrigation system was evaluated in a subunit comprising 5 lateral lines, 2m long and 50cm apart from each other, set in a flat area. The main line and laterals were made of bamboo (43.6mm and 76mm internal and external diameters respectively). The septa at the nodes were removed using a set of hole saw blades except at one end of the bamboo section to act as the end plug. On each lateral, 10 drip points were made using a 5mm drill bit to ensure fixing of the medi-emitters. The mainline and the laterals were joined using 76mm PVC tee joints with the joints secured by using strips of used motorcycle tubes after the use of Abbro gum had failed. Fifty medical infusion sets were purchased and each was reduced to 10mm length. They were forced into the drip points already drilled on the bamboo laterals thereby constituting line-source emitters on each lateral. The derivation line was made of polyvinylchloride pipe (50.4mm diameter), with a gate valve to control flow and a screen filter to reduce clogging. The water supply system was from two tanks, a main tank and a refill tank (each 120 litres). The main tank supplies water to the field at a constant head, 5m high (enough to supply water to every part of the subunit) and the refill tank is filled with water occasionally to supply water to the main tank through a float valve and a screen filter with a view to maintaining a constant water head throughout the experiment. After the installation of the jig, a test run was done by adjusting the medi-emitters to close position while the gate valve was fully opened. Leakages along the mainline and the joints were corrected. The medi-emitters were then partially opened one after the other to ensure all the emitters discharge water to the field. After the test run, calibration of the emitters was done to obtain the application rates of 10, 15, 20, 25 and 30 drops of water per minute per lateral respectively as suggested by Mofoke *et al* (2004). The system performance parameters used to measure the uniformity of water flow to the field and these include:

1. Emitter Flow Rate Variation (q_{var}) expressed as:

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

where

q_{max} = maximum emitter flow rate, L/h.

q_{min} = minimum emitter flow rate, L/h (Keller and Karmeli, 1974).

2. Coefficient of Global Variation (CGV or CVq) determined by means of the flow rates measured during the field tests, including hydraulic and manufacturing effects, and also those due to the clogging of the emitters from the equation below:

$$CGV = \frac{Sq}{\bar{q}} \times 100$$

where

Sq = standard deviation of the emitters' flow rate, L/h

$\bar{q}$ = average flow rates, L/h

3. Statistical Uniformity (SU) is computed from the following equation:

$$SU = \{1 - \frac{Sq}{\bar{q}}\} \times 100$$

where

SU = statistical uniformity, % (Wilcox and Swailes, 1947 and Bralts *et al,* 1987).

4. Distribution Uniformity expressed as:

$$DU = \frac{\bar{q}_{25}}{\bar{q}} \times 100$$

where

DU = Distribution Uniformity, %

$\bar{q}_{25}$ = average of the 25% lowest value of flow rate, L/h (Keller and Karmeli, 1974).

The flow rates were determined by direct process of collecting the volume in a container and measuring it in a graduated 1000ml measuring cylinder. The collection time was set to 20 minutes to obtain enough volume (ASAE EP 458, 1996).

The performance indices were determined from two perspectives. First, using point discharges measured from every medi-emitter for five days before sowing *Amaranth*, giving spatial measure. These parameters were again computed from each emitter point on a weekly basis through to the end of the growth period to reveal the system's change in variation and uniformity with time as suggested by Mofoke *et al* (2004). The results obtained were compared with ASAE EP 405 (1985) standards for optimum operating system for trickle (drip) irrigation systems. Plant growth parameters such as plant height were measured using a steel tape from then soil surface to the tip of the terminal bud, while the number of leaves was counted manually. Matured vegetables were harvested weekly after maturity (4WAS) and the fresh weight was determined using a top loading balance. Statistical analysis of the results was done using Duncan Multiple Range (DMRT) to determine if there is significant difference ($p<0.05$) between the performance indices and the different flow rates.

3. Results and Discussion

3.1. Variation in Discharge

Average spatial discharge variation decreased significantly ($P<0.05$) with increased water application rate (Tables1and 2). Application of 10drops of water/minute gave the highest discharge variation of 9.16 % while discharge variations of 8.54, 8.33, 7.99 and 7.45 % respectively were obtained as the water rate was increased from 15 to 30drops of water/minute on daily basis. The same trend was obtained when the discharge parameter was evaluated on weekly basis (with *Amaranthus cruentus* as the test crop), as 10drops/minute gave 10.21% which is significantly higher than 9.22, 7.71, 7.01 and 6.35% obtained from 15, 20, 25, and 30drops of water/minute. The high values obtained from 10drops of water/minute may be due to partial clogging of the emitters in the first week of crop growth, high head loss and excessive pressure variation along emitter centre line in maintaining such low flow rate. The general variation in discharge could also be attributed to major and minor losses which Mofoke *et al* (2004) suggested were due to the bamboo internal walls, joints, fittings pressure variation right from the tank to the emitters and water temperature.

Table 1. Spatial Discharge Variation and Emission Uniformities on daily basis.

Flow rate(drops/min)	q_{var} (%)	CGV (%)	SU (%)	DU (%)
10	9.16a	3.15a	97.30a	96.06ab
15	8.54ab	3.02a	97.36a	96.48ab
20	8.33ab	2.75a	97.48a	96.57a
25	7.99ab	2.62a	98.02a	96.95a
30	7.45b	2.42b	98.03a	97.09a

Means with the same letter in a column are not statistically significant ($P<0.05$)

Table 2. Average Discharge Variation and Emission Uniformities based on weekly readings.

Flow rate(drops/min)	q_{var}%	CGV %	SU %	DU %
10	10.21a	3.35a	97.21a	96.46ab
15	9.22b	3.01a	97.55a	97.25a
20	7.71c	2.49b	97.96a	97.26a
25	7.07c	2.40b	98.21a	97.29a
30	6.35d	2.31b	98.33a	97.69a

Means with the same letter in a column are not statistically significant ($P<0.05$)

3.2. Coefficient of Global Variation in Discharge

The Coefficient of Global Variation (Coefficient of Manufacturer's Variation) in discharge describes the quality of the processes used to manufacture emission devices. This implies that it is possible to obtain variable flow rate from emitters by the same manufacturer. Coefficient of Global Variation was not significantly affected by the rate of water application. The values in Tables 1 and 2 obtained from the emitters decreased from 3.15 to 2.42 % as the flow rate increases from 10 to 30 drops of water/minute when evaluated spatially on daily basis and from 3.35 to 2.31 % also as the flow rate increases during the crop growth stage on weekly basis. Based on American Society of Agricultural Engineering (ASAE, 1985) recommended classification of Coefficient of Global Variation in discharge, these values are below the 10 % margin as 'good' for line source emitters. This showed that the adopted medical infusion sets, or medi-emitters, coupled with mechanism to control flow rate and bamboo in place of PVC pipes to convey water, can be employed as substitute for the conventional drippers for drip irrigation system. A similar finding was obtained by Mofoke *et al* (2004) on the adoption of the medi-emitters as drippers for the design, construction and evaluation of an affordable continuous-flow drip irrigation system.

3.3. Emission Uniformity

The uniformity of application describes how evenly an irrigation system distributes water over a field. Application uniformity was not significantly affected by the rate of water application. Tables 1 and 2 showed that the uniformity of application, using the statistical uniformity criterion, had values ranging from 97.30 to 98.03 % as the flow rate increases from 10 to 30 drops of water/minute when evaluated on daily basis and between 97.21 and 98.33 % as the flow rate increases when the setup was tested with *Amaranthus cruentus* on weekly basis. The trend is shown in Figure 2. These values were above the 80 – 90% expected for micro-drip irrigation system. The relatively high values were indication of recorded low coefficient of manufacturer's variation in discharge. Also the experiment was carried out on a flat bed with gradient less than 2% as recommended by James (1993) which reduced the effects of pressure variation and head loss to minimum that characterized higher gradients. The Pearson correlation coefficient test is positive (r^2 = 0.214 on daily basis, and r^2 = 0.712 on weekly basis) between statistical uniformity and the flow rates. This means that as the flow rate increases, the coefficient also increases up to 21.4 % on daily basis and 71.2 % on weekly basis during the crop growth stage.

Distribution uniformity, another criterion for assessing trickle ((drip) irrigation system, gave similar results, with values ranging from 96.06 to 97.09 % as the flow rate increases from 10 to 30 drops of water/minute when evaluated spatially on daily basis and from 96.46 and 97.69 % also as the flow rate increases when the setup was tested with *Amaranthus cruentus* on weekly basis. The Pearson correlation coefficient test also indicated the same trend (r^2 = 0.1386 on daily basis and r^2 = 0.601 on weekly basis). However, the correlation between the distribution uniformity and manufacturer's coefficient of variation in discharge is negative (r^2 = -0.7205 on daily basis and r^2 = -0.7671 on weekly basis) which implies that as coefficient of manufacturer's variation decreases (as expected for good emitters), the distribution uniformity must increase (James, 1993).

3.4. Level of Clogging of the Medi-Emitters

Plugging of emitters is the major problem of drip irrigation system (Schwab et al, 1993). The partial plugging recorded was caused mainly by the formation of green algae due to transparency of water in the medi-emitters (a favourable condition for algae growth) in the first two weeks of experiment. This was curtailed by wrapping black cellophane (to prevent sunlight for photosynthesis) round the affected part of the medi-emitters. No blockage caused by soil particles or precipitated salt was detected. This implies an almost 100 percent efficiency of the improvised micro-strainer employed and that the well water used was free from precipitate-forming salts of the pipe reported by Mofoke *et al* (2004).

3.5. Effects of Flow rates on Plant Growth Parameters

Amaranth plant height was not significantly affected. From Table 3, the average height ranged between 4.34 and 5.31, 10.89 and 13.54, 27.71 and 37.36, 41.80 and 43.45 cm one, two three and four weeks after sowing respectively as the flow rate increases from 10 to 30 drops of water/minute. The recorded increase in plant height was an indication of satisfactory water application and effective distribution. The high plant heights recorded from 25 and 30 drops of water/minute in the first two weeks may be attributed to high water application required for crop emergence and establishment and higher values recorded from 15 and 20 drops/minute three and four weeks after sowing may be attributed to almost meeting the irrigation water requirement while the lower values from other flow rates may be due to under- and over-irrigation which might lead to not meeting the crop water requirement and excess water in the root zone than the plant requires respectively.

Table 3. Effects of flow rates on Plant Height.

	Height of plant (cm)week after sowing			
Flow rate (drops/minute)	1	2	3	4
10	4.34a	10.89ab	28.64bc	41.80ab
15	4.75a	13.23a	37.09a	43.45a
20	4.91a	13.14a	37.36a	42.61a
25	5.31a	13.54a	31.33b	43.24a
30	4.95a	11.86ab	27.71bc	41.82ab

Means with the same letter in a column are not statistically significant ($P<0.05$)

In Table 4, the number of leaves per plant also recorded the same trend. 25 drops of water/minute had plant with about 4 leaves which is not significantly higher than the 3 leaves each obtained from other flow rates a week after sowing. A similar result was obtained two weeks after sowing while 15 and 20 drops of water/minute gave the highest values of about 9 and 13 at three and four weeks after sowing respectively.

3.6. Amarantus Yield

From Table 4, water flow rate significantly affected *Amaranthus* yield. The 15drops/minute water regime had an optimum yield of 4.13 Kg/m^2 (as shown in Figure3) which is significantly higher than 2.25, 3.85, 3.33 and 2.50 Kg/m^2 from 10, 20, 25 and 30 drops of water/minute respectively. This high yield at such flow rate may be attributed to meeting the crop water requirement of *Amaranth* while the low yield recorded from the lowest and highest flow regimes mean there may be under and over irrigation respectively.

Table 4. Number of leaves and crop yield.

	No. of leaves week after sowing				
Flow rate (drops/minute)	1	2	3	4	Yield (Kg/m^2)
10	3.00a	5.00a	8.00a	12.00a	2.25bc
15	3.33a	5.33a	8.67a	12.67a	4.13a
20	3.00a	5.33a	8.67a	12.67a	3.85a
25	3.67a	5.33a	8.33a	12.33a	3.33b
30	3.00a	5.00a	8.33a	12.33a	2.5b

Means with the same letter in a column are not statistically significant ($P<0.05$)

4. Conclusions

The performance evaluation of the system revealed a good exploit of the adopted materials. The variation in discharge is considerably low. The high values from 10drops of water/minute indicated higher variation is expected if the flow rate is reduced further. However, higher flow rates that gave low variations imply more water losses which are undesirable. It is evident from the study that the bamboo and medi-emitters conformed to recommended standard as stipulated by American Society of Agricultural Engineering (ASAE) in terms of coefficient of global variation (coefficient of manufacturer's variation). The values obtained were below the less than 10 percent margin for very good emitters. The adoption of the substitute materials performed very well, yielding high uniformities, an indication of low coefficients of manufacturer's variation. The plant (*Amaranthus cruentus*) growth parameters studied showed an increase in plant height and number of leaves. However the low heights recorded from 10 and 30drops/minute revealed under- and over-irrigation at those levels respectively. Highest yield was obtained from 15drops/minute. This optimum yield is an indication of meeting crop water requirement of *Amaranthus*. The design therefore presents an attractive prospect for the propagation of bamboo and advancement of affordable micro (drip) irrigation technology.

REFERENCES

[1] Anjoyi HI, Wu IP (1994). Normal Distribution and water ap-

plication for drip irrigation schedules. *Transaction of ASAE*, 37, 159-164

[2] ASAE- American Society of Agricultural Engineers. (1985). *Design, Installation and Performance of Trickle Irrigation Systems,* EP 405, pp.508

[3] ASAE- American Society of Agricultural Engineers. (1996). *Field Evaluation of Microirrigation Systems*, EP 458, 792-797

[4] Assouline S, Cohen S, Mecbach D, Harodi T, Rosner T (2002). Effect of Micro-drip irrigation on yield, water uptake and drainage in sweet corn. *Soil Science of American Journal*, Vol. 66, Pp 228–235

[5] Bralts VF, Edwards DM (1986). Field evaluation of drip irrigation submain units. *Transaction of ASAE*, 29. pp1659-1664

[6] Bralts VF, Edwards DM, Wu IP (1987). Drip irrigation design and evaluation based on the statistical uniformity concept. In Hillel, D. (ed.). Advances in Irrigation, Massachusetts, Academic Press Inc., Amherst. Pp 67-117

[7] Bralts VF, Wu IP, Gitlin HM (1981). Manufacturing variation and drip irrigation uniformity. *Transaction of the ASAE*, 24,113-119

[8] Ivie MA (1994). A simple home drip irrigation system. *Technical Report. Cooperative Extension Services*, University of the Virgin Islands. Pp 1-4

[9] James G. Larry (1993). Principles of Farm Irrigation System Design. 2nd Edition. John Wiley & Sons Inc., USA. 543pps

[10] Keller J, Bliesner RD (1990). Sprinkler and trickle irrigation. Van Nostrand Reinhold, New York. Pp 427-602

[11] Keller J, Karmeli D (1974). Trickle irrigation design parameters. *Transaction of ASAE*, 7, 687-684

[12] Lamont WJ (2002). Drip Irrigation for Vegetable Production. *Technical Report. Agricultural Research and Cooperative Extension Services*. The Pennsylvania State University. Pennsylvania, PA 16802. Pp20-25

[13] Liese W (2003). Structures of bamboo culm affecting its utilization. *Proceedings of International Workshop on Bamboo Industrial Utilization*, Sponsored by INBAR, China. Pp9-16

[14] Mofoke ALE, Adewumi JK, Mudiare OJ, Ramahan AA (2004). Design, construction and evaluation of an affordable continuous – flow drip irrigation system. *Journal of Applied Irrigation Science*. Vol. 39, No.2, pp253-269

[15] Onilude MA (2005). Potentials of Bamboo as a raw material for the industry in Nigeria. *A Technical Report.* 17pps

[16] Quintans KN (1998). The National Bamboo Project of Costal Rica: A case study of the Role of Bamboo in International Development. *INBAR Working Paper Series*. Published by International Network for Bamboo and Rattan, Beijing. P.R. of China. Pp3-9

[17] Schwab GO, Fangmeier DD, Elliot WJ, Frevert RK (1993). Soil and Water Conservation Engineering. 4th Edition, John Wiley & Sons Inc., USA. 673pps

[18] Soccol OJ, Ullmann MN, Frizzone JA (2002). Performance Analysis of a Trickle Irrigation Subunit Installed in Apple Orchard. *Brazilian Archives of Biology and Technology*. Vol.45 (4). Pp 525-530

[19] Wilcox JC, Swailes GE (1947). Uniformity of water distribution by some undertree orchard sprinklers. *Scientific Agriculture*, 27, 565-583

[20] Yanbo H, Fipps G (2003). Modeling flows in Irrigation Distribution Networks – model description and prototype. *A paper presented at the 2003 ASAE Annual International Meeting*, sponsored by ASAE, Riviera Hotel and Convention Center, Las Vegas, Nevada, USA. Pp2-5