Evaluation Of Bamboo (*Bambusa Vulgaris* (Schrad)) Culm For Drip Irrigation

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Abstract

Pipes used for irrigation are expensive for small holder farmers. Therefore, bamboo with its pipe-like aerial stem (culm) may be a promising substitute for irrigation pipes. However, there is a dearth of information on the Bamboo Pipe (*BP*) for this application. The potential of bamboo for agricultural land irrigation was therefore investigated. Medical infusion tubes were forced fixed on the prepared bamboo pipes irrigation unit to act as emitters and *Amaranthus hybridus* (vegetable) was irrigated as the test crop. Emitters Coefficient of discharge (CV_q) and Christiansen Uniformity Coefficient (CUC) were determined during its use for the drip irrigation of *Amaranthus hybridus*. The results obtained were analysed using Pearson's correlation coefficient and t-test. The BPs were effective in carrying out drip irrigation (flow rate 0.042 - 0.117 L/hr) of the *Amaranthus hybridus*. The CV_q and CUC varied between 1.82–2.38 and 96.20–98.86 % respectively, which were within acceptable limits. There was negative correlation between CV_q and the discharge rate. The maximum yield of *Amarathus hybridus* obtained was 4.6 kg/m^2 (4600 kg/ha) with the medi-emitters discharging at 20 drops/min, a high yield per hectare for an irrigated vegetable.

Keywords: Bambusa vulgaris Irrigation Drip irrigation, Medi-emitters, Irrigated crop, *Amaranthus hybridus*, Emitters Coefficient, Renewable product

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1 Introduction

Bamboo is classified as a 'non-timber renewable forest product' which comprises 1575 species and has been put into a wide variety of applications (Bystriakova et al., 2002; Gielis, 2002; Paudel, 2007). The most useful part of the plant is the cylindrical stem called culm that stands above the ground and develops quickly, even in extreme agroclimatic conditions, into a hardy, flexible and strong natural product (Steinfeld, 2001). Some species grow at the rate of 100 cm/day, reaching up to 40m in height and some expand to 30cm in diameter (Sattar, 1995; Liese, 2004; Armstrong, 2006). Bamboo is renewable and grows abundantly in the tropics and temperate regions, within latitude 400S and 400N and from jungle to high mountain sides (Liese, 2004; Ralambondrainy, 1983).

Information from available published work reveals that *Bambusa vulgaris* is regarded as the most common species in the world (Bamboo world, 2005). *Bambusa vulgaris* (Schrad) is the commonest bamboo in Nigeria and it is widely used for scaffolding at building sites, stakes for yam tubers production, etc.(Lucas and Ogedengbe, 1987). *Bambusa vulgaris* (Schrad) like most bamboos contains two parts, the woody jointed cylindrical stem or culm that stands tall above ground and the underground stem called rhizome from which the culms grow (Armstrong, 2006). Culm of *Bambusa vulgaris* (Schrad) seems to have some of the desired qualities for usage as pipe in water conveyance considering its diameter and thickness (Lucas and Ogedengbe, 1987). Hydraulically, the culms are tube like in appearance having uniform diameter over a considerable part of the length (Armstrong, 2006). By nature bamboo culm consists of a series of nodes, which cause discontinuity in the culm when put to use as water conveyance material (Liese, 1998). To enhance its utilization for water conveyance, the diaphragm at the node that causes discontinuity is removed using drilling bit to make way for a hollow length of bamboo for water conveyance (Lipangile, 1987).

Bamboo pipes were utilized by the Japanese during the second world war to supply water to some of their cities when there was shortage of raw material to manufacture pipes from metals (Lamb, 1979).The Tanzanian Government also adopted the use of bamboo pipe to supply potable water to some rural communities in Tanzania because of reduced cost of procurement as compared to the manufactured pipes (Lipangile, 1987). From the foregoing it seems that paucity of fund and restricted access to manufactured pipes are some of the reasons that enhance the adaptation of bamboo pipe in water conveyance. Most farmers in Nigeria live in rural communities and are often too poor to afford the purchase of manufactured pipes to practice irrigation on their small farm holdings (Musa, 2001). Bamboo which is available in some parts of the country at little or no cost to the farmers seems to have the potential to convey water for irrigation practice. The objective of this study is to find out if Bamboo (*Bambusa vulgaris*) pipe may be useful in the drip irrigation.

2 Materials and Methods

2.1 Fabrication of the Bamboo Pipe Drip Irrigation Unit

Only the bottom portions of the selected bamboo culms, free of defects, were used in this experiment because of their greater thickness and ability to withstand pressure than the other portions of the bamboo (Ogedengbe, 2010). The hole- saw was used to drill out the septa but the last diaphragms were left in place to act as stoppers, based on the observations reported by Ogedengbe (2010). Holes of 7mm were drilled on the selected bamboo pipes lateral (BPL) to allow emitters to be fixed. Medical infusion tubes were used as emitters (medi-emitters) to supply water to the crop. The medi-emitters have control mechanisms which were used to control the quantity of water to be applied to crop during drip irrigation. Seven of such medi-emitters were force-fixed into the drilled holes on the BPL with an intra-row spacing of 50mm. Five of such laterals (BPL) carrying the medi-emitters were connected to the Bamboo Main line (BML). One hundred (100) mm polyvinyl chloride (PVC) tee-joints were used to connect the BPL and BML with used bicycle hose and Abro gum as seals and sealant respectively. The assembly of the BPL, BML and the medi-emitters constituted the bamboo irrigation unit (Figure 1).

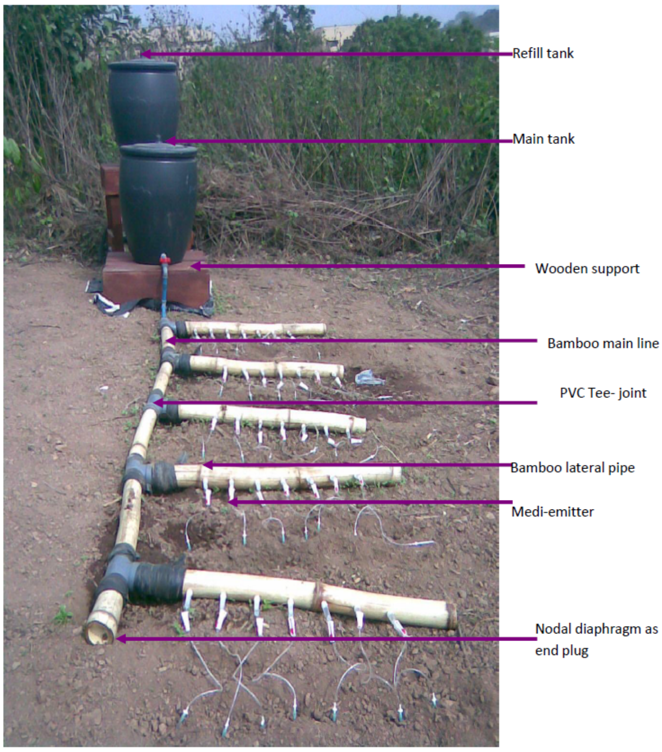

Figure 1: The Set-Up of the Bamboo Pipes Drip Irrigation System

2.2 The Water Supply System

The water supply system was made up of two plastic containers of 120 litres each; one of these was used as the main tank and the second one as the refill tank. The refill tank ensured the maintenance of a constant head in the main tank with the aid of a float. The float controlled the opening of the bottom of the refill tank that supplied water to the main tank. The two tanks were placed on wooden stands made from hard wood. The stands were made to different heights to allow for easy flow of water from the outlet of the refill tank to the inlet of the main tank. The tanks were connected by 25mm PVC plastic pipe and 25mm PVC plastic union. The float valve was connected to the supply pipe from the refill tank by using a 12.5-25mm reducer. A 25mm gate valve was connected to the main line through 25mm hose to connect it to the Bamboo irrigation unit (Figure 1).

2.3 The Water Source

This was a hand dug well located close to the water supply system. Water was fed from the well to the refill tank of the water supply system using 20 litres plastic buckets.

2.4 Test Running the Bamboo Pipe and Calibration of the Emitters

The gate valve of the supply tank was opened to allow water to flow into the bamboo pipe. All the emitters were initially fully closed to allow for the detection and repair of any leakage at the joints of the lateral to the main pipe of bamboo irrigation unit. The emitters were then opened to run and calibrated for different drop rates. The emitters on the first lateral were calibrated for 10 drops/minute, the second for 15 drops/minute, the third for 20 drops/minute, the fourth for 25 drops/minute and the fifth for 30 drops/minute. These different rates were chosen to study the effect of different rates of water application on the selected crop.

While irrigation was going on, the emitters were also monitored to determine their performance indices using uniformity parameters according to Mofoke et al.(2004). These parameters were:
(i) Discharge coefficient of variation

$$CV_q = \frac{\text{Standard deviation of emitter discharge}}{\text{Emitters average flow}} \times 100 \quad (1)$$

(ii) Christiansen Uniformity Coefficient (CUC)

$$CUC = \frac{1 - \frac{1}{n}\sum I_{q_i} - q\bar{I}}{\bar{q}} \times 100 \quad (2)$$

where:

q_i = individual emitter discharge
$\overline{q}$ = emitter average discharge
n = number of emitters

These performance indices were determined on a weekly basis during the growth period of the Test Crop.

2.5 The Test Crop

A vegetable *Amaranthus hybridus* was selected as the test crop because it has a short growing season of 28 days. During the growth of the crop, the plant height was monitored per lateral by measuring with metre rule. At the end of the 28 days growing period the crop was harvested per lateral and weighed for comparison.

2.6 Field Experiment Using the Bamboo Drip Irrigation System

A plot of land 3m x 5m was selected on a private farm located in Ibadan, Oyo state, Nigeria. The land was cleared of weed using hoes before the bamboo drip irrigation system was laid in place. The water supply and refill tanks were placed on their stands connected together and filled up to supply water to the drip irrigation unit. All the emitters were fully opened to soak the soil before the seeds of *Amaranthus hybridus* were planted. The soaking was to allow for easy germination of the seed for the dry season irrigation. The seeds were obtained from the National Institute for Horticultural Research and Training, Ibadan, Oyo State and they were planted at the recommended rate of 6kg/hectare.

The emitters were re-adjusted to deliver water at different rates of 10, 15, 20, 25 and 30 drops/ minute for different laterals. Water flowed from the supply tank to the drip irrigation unit by gravity and the refill tank maintained a constant head. The discharge at each emitter was measured by determining the volume of water discharged in five minutes. The discharge uniformity and Christiansen coefficient of uniformity were calculated for the 4 weeks duration of the study. The plant height was determined on weekly basis. At maturity the crop was harvested per lateral and weighed.

2.7 Data Analysis

The data that evolved from this study were subjected to various statistical analyses. One sample T-Test was used to compare the significance of values within the same variable. Pearson's Correlation Coefficients were calculated to determine the correlation between the plant height

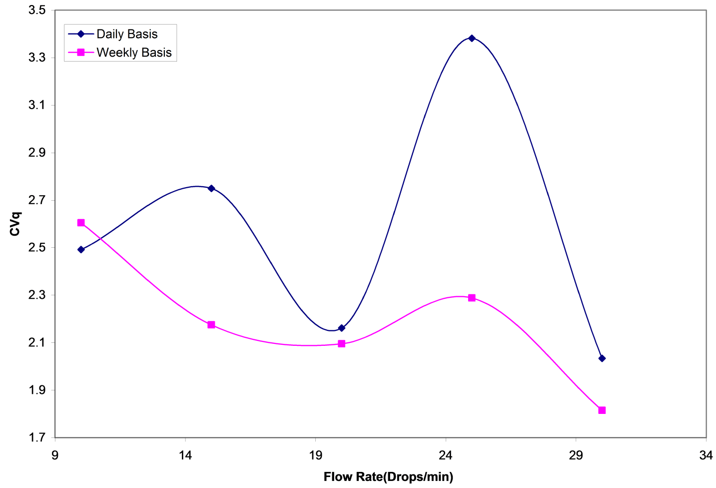

Figure 2: Effect of Flow Rate on Coefficient of Discharge Variation (CV_q).

and plant yield and between the plant height and discharge rate of the medi-emitters All comparisons were made at a statistical confidence interval of 95%.

3 Results and Discussion

3.1 Coefficient of Discharge Variation

Figure 2 shows the coefficient of discharge variation (CV_q) for the medi-emitters (adopted to dispense irrigation water) on daily and weekly bases. For the daily measurement over a period of 5 days, the variation in the discharge obtained was highest for lateral No.4 (i.e. 25 drops/min) with a mean value of 3.38 ± 1.35 (Table 1) and lowest for lateral No. 3 (i.e. 20 drops/min) with a mean value of 2.16 ± 0.40.

Table 1: Results of After Sowing Daily CV_q and CUC of the Medi-Emitters.

Day	Lateral 1 (10 drops/min)		Lateral 2 (15 drops/min)		Lateral 3 (20 drops/min)		Lateral 4 (25drops/min)		Lateral 5 (30 drops/min)	
	CV_q	CUC	CV_q	CUC	CV_q	CUC	CV_q	CUC	CV_q	CUC
1	1.70	98.53	4.13	96.61	2.35	98.04	2.46	97.70	1.49	98.70
2	2.25	98.36	1.15	99.19	2.70	98.00	5.73	94.70	1.62	98.75
3	2.23	98.25	2.44	98.20	1.70	98.53	3.27	97.10	2.17	98.27
4	4.56	96.20	3.52	96.93	1.83	98.63	2.70	98.90	1.45	98.58
5	1.72	98.57	2.51	97.79	2.23	98.15	2.75	97.50	3.44	96.79
Mean	2.49	97.98	2.75	97.74	2.16	98.27	3.38	97.20	2.03	98.22
St.dev ±	(1.19)	(1.00)	(1.14)	(1.03)	(0.40)	(0.29)	(1.35)	(1.52)	(0.84)	(0.80)

CV_q=Discharge coefficient of variation; CUC=Christiansen Uniformity Coefficient

For the weekly measurement over a period of 4 weeks, the CV_q obtained was highest for lateral No. 1 (i.e. 10 drops/min) with a mean CV_q of 2.61 ± 0.97 and lowest for lateral No. 5 (30 drops/min) with a mean CV_q of 1.82 ± 0.46. All the values obtained were less than 10% this implies that the process of manufacturing the medical infusion tubes which was adopted as emitters (medi-emitters) was satisfactory. Similar observation was reported by Mofoke et al.(2004).

Table 2: Level of significance of CV_q Values on Daily and Weekly Bases.

	Descriptive Summaries				T-test summaries[‡]				
	N	Mean	St.dev	St.Error	t	df	p-value	Mean difference	95% CI[†]
CV_q on daily basis	5	2.56	0.54	0.24	10.69	4	< 0.001	2.56	(1.89, 3.23)
CV_q on weekly basis	5	2.19	0.29	0.13	17.05	4	< 0.001	2.19	(1.84, 2.55)

[‡]Tested at $\mu = 0$.
[†]CI= confidence interval

From Figure 2, it was observed that the daily CV_q showed greater variation than the weekly CV_q. Results of statistical analysis (Table 2) showed that the significant values for both daily and weekly CV_q were 0.01 which are less than 0.05 meaning that there were significant differences (p<0.05) in the values of the CV_q on daily and or weekly basis. In addition, results on correlation (Table 3) showed that there was a negative correlation (Pearsons correlation = -0.084 at $p < 0.5$) between CV_q and discharge rate. The two variables were also not linearly correlated (significant value = 0.894 which was > 0.05). The corresponding values obtained for Pearsons correlation between CV_q and discharge rate on weekly basis was -0.806, indicating a strong negative correlation. The two variables were not linearly correlated (significant value was 0.10 which was > 0.05) as shown in Figure 2. The observed differences between daily and weekly variation might be due to the fact that the emitters are known to show self regulation in the discharge of water over a longer period than over a shorter period (Mofoke et al. 2004).

Table 3: Correlation between Discharge Rate and CV_q on Daily and Weekly Bases[‡].

	Discharge Rate	
	Correlation Coefficient	p-value
CV_q on daily basis	-0.084	0.89
CV_q on weekly basis	-0.806	0.10

[‡]Sample size $N = 5$.

3.2 Christiansen Uniformity Coefficient

Figure 3 shows the trend in the values of the Christiansen Uniformity Coefficient (CUC) obtained for the discharge from the adopted medi-emitters on daily and weekly bases. The mean values for all the discharges on daily basis varied between 97.20 ± 1.52 to 98.27 ± 0.29 (Table 1). These daily values showed that the highest value was obtained for the 20 drops /minute and the lowest for the 25 drops/minute Those for weekly basis varied between 97.70± 0.68 to

98.53 ± 0.30 (Table 4) with the highest *CUC* value obtained for 15 drops/minute These values of *CUC* revealed high level of uniformity in water distribution by the medi-emitters since they are all higher than 90%. However, the fact that these values were not 100% showed that there were losses. These losses might be due to roughness of the inner wall of the bamboo pipe; minor leakage at the intersection of lateral and main supply line and the imperfection in the medi-emitters materials. Though these values are small, they may add up to be large for very large pipe network. This may result in over-irrigating at some points and under-irrigating at some others.

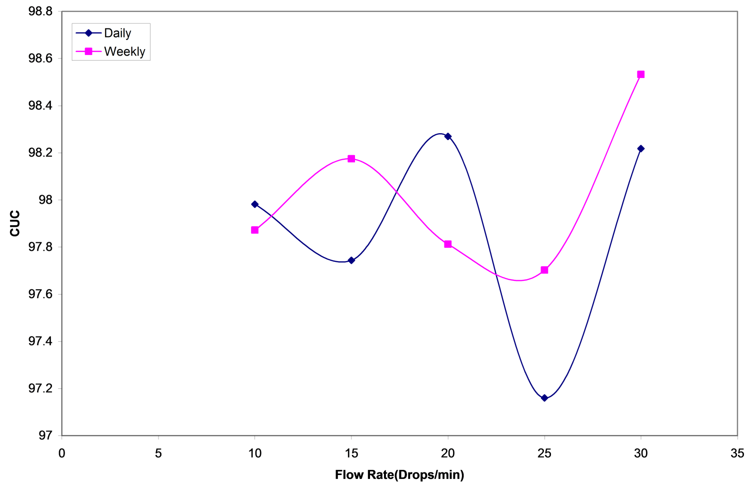

Figure 3: Effect of Flow Rate on Christiansen Uniformity Coefficient (*CUC*).

Figure 3 also shows the variation in the values of *CUC* for both daily and weekly bases. Results of statistical analysis showed that the significant values for both daily and weekly *CUC* were <0.0001 which are less than 0.05 meaning that there were significant differences (p<0.005) in the values of the *CUC* on daily and or weekly basis. The differences between daily and weekly variation might be due to the fact that the emitters are known to show self regulation in the discharge of water over a longer period than over a shorter period (Mofoke et al., 2004).

Table 4: Results of After Sowing Weekly CV_q and *CUC* of the Medi-Emitters.

Week	Lateral 1 (10 drops/min)		Lateral 2 (15 drops/min)		Lateral 3 (20 drops/min)		Lateral 4 (25drops/min)		Lateral 5 (30 drops/min)	
	CV_q	*CUC*	CV_q	*CUC*	CV_q	*CUC*	CV_q	*CUC*	CV_q	*CUC*
1	2.79	97.92	2.52	98.08	2.74	97.65	3.22	96.87	2.36	98.13
2	3.63	96.76	2.40	97.86	2.12	98.44	1.82	97.54	1.24	98.79
3	1.53	98.86	1.63	98.53	1.87	98.32	2.31	97.92	1.84	98.45
4	2.47	97.95	2.15	98.23	1.65	96.84	1.80	98.48	1.82	98.76
Mean	2.61	97.87	2.18	98.18	2.10	97.81	2.29	97.70	1.82	98.53
St.dev ±	(0.87)	(0.86)	(0.39)	(0.28)	(0.47)	(0.74)	(0.66)	(0.68)	(0.46)	(0.30)

CV_q=Discharge coefficient of variation; *CUC*=Christiansen Uniformity Coefficient

3.3 Drip Irrigation of the Test Crop with the Bamboo Pipe and the Medi-Emitters

The effect of bamboo drip irrigation system on the test crop (Amaranthus hybridus) was measured using plant height and yield. The values are as presented in Table 5. The Table shows the height of *A. hybridus* at every lateral over the 28 days (4 weeks) growth period of the test crop. The mean value of the height was 4.8±0.5 (cm) to 5.8±0.7 (cm) for the first week; 11.4 ± 2.1 (cm) to 13.9 ± 2.3 (cm) for the second week; 28.2 ± 3.9 (cm) to 37.8 ± 4.8 (cm) for the third week and 42.5 ± 6.1 (cm) to 46.5 ± 3.4cm for the fourth week. The values showed increased growth of the test crop throughout the four weeks of its growing season.

Table 5: Mean Height (cm) of the Irrigated Crop *Amaranthus hybridus* at each Lateral over the 4 Weeks Growth Period.

Week		Lateral 1 (10 drops/min)	Lateral 2 (15 drops/min)	Lateral 3 (20 drops/min)	Lateral 4 (25 drops/min)	Lateral 5 (30 drops/min)
1	Mean	4.8	5.5	5.3	5.8	5.2
	(±St.dev)	(0.5)	(0.5)	(0.5)	(0.7)	(0.4)
2	Mean	11.4	13.7	13.9	13.6	12.3
	(±St.dev)	(2.1)	(1.8)	(2.3)	(0.9)	(1.3)
3	Mean	29.1	37.5	37.8	32.2	28.2
	(±St.dev)	(3.1)	(6.8)	(4.8)	(2.0)	(3.7)
4	Mean	42.5	45.2	46.5	43.7	43.4
	(±St.dev)	(6.1)	(2.6)	(3.4)	(3.2)	(4.4)

From Table 5 the plants under lateral No. 3 (20drops/min) grew up to be the tallest (46.5 cm) and from Table 6 the plants also gave the highest yield of 4.6 kg/m^2(4600 kg/ha). The values of the yield of A. hybridus irrigated under lateral No. 1 (10drops/min) and lateral No. 5 (30drops/min) were lowered than the mean yield of 3.41 ±1.07 (kg/m^2). These lower yields may be due to under irrigation observed at lateral 1 (10drops/min) and over-irrigation observed at lateral 5 (30drops/min).

Table 6: Yield of Irrigated Crop *Amaranthus hybridus* at Harvest.

Week	Plant weight (kg)	Plant area(m^2)	Yield (kg/m^2)
1 (10 drops/min)	0.51	0.25	2.04
2 (15 drops/min)	1.05	0.25	4.20
3 (20 drops/min)	1.15	0.25	4.60
4 (25 drops/min)	0.90	0.25	3.60
5 (30 drops/min)	0.65	0.25	2.60
Mean	0.85	0.25	3.41
St.dev ±	(0.27)	(0.00)	(1.07)

Results of statistical analysis (Table 7) show that there was a strong positive correlation (Pearson's correlation = 0.942) between the plant height and the plant yield. This high positive correlation value showed that the greater the height of the plant the more the yield of the crop. The significant value obtained was 0.017 which is less than 0.05 indicating that there was linear relationship between height of *A. hybridus* and its yield. Also, the Pearson's correlation between the height and discharge rate was 0.030 indicating that there was a weak positive correlation between the two variations. This low positive value showed that the height of the crop was not always correlated with the discharge rate of the emitter. Too much water may sometimes lead to poor yield. The significant value between the two (height and discharge) was 0.962 (Table 7) which is greater than 0.05 indicating that there was no-linear relationship between discharge rate and height of the test crop (*A. hybridus*).

Table 7: Correlations between Height of plant, Yield of Plant and Discharge Rate‡.

	Height of the plant	
	Correlation Coefficient	p-value
Yield of the plant	0.942	0.017
Discharge Rate	0.030	0.962

‡Sample size $N = 5$.

4 Conclusion

The study showed that it was possible to use bamboo pipes with medi-emitters to effectively drip-irrigate vegetable crop, for example, *A. hybridus*. The bamboo pipes as main pipe and laterals were able to supply water adequately, throughout the growing season through the medi-emitters to the crop. The emitters showed very low, long term, variation in the discharge coefficient with values ranging from 1.82 to 3.38 and showed high Christiansens uniformity coefficient greater than 96%. The crop under the lateral with a discharge of 20 drops/min gave the highest yield of harvested vegetable of 4.6 kg/m^2.

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