

EVALUATION OF BAMBOO POROUS PIPE AS LINE SOURCE EMITTER IN TRICKLE IRRIGATION SYSTEM

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ABSTRACT

This paper attempts to evaluate the use of bamboo as porous pipe (line source) emitter in trickle irrigation at the Cross River University of Technology Teaching and Research Farm Obubra. Two sets of bamboo laterals: opened and plugged ends were used for the trial. The experiment was conducted using four different pressure heads calibrated by pressure gauge. The volume of water discharged from each emitter and pressure drops along the respective laterals were recorded. The results showed that the mean values for the emitter discharge increased as the operating pressure head increases for the respective laterals. However, the overall mean discharge for plugged end lateral significantly ($P \leq 0.05$) differed from the opened end lateral. Pressure drops decreased as the emitter distance increases along the respective laterals. The pressure drop overall mean values did not significantly ($P > 0.05$) vary between the laterals, but the value recorded for the opened end lateral was about 17.99% higher than the plugged end lateral. The emission exponent (X) and proportionality constant (K) were also computed for the respective laterals. There was a significant difference between the laterals with respect to the overall mean values of X and K. The relationship between operating pressure and discharge, emitter distance and pressure drops were also established. A highly positive significant value of "r" (0.97**) for opened end and non significant "r" value (0.96) for plugged end were obtained in relating discharge and operating pressure. For the pressure drops and emitter distance, a strong negative significant "r" values of -0.98** and -0.99** were obtained for opened and plugged ends, respectively. These findings are observed to be in accordance with the principle of trickle irrigation and suggest that the use of bamboo as line source emitter might be possible, if appropriate measures such as environmental, socio-economic and technical issues could be considered.

KEY WORDS: Trickle irrigation, Bamboo, emitter, Porous-pipe

INTRODUCTION

Trickle irrigation system also known as drip irrigation is one of the examples of localized or micro-irrigation techniques. It is characterized by small but frequent deliveries of water at designated points on the soil surface near the

base of the plant. The volume of water applied approaches the consumptive use of plants thereby minimizing such conventional losses as deep percolation, runoff and soil water evaporation (Burt and Styles, 1999; Michael and Ojha, 2003).

The benefits of this system in terms of

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reduced water usage and high crop yields convinced many farmers in developing countries to drip-irrigate their crops (FAO, 1997; Frenken, 2005). The system is also suited to areas where water is scarce, land is steeply sloping and labour is expensive (FAO, 1988).

The basic components of the system include pumping station, main, submain (lateral) and emitter. The emitter is the most important component as it dissipates the pressure from the distribution system, thus allowing a limited volume of water to discharge (Vamadevan, 1985; Michael, 1992). The water is being applied under low pressure and at slow rates for a sufficient period of time to maintain part of the soil at or near field capacity. With adequate soil moisture, usually $\leq 50\%$ of the root system can be saturated with water depending on the rate of application, density of wetting points and the soil properties (Howell *et al.*, 1980; Wu and Barragan, 2000).

However, one of the main aspect to be considered in the design and management of irrigation systems is the net economic benefits. Trickle irrigation generally have high installation cost and require regular inspection and maintenance to avoid blockage of emitters (Wu *et al.*, 2010). In an attempt to reduce the cost, various theoretical models developed by many researchers for drip irrigation where the cost is minimized while meeting the peak water demand have been reviewed and documented by Eduardo *et al.* (1990). Empirically, some researchers have started developing local technology by modifying the conventional trickle equipment to suit socio-economic and agro-environmental conditions of the farmers (Yadav and Michael, 1980; Aniekwe, 1991). One of such viable approaches in low-resource settings is the use of suitable local materials like bamboo (Adeniji, 1990; Aniekwe, 1991; Kay, 2001).

Bamboo is the common name for about 45 genera of a perennial tree-like plant. It grows most abundantly in almost all the countries in the world including Nigeria. It has many practical applications such as in construction, decoration, paper making and in some areas as food (Marshall, 2000). The stem is erect, stiff and consists of hollow sections interrupted by regular spaced nodes giving its jointed appearance. Hence, the need for the choice of bamboo as trickle irrigation line source emitter.

However, in developing countries like Nigeria, several trials were conducted to evaluate

bamboo used as a conduit material in trickle or sprinkler irrigation, but little was done to try it as a line source emitter. Moreover, the use of bamboo as a low-cost trickle irrigation line source emitter might be an alternative solution to reduce the cost implications to the local farmers. This study therefore, attempts to evaluate the use of bamboo as porous pipe (line source) emitter in trickle irrigation system.

THEORETICAL BACKGROUND

Porous-pipe (line source) emitters are pipes (laterals) with many small pores or perforations at closely spaced points on the pipe wall that allow water to exit from the pipe (Jensen, 1983). The flow rates from porous-pipes depend on geometry of the material and the applied pressure (Jensen, 1983; James, 1988; Ravikumar *et al.*, 2003). Usually emitter flow rates are best characterized by empirically determining flow rates as a function of operating pressure. This empirical characterization is referred to as emitter flow function (Jensen, 1983) designated as:

$$q = KH^X \text{ -----(1)}$$

Where;

- q is the emitter flow rate in l/hr;
- K is the proportionality constant that characterized the emitter dimension;
- H is the operating pressure head in m; and
- X is the emitter discharge exponent which characterizes the flow regime (Keller and Karmeli, 1975; Nir, 1982).

The exponent X plays a major role in the uniformity of water application and can be computed by taking the logarithms of flow and operating pressure in Equation (1) (Baswell, 1985; Von Barnuth and Solomon, 1986).

$$X = \frac{1n(q_1/q_2)}{1n(H_1/H_2)} \text{ -----(2)}$$

Where;

- q₁ is the initial discharge in l/hrs;
- q₂ is the second discharge in l/hr;
- H₁ is the initial operating pressure in m; and
- H₂ is the second operating pressure in m.

The value of X characterizes the emitter flow regime as follows (Keller and Karmeli, 1975; Nir, 1982):

- i) A fully turbulent regime corresponds to $X = 0.5$, can be considered as an orifice type point source emitter.
- ii) A laminar regime corresponds to $X = 1$, the emitter here can be considered to be a long path emitter.
- iii) An intermediate flow regime state corresponds to $0.5 \leq X \leq 1$. A porous-pipe (line source) emitter can be considered to fall in this category.

The proportionality constant K can be computed from Equation 1 as:

$$K = \frac{q}{H^x} \text{-----(3)}$$

Where;

- q is the emitter discharge in l/hr;
- H is the operating pressure head in m; and
- x is the emission exponent.

MATERIALS AND METHODS

Study area

The study was carried out in Cross River University of Technology Teaching and Research Farm, Obubra in Obubra Local Government Area of Cross River State. The area lies within Latitudes $5^{\circ}54'$ and $6^{\circ}15'$ North and longitudes $8^{\circ}45'$ and $8^{\circ}23'$ East with an altitude of about 180m above sea level (Bulktrade, 1989). The area has undulating topography and scattered vegetation. The soils are formed from cretaceous sediments of Eze-Aku formation, poorly drained and range from fine to medium texture (Esu, 2005). The climate is tropical with mean annual temperature varies between 27 and 29°C, relative humidity between 60 and 70%, and rainfall between 2000 and 2500mm, respectively (Bulktrade, 1989). The rainy season last between April and October, while the dry season is between November and March. The area is drained mainly by Cross River and its major tributaries.

EXPERIMENTAL MATERIALS

The materials used for the study were bamboo trees harvested from Awi in Akamkpa Local Government Area of Cross River State and allowed to air season for four weeks to attain its maximum strength. The bamboos were trimmed to a length of 3m long. The internal diameter of the bamboos was measured using the venier calipers at the head and tail ends. The average values obtained and used were 50mm and 35mm for the head and tail, respectively. A drill of 15mm was used to break the internode of the bamboos,

while a drill bit of 3mm was used in punching the bamboo on one side at a spacing of 1.2m to make perforations.

Canvas materials were sown to a diameter equal to the external diameter of the bamboos and were wrapped and clipped at both ends to cover the perforated sections which serve as a line source emitters. Piezometers were fixed between the emitters at the internode connections. Other materials used were stop watch, control valves, tap water and other accessories.

METHODOLOGY

The experiment was conducted in two phases: one in lateral laid with opened end and two in lateral laid with plugged end. In each case, the experiment was carried out with four different operating pressure heads (7.5, 15, 22.5 and 30m) calibrated by using pressure gauge (Nir, 1982; Jensen, 1983; Zhu *et al.*, 2012). The calibration was done by opening and regulating the tap control valve to allow the water to flow into the laterals until the desired operating pressure head was obtained for each experiment.

For each operating pressure head, the volume of water discharged from the emitters were collected after one hour using transparent graduated plastic buckets placed under each emitter. At the same time, the pressure drops along the respective laterals where recorded using the piezometer mounted between the emitters at the internode connections. The emission exponent (X) and the proportionality constant (K) values were computed from Equations 2 and 3, respectively.

The data obtained and recorded were subjected to statistical analysis using descriptive statistics, t-test, as well as regression and correlation analysis as outlined in Wahua (2010).

RESULTS AND DISCUSSION

The results obtained and recorded for the opened and plugged end laterals are statistically summarized in Table 1. It was observed that the mean values for the emitter discharge increased as operating pressure head increases for the respective laterals. The highest values (1.42 l/hr) and 2.08 l/hr) were recorded when operating with the highest operating pressure (30m) in both cases. This is in line with the principle in drip irrigation as the average operating pressure usually influences discharge (Zhu *et al.*, 2010). The values obtained were also low, but falls between the normal range of 1 and 10 l/hr,

depending on the operating pressure as documented in literatures (Nir, 1982; Michael, 1992; Garg, 2007; Sharma and Sharma, 2008). However, the overall mean value of the emitter discharge for plugged end lateral significantly ($P \leq 0.01$) differed from the opened end lateral (Table 2). This is probably due to the pressure build up in the plugged end lateral which forces more water to discharge from the emitters.

The relationship between the emitter discharge and operating pressure for opened and plugged end laterals were also presented in Figures 1 and 3, respectively. It was observed that there was a highly positive significant ($P \leq 0.01$) value of "r" (0.97**) for the opened end lateral (Fig. 1), while for the plugged end lateral, the high positive "r" value (0.96) was not significant (Fig. 3). However, in each case, the high positive value of "r" obtained indicates a strong positive linear relationship between the emitter discharge and operating pressure. This implies that the higher the operating pressure, the more discharge obtained for the respective laterals.

The mean values of the emission exponent (X) for opened end lateral were observed to have maintained the same values at different operating pressure (Table 1). Similar trend was obtained for the plugged end lateral. However, there was a significant difference ($P \leq 0.05$) between the opened and plugged end laterals with respect to the overall mean values of the emission exponent (Table 2). Although, a significant variation between the laterals was obtained, the mean values recorded for both laterals fall within the range ($0.5 \leq x \leq 1$), implying an intermediate flow regime (Keller and Karmeli, 1975; Nir, 1982). This means that the flow was neither turbulent nor laminar in each lateral.

The proportionality constant (K) mean values had no consistent trend at different operating pressures for the respective laterals (Table 1). High values (0.1 and 0.05) were obtained with the lowest operating pressure (7.5m) for opened end and plugged end laterals, respectively. The overall mean value for opened end lateral significantly ($P \leq 0.05$) differed from the plugged end lateral (Table 2). Pressure drops along the opened end lateral did not significantly

($P > 0.05$) vary from the plugged and lateral (Table 2). However, the overall mean value recorded was about 17.99% higher than the plugged end lateral, implying that in the opened end lateral, more pressure might be required for the water to flow.

In relating the pressure drop and emitter distance along the laterals, a strong negative relationships were respectively obtained for each lateral (Figs. 2 and 4). The relationships were observed to be highly significant ($P \leq 0.01$) with "r" values of -0.98** and -0.99** for opened and plugged end laterals, respectively. This indicates that as the emitter distance increases along the respective lateral, the pressure drop keeps on decreasing.

Thus, the findings from the study suggests that the use of bamboo as trickle line source emitter might be possible, taking into considerations other factors such as environmental, institutional, socio-economic and technical problems of the farmers especially in developing countries.

CONCLUSION

The possibilities of using bamboo as trickle irrigation line source emitter was evaluated. The evaluation was carried out by using opened and plugged end bamboo laterals. The result highlights that the emitter discharge for the respective laterals increased as the operating pressure head increases. The discharge from both laterals were low, and falls within the recommended range of 1 and 10 l/hr. The pressure drops decreased as the emitter distance increases along each lateral. The flow regime in each lateral was observed to be an intermediate flow based on the computed emission exponent (X) values.

Based on the results, the study concludes that the use of bamboo lateral as a line source emitter in trickle irrigation might be real. It might be also used in advising the local farmers on how to modify the conventional trickle irrigation laterals into bamboo (as line source emitter) in order to reduce the cost implications of the system.

Table 1: Statistical Summary of the results for emitter discharge (q), emission exponent (x) and constant (k) for opened and plugged end laterals

Emitter Discharge (l/hr)												
Operating Pressure (m)	Opened end						Plugged end					
	N	Min.	Max.	Mean	S.D	C.V%	N	Min.	Max.	Mean	S.D.	CV%
7.5	7	0.47	0.57	0.52	0.03	5.77	7	0.59	0.78	0.65	0.07	10.76
15	7	0.70	0.76	0.73	0.02	2.74	7	0.71	1.01	0.88	0.11	12.50
22.5	7	0.91	0.97	0.95	0.02	2.11	7	1.35	1.65	1.48	0.12	8.11
30	7	1.33	1.48	1.42	0.05	3.52	7	1.75	2.27	2.08	0.20	9.62
Emission Exponent (x)												
7.5	7	0.84	0.89	0.86	0.02	2.33	7	0.84	1.25	1.00	0.18	18.00
15	7	0.84	0.89	0.86	0.02	2.33	7	0.84	1.25	1.00	0.18	18.00
22.5	7	0.84	0.89	0.86	0.02	2.33	7	0.84	1.25	1.00	0.18	18.00
30	7	0.84	0.89	0.86	0.02	2.33	7	0.84	1.25	1.00	0.18	18.08
Emission Constant (k)												
7.5	7	0.083	0.111	0.10	0.01	10.00	7	0.025	0.099	0.05	0.03	60.00
15	7	0.073	0.087	0.08	0.006	7.50	7	0.017	0.071	0.03	0.02	66.67
22.5	7	0.073	0.086	0.07	0.005	6.25	7	0.025	0.094	0.02	0.02	50.00
30	7	0.079	0.099	0.09	0.007	7.78	7	0.018	0.09	0.04	0.03	75.00

N = Number of samples

S.D. = Standard deviation

C.V. = Coefficient of variability in percentage (%)

Table 2: Mean parameters recorded/computed for opened and plugged end laterals and the calculated t-values

Parameters	Unit	Laterals		Calculated value	t-
		Opened end	Plugged end		
Emitter Discharge (q)	l/hr	0.905	1.274	2.897**	
Pressure Drop (H)	m	0.239	0.196	1.659 ^{ns}	
Emission exponent (x)	-	0.860	1.000	4.336*	
Emission constant (k)	-	0.086	0.042	8.918*	

*Significant at 5% level of probability using group t-test statistics

**Significant at 1% level of probability using group t-test statistics

^{ns}Non significant

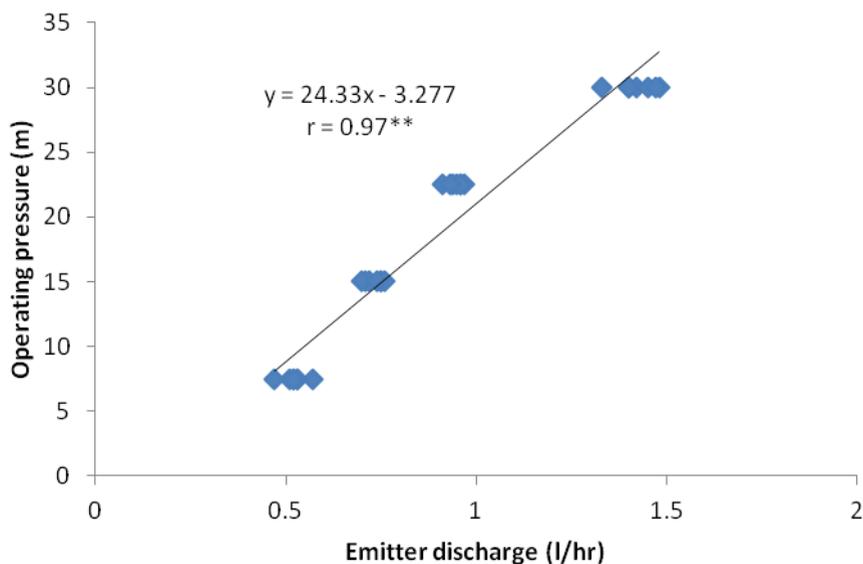


Fig. 1. Relationship between operating pressure and emitter discharge for an opened end lateral.

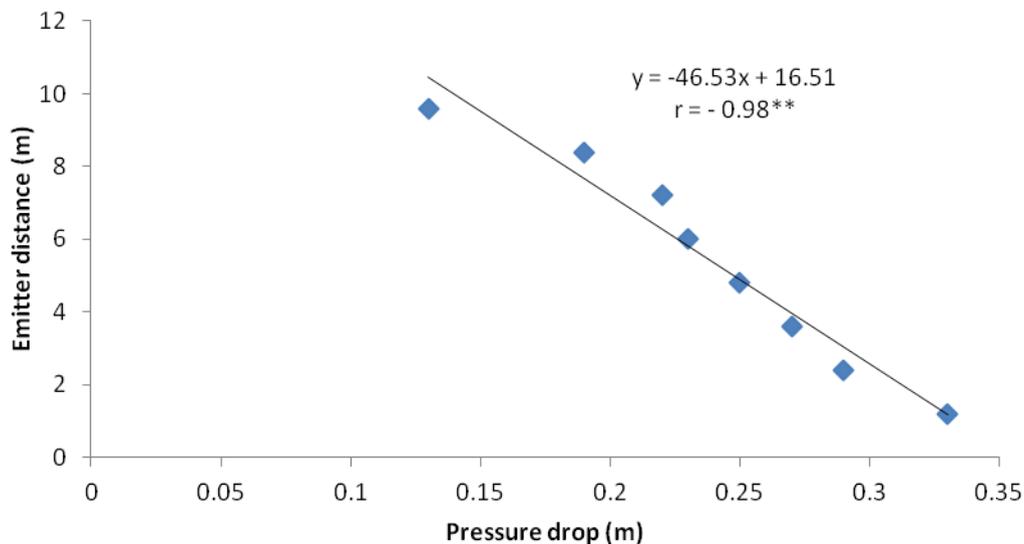


Fig. 2. Relationship between emitter distance (spacing) and pressure drop for an opened end laterals.

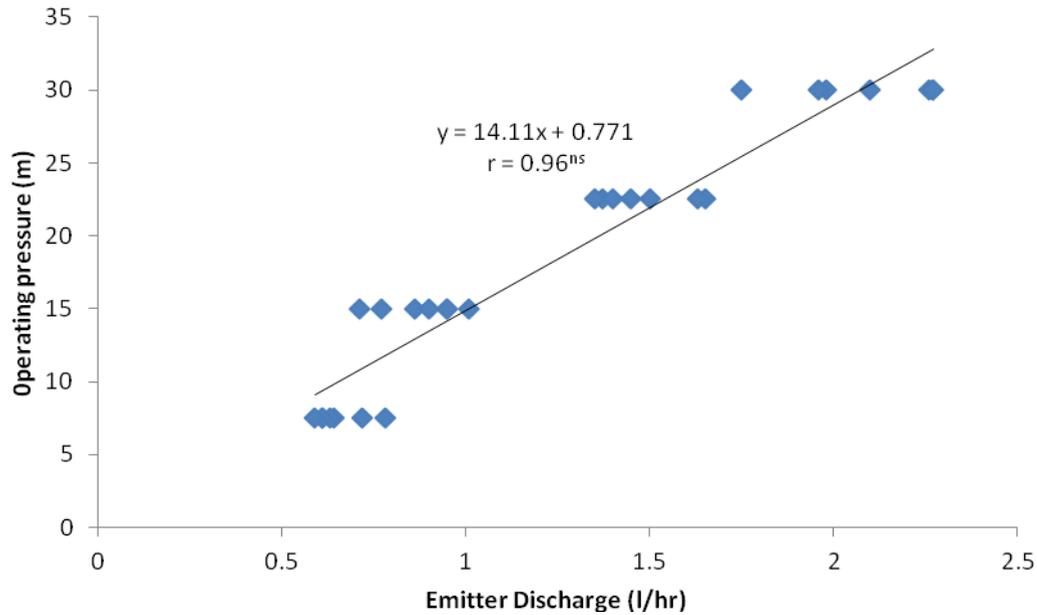


Fig 3. Relationship between operating pressure and emitter discharge for plugged end laterals.

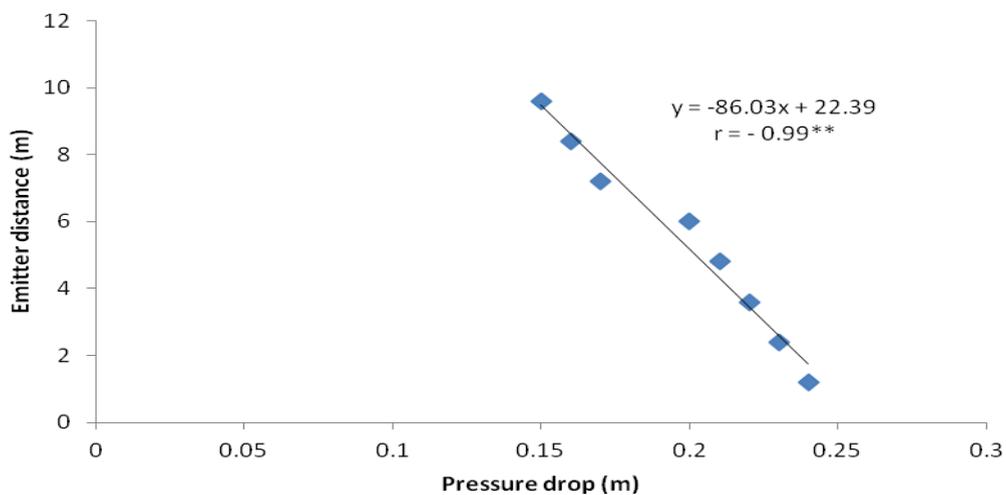


Fig. 4. Relationship between emitter distance (spacing) and pressure drop for plugged end laterals.

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