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Design, construction and evaluation of an affordable continuous-flow drip irrigation system

Entwurf, Konstruktion und Bewertung eines preiswerten Tropfbewässerungssystems mit kontinuierlichem Zufluss

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Stichworte
Preiswertes Tropfbewässerungssystem, Schwerkraftbewässerung, kontinuierlicher Bewässerungszufluss, Infusionsbesteck

Key words
Affordable drip irrigation system, gravity irrigation, continuous-flow, infusion set

Zusammenfassung

Die Arbeit berichtet über ein preiswertes Tropfbewässerungssystem, das in Bauchi State, Nigeria entworfen, konstruiert und bei Bewässerung einer Tomatenkultur geprüft und bewertet wurde. Dem Entwurf des Systems liegt zu Grunde, dass der Tagesspitzenbedarf der jeweiligen Kultur auf der Basis des kontinuierlichen Bewässerungszuflusses abgedeckt wird. Das System wurde ausschließlich aus preiswerten, lokal verfügbaren Materialien hergestellt. Dies schließt die modifizierte Form des in der Medizin gebräuchlichen Infusionsbesteckes als Tropfer ein.

Die durchgeführten Untersuchungen ergaben selbst bei unterschiedlichen Ausflussraten hohe Effizienzen in der Anwendung des Verfahrens, der erzielten Wasserverteilung etc. Das insgesamt positive Erscheinungsbild der ermittelten Leistungsparameter deutet auf eine gute Praxistauglichkeit des Verfahrens mit kontinuierlichem Zufluss hin. Der Verstopfungsgefährdung der Tropfer konnte hinreichend mit Hilfe von preiswerten lokalen primären und sekundären Filtern und der wöchentlichen Reinigung des Systems mit einer Lösung aus Natriumhyperchlorid begegnet werden.

Die Ergebnisse der durchgeführten Untersuchungen ergaben, das das Verfahren die Möglichkeit zur Steigerung der Nahrungsmittelproduktion in den Entwicklungsländern eröffnet und zwar in einer nachhaltigen Form. Das entwickelte Tropfbewässerungsverfahren mit kontinuierlichen Zufluss besitzt zu dem das Potential zur Armutsbekämpfung in den ländlichen Gebieten der Entwicklungsländer.

Abstract

An affordable continuous-flow drip irrigation system was designed, and evaluated in Bauchi state, Nigeria with tomato as test crop. The system was designed to deliver the peak daily crop water requirement on a continuous basis throughout the day. The calculated continuous-flow rate was 9 drops of water per minute. The hydraulic design was based on a step wise use of the energy equation. The system was constructed exclusively from cheap and locally available materials, incorporating a modified form of the medical infusion set as emitter. Results of the system's evaluation revealed high Application Efficiencies in the order of 95, 96, 96, and 98% under continuous discharges of 9, 13, 17, and 21 drops/min respectively. The corresponding Irrigation Efficiencies were 94.0, 90.1, 91.0, and 88%. Measured Distribution Uniformity for the four treatments were 90.0, 91.4, 93, and 97% while the Adequacy of Irrigation were 92.0, 93.1, 94.0, and 98% for the four treatments in same order. Such high values of measured performance parameters indicate an excellent exploit of the continuous-flow system. Emitter clogging which is a common menace with drip systems was controlled fairly well by two improvised low-cost primary and secondary filters, and a weekly addition of sodium hypochloride solution. The drip system has an initial cost of ₦ 11,280 to ₦ 48,480 (US $80 to 350) depending on materials used, and can irrigate 288 vegetable crop stands continuously for ten days without refill. This research therefore recommends a new dimension in affordable micro-irrigation technology that could assist developing countries to increase their food production several folds in a sustainable manner. The continuous-flow drip system also provides potential to accelerate poverty alleviation within rural communities of developing countries.

1. Introduction

World population currently growing at a rate of about 1.5% (HINRICHSEN et al., 1998) is intensifying pressure on our natural resources especially water. Predictions inform that by the year 2025 about 35% of the world population may face water shortages (HINRICHSEN et al., 1998). This worrisome forecast has attracted concerted efforts to speedily institute potent water management policies that may prevent water scarcity in the future. Most recommended strategies to avert an impending water crisis emphasis increased efficiency from the irrigation sub-sector, and one way of achieving this is for farmers to switch over from the traditional flooding method of irrigation to the highly efficient drip system. Regrettably, the cost of conventional drip systems deters their adoption by peasant farmers who command the agricultural sector of developing countries. Consequently, only about 1% of the total irrigated land world wide is currently under drip irrigation (POSTEL, 2003).

Recently, the concept of Affordable Micro-irrigation systems has been identified as a commensurate drip technology for low-income farmers. These systems equally posses momentous potential for efficient agricultural water use. Considerable research has therefore been conducted in this domain with much successes (BAQUI and ANGELES, 1995; POLAK et al., 1997; BISSRAT et al., 2001; ANON., 2002; MASIMBA, 2003). Most low-cost micro-irrigation systems in use today such as the drum and bucket drip kits (CORNISH and BRABBEN, 2001), and the Nica Irrigation (ANON., 2003) apply water in pulses often twice a day. This custom necessitates frequent farm visits, leading to increased systems running cost. To over come this, an improved low-cost drip system is introduced in which the daily crop water requirement is applied continuously over the 24 hours of a day. The system incorporates a modified form of the medical infusion set as emitter, here after referred to as “medi emitter”. It operates under very low continuous flow rates in the order of 9-25 drops of water per minute for vegetable crops. The system has the distinct advantage of offering farmers sufficient opportunity to undertake other off farm economic activities to generate more income.

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. The affordable continuous-flow drip system introduces two novel attributes: the continuous flow principle, and the emission device. These constitute two sources of extraneous variables that would affect the emitter clogging and hydraulic variation of the drip system, and so influence the overall systems performance. This study therefore investigated the effect of a continuous water flow, and adoption of the medi-emitter, on the hydraulic performance of the affordable continuous- flow drip system.

2. Materials and methods

2.1 Systems description and operational principles

The irrigated field was partitioned into four plots (3m x 3m) to reduce the pressure head requirement. Fig. 1 shows the system layout. Each plot was supplied by a distributary tank shown in fig. 2. Gate valves were placed at the outlet of each distributary tank to control flow. Float valves were equally fitted at the inlet of these tanks to maintain constant pressure head which would ensure a steady discharge to the crops. The plots were interconnected and eventually linked to two main water reservoirs (fig. 3) situated at the farm gate. The mains and manifolds were buried 200mm below ground surface to protect them from destruction during farm activities. Two types of low-cost filters were improvised for the system: A primary filter, made of 10mm thick foam placed at the pipe intake from the main water reservoir, and a secondary filter adapted from automobile fuel filter (fig. 4) inserted along the main pipeline.

Initially, the valves at the exit of the distributary tanks were closed while water was released from the main storage reservoir. All emitters were adjusted to 30-40% open position. Water flowed into the distributary tanks up to a height corresponding to the calculated pressure head required to cause flow- in this case 250mm. The float valve in the distributary tank cuts water supply when this pressure head is reached.

Next, the gate valves at the exit of the distributary tanks were opened fully. This supplied water to the field through the medi-emitter in jets, with discharges of 14-15 *l*/hr. Water was allowed to flow thus for about 30 minutes to permit the pre-irrigation water requirement to be satisfied. The water level in the distributary tanks dropped during this irrigation phase because the outflow from the tank was higher than the inflow. Transplanting was done towards the end of pre-irrigation. Thereafter, each emitter was tuned to deliver water at pre-determined continuous-flow discharges in drops per minute. After calibration, the water level built up back to the design 250mm mark, and a continuity was achieved. The continuity was maintained throughout the growth season.

2.2 Field procedure

The hydraulic evaluation of the continuous-flow drip system was conducted during the 2003/2004 irrigation season. The system was assessed under four continuous flow rates: 9 drops/min, 13 drops/min, 17 drops/min, and 21 drops/min, replicated three times in a randomised complete block design. The treatments were represented by each of the four laterals for every plot. Water was sourced from a near by well and delivered to the main water reservoir using a pump. From the main reservoir, flow was by gravity to the distributary tanks and thence to the crops. Growth of micro-organisms was controlled in the system through weekly addition of a 3.5% sodium hypochlorite solution to the irrigation water (ENGLISH, 1985). The quantity of hypochlorite solution injected was calculated from eqn. 5 (MEYER, 1985).

$$V_{cl} = \frac{required\ \ ppm\ chlorine \times 12.8}{Y} \tag{1}$$

Where:

V_{cl} = ounces of liquid chlorine material required per 3785l of water.

Y = rated chlorine percentage in the material.

Figure 1:
Field layout

Figure 2:
Side view of the distributary tank

Figure 3:
Main water reservoirs

Figure 4:
The low-cost secondary filter

2.3 Determination of hydraulic performance parameters

The hydraulic design of drip systems is essentially centred on ensuring that water is conveyed to each emitter at a pre-determined pressure head that would cause satisfactory flow. The general design criterion is to limit the pressure and discharge variation in the system to within 30% (WU, 1997). The hydraulic performance parameters used to evaluate drip systems therefore exposes the differences in discharge within the system. Differences in flow rates are reflected in discharge coefficients of variation. Five discharge coefficients of variation (WU, 1997) are conventionally used to evaluate micro-irrigation systems. These are:

- – Coefficient of variation of emitter flow caused by hydraulic design, CV(H).
- – Coefficient of variation of emitter flow caused by manufacturer's variation, CV(M).
- – Coefficient of variation of emitter flow caused by hydraulic design and manufacturer's variation, CV(HM).
- – Coefficient of variation of emitter flow caused by hydraulic design, Manufacturer's variation and grouping CV(HMG).
- – Coefficient of variation of emitter flow caused by emitter plugging, CV(P).
- – Coefficient of variation of emitter flow caused by hydraulic design, Manufacturer's variation and plugging CV(HMP).

Fig. 5 shows the lateral layout for the low-cost drip system. The total energy upstream each lateral was calculated using the energy equation in a step by step manner (DAKE, 1983; CAMP et al., 1997), while the head loss along the lateral was computed from eqn. 2 (SCHWAB et al., 1993).

$$H = \frac{K_s L\ Q^r}{D^{4.9}} \left(4.10 \times 10^{-6}\right) F_n \tag{2}$$

Where:
H = friction head loss in pipeline with several outlets, m
K_s = Scobey's coefficient of retardation.
L = pipe length, m
Q = discharge through pipe, l/s
D = inside diameter of pipe, mm
r and F are constants depending on the number of outlets and pipe material.

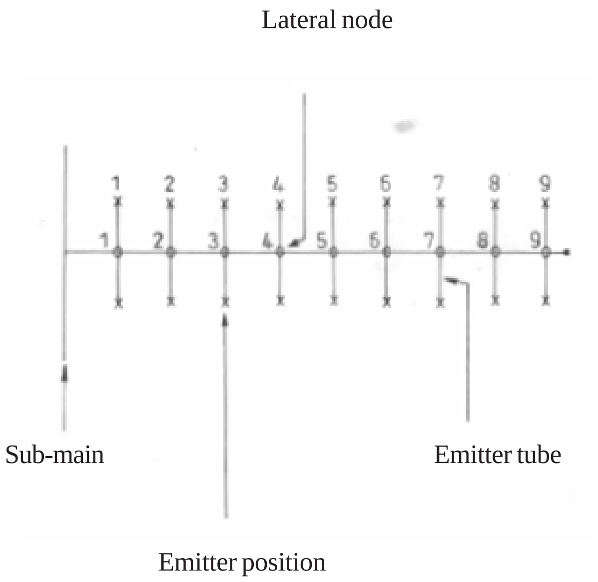

Figure 5:
Lateral layout of the affordable continuous-flow drip system

When the valves are opened and the entire lateral length is filled with water, the continuous flow principle enables equilibrium to be attained. Thereafter, emitters would experience additional hydrostatic pressure caused by the column of water upstream a particular node. The value of this additional pressure head reduces from about 3.8 cm at the last node to 0 cm at the first node since the lateral sloped downwards. The total pressure head at the lateral nodes was therefore taken as the sum of the hydrostatic pressures from the water column in the lateral before any particular node and the hydrostatic pressure delivered by the water column in the distributary tanks. The energy loss along the emitter tube was subtracted from the total hydrostatic pressure at the lateral node to obtain the pressure at the emitter available to cause flow. The pressure head at each emitter point was substituted into the emitter flow function to determine the theoretical discharges. The emitter flow function is of the form.

$$q_e = 15 P_e^{1.038} \tag{3}$$

Where P_e is water pressure at emitter centre line in m.

CV(M) is a measure of the precision with which emitters are made by manufacturers. This discharge coefficient was calculated as the standard deviation of emitter flow rates divided by the mean discharge value. Fifty medi-emitters were used to determine CV(M). The emitters were fitted one after the other at same point on each lateral. This ensured pressure and all other flow variables were maintained constant at the reference locations. Discharge was measured from each of the emitters using the volumetric method, and values used to determine CV(M).

CV(HM) expresses the total variation in emitter flow rate caused by both hydraulic and manufacturing variations. CV(HM) was calculated from eqn. 4 (WU, 1997).

$$\mathrm{CV}^2(\mathrm{HM}) = \mathrm{CV}^2(\mathrm{H}) + \mathrm{CV}^2(\mathrm{M}) \tag{4}$$

CV(HMG) was not computed because the emitters were not grouped into sub-units. This parameter is applicable only when a number of emitters are grouped together into one unit, typically to irrigate crops requiring wide wetting diameter such as orchard crops.

CV(P) was computed as a function of percentage plugging from eqn. 5 (WU, 1997).

$$CV(P) = \sqrt{\frac{P}{1-P}} \tag{5}$$

Where $P =$ level of plugging

No complete plugging was identified. The few cases of plugging isolated, were all partial plugging. The level of partial plugging was reckoned by the degree of discharge reduction from each emitter. This procedure embraced a spectrum of P values because the emitter experienced varying levels of partial blockage. Nevertheless, for simplicity and proper representation the highest value of P was used for computation of *CV(P)*.

Finally, CV(HMP) was obtained from eqn 6 (WU, 1997).

$$CV^2(HMP) = \frac{CV^2(HM)}{1-P} + \frac{P}{1-P} \tag{6}$$

The hydraulic performance parameters were determined for all treatments on a weekly basis throughout the growth season. Values obtained were averaged and recorded in tables.

2.4 Determination of systems performance parameters

The hydraulic characteristics of an irrigation system eventually translates to observable systems performance parameters which are of more direct implication to crop growth and yield. 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 systems goal in this case is to supply each plant with the calculated water requirement at same delivery rate. The systems performance parameters used in this study are therefore those that measure the uniformity of water flow to the field. The most widely accepted hydraulic performance parameters used in assessing micro-irrigation systems vis-à-vis parity in water distribution are: Emitter flow rate variation (q_{var}), Discharge coefficient of variation (CV_q), Christiansen uniformity coefficient (*CUC*), and Distribution uniformity (*DU*) (CAMP et al., 1997; KANG et al., 1999; KANG and NISHIYAMA, 1996).

q_{var} was calculated from eqn. 7.

$$q_{\text{var}} = \frac{q_{\max} - q_{\min}}{q_{\max}} \times 100\% \tag{7}$$

Where q_{max} is the maximum emiter flow and q_{min} is the minimum emitter flow. CV_{qar} was taken as the ratio of the standard deviation of the emitter discharges to the average flow rate, and expressed as a percentage. *CUC* was computed from eqn 8 as follows (KANG et al., 1999)

$$CUC = \left[1 - \frac{\frac{1}{n}\sum_{i=1}^{n}\left|q_i - \bar{q}\right|}{\bar{q}} \right] \times 100\% \tag{8}$$

Where $\bar{q}$ = average discharge.

Finally, *Du* was evaluated as the ratio of the average low-quarter discharge to the average discharge, expressed as a percentage. These uniformity parameters were calculated from two perspectives. Firstly using point discharges measured simultaneously from every emitter. This gave a spatial uniformity measure. The performance indices were again computed for each emitter position on a weekly basis through to the end of the growth season. This revealed the system’s change in discharge uniformity with time. The results are presented as discrete entries in tables.

3. Results and discussion

Table 1 contains the calculated pressure heads at the emitter centre lines, and the theoretical discharges for a typical lateral of the affordable continuous-flow drip system. Fig 6 shows the trends in the water energy components of same lateral. Table 1 depicts that the available pressure heads at the emitters is not equal. The pressure head increases from about 3.43 cm at the first emitter position to 7.04 cm at the last emitter. The difference between these two extreme pressure values is about 51%. This value exceeds the 30% criterion for drip systems (WU,1997). This pressure variation would evidently cause excessive discharge irregularity among the emitters of same lateral. The design recommendation to reduce the pressure variation is to use laterals with larger diameters. This suggests a recourse to the more expensive pressure PVC pipes since the cheaper electrical conduit pipes used as laterals for the system have been standardised to 20mm diameter, at least within most rural communities of developing countries. Alternatively, equal emitter discharge may be achieved by use of emitters that have provision for discharge regulation. The affordable continuous-flow drip system analysed in this study incorporates a modified form of the medical infusion set as emitter. This device has provision for precise flow control. With this emitter, drip systems could be designed for any combination of lateral length and diameter. Discharge variation are damped out by simply adjusting the emitters to deliver same pre-calculated discharge. This regulatory advantage connotes that any cheap and locally available conduit could be adapted to serve as lateral pipes.

The observed pressure variation among the emitters results largely from topographical irregularities, the kinetic energy component being insignificant. The contribution of the hydrostatic pressure to the total energy of the water was between 0-54 %. Presence of a bumpy land slope generates variable hydrostatic pressures along the lateral length. Therefore proper land levelling is very crucial for such low-cost micro-irrigation systems designed with non-regulatory and non-pressure compensating emitters.

Fig 6 shows that the reduction in pressure and kinetic energy of water flowing through the system’s lateral follows a decay curve. Nevertheless, the shape of the total energy line is linear. This is in contrast with the energy grade lines of conventional micro-irrigation systems. The reduction in water energy for standard drip systems follows a decay curve that stabilises after ¾ of the lateral length. Only the pressure and kinetic energy curves of the affordable continuous-flow drip system conforms to this trend. The shape of the energy grade line is linear, probably because the contribution of the curvilinear kinetic energy component to the total water energy is very infinitesimal- in the order of $4.66x10^{-8}$ to $1.77x10^{-4}$ %. The very small water kinetic energy of this system results from the very low discharges (9-25 drops of water per minute). According to the energy grade line equation, an available pressure head of only 20 cm at the entrance of the lateral can successfully supply similar lateral of length up to 750 cm. In same vain, a hydrostatic pressure head of only 1m at the distributary tanks could supply four laterals each of length 750cm, with 33 emitters per lateral. Therefore a 1m pressure head can irrigate up to 132 vegetable crop stands with continuous flow rates of 9-25 drops/minute.

Table 1:
Calculated pressure heads and theoretical discharge for a typical lateral of the Low-Cost Continuous-Flow Drip Irrigation System

Lateral node No.	Hydrostatic pressure head component from lateral (cm)	Hydrostatic pressure head component from distributary tank (cm)	Available pressure head at emitter centre line (cm)	Theoretical discharge (*l*/hr)
1	0.00	3.62	3.43	0.45
2	0.80	3.56	4.17	0.55
3	1.20	3.52	4.53	0.60
4	1.60	3.49	4.90	0.65
5	2.00	3.46	5.27	0.70
6	2.40	3.44	5.65	0.76
7	2.80	3.43	6.04	0.81
8	3.20	3.43	6.44	0.60
9	3.80	3.43	7.04	0.95
Average	2.23	3.49	5.27	0.67
Standard error	0.43	0.02	0.20	0.21

Table 2 shows the hydraulic performance parameters of the continuous flow drip system. From the table, measured CV(H) values for all treatments are less than 30% despite an excessive pressure variation of 51% between the two extreme pressure values. Wu (1997) reported that a CV(H) of not more than 30% could yield spatial uniformities greater than 80%, which are characteristic of drip systems. Therefore, these CH(H) values indicate an acceptable systems performance of the continuous-flow drip kit. Also, the CV(M) values of the medi-emitter measured at the four discharges are all less than 10% and fall within the general 2-20% range reported by Solomon (1979) for common emitters. The low CV(M) values reflect high manufacturing precision of the medi-emitter. This permits the device to be safely used for low-cost drip systems.

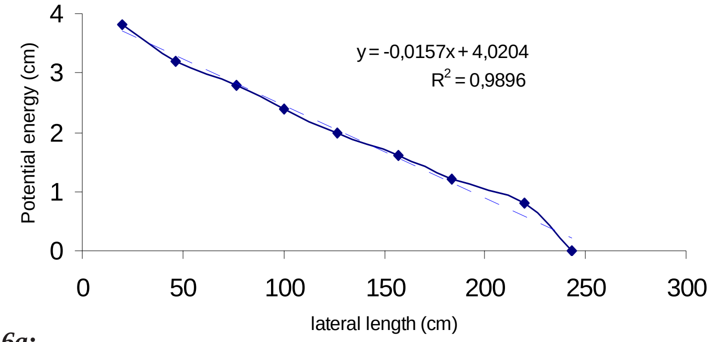

Figure 6a:
Graph of water potential energy against lateral length of the continuous-flow drip system

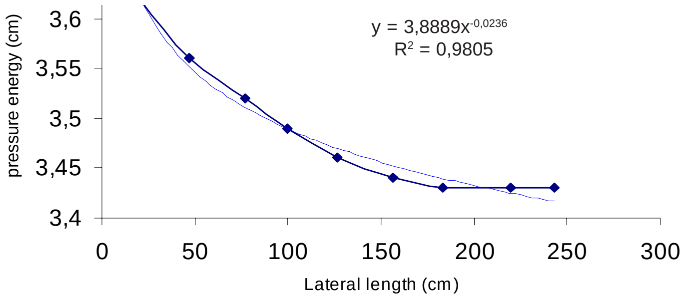

Figure 6b:
Graph of water pressure energy against lateral length of the continuous-flow drip system

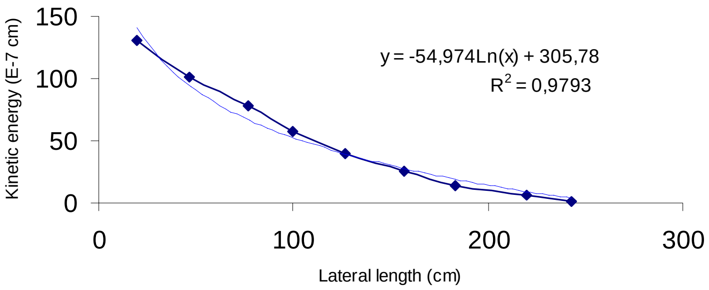

Figure 6c:
Graph of water kinetic energy against lateral length of the continuous-flow drip system

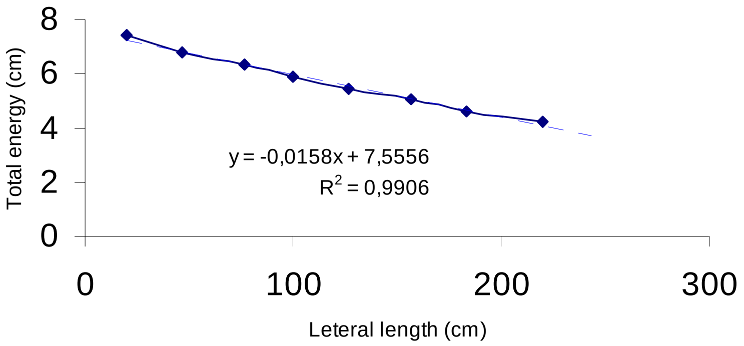

Figure 6d:
Graph of total water energy against lateral length of the continuous-flow drip system

The CV(P) values however seem relatively high . Plugging in the system was caused solely by precipitated salts in the water. No blockage caused by solid soil or organic particles was detected. This implies a 100% efficiency of the improvised primary and secondary filtration units. The very low flow rates favored settlement of the precipitates within the pipeline, leading to observable plugging conditions. Nevertheless, all identified plugging were partial plugging which were effectively corrected using practicable low-tech procedures.

Table 2:
Hydraulic performance parameters of the low-cost continuous flow drip system

Discharge (drops/min.)	Hydraulic performance parameter (%)				
	CV(H)	CV(M)	CV(HM)	CV(P)	CV(HMP)
9	20.61	7.98	22.10	62.0	45.7
13	20.83	7.92	22.28	53.0	34.6
17	20.92	7.89	22.36	35.0	18.1
21	20.96	7.88	22.39	35.0	18.1
Average	20.83	7.92	22.28	46.25	29.1
Standard error	0.007	0.005	0.005	0.25	0.40

The relatively high CV(P) values simply insinuate that plugging is the strongest factor affecting the discharge coefficient of variation of the continuous flow drip system. This CV(P) range (35-62%) resulted from 11-28% partial plugging. Similar observation was reported by Wu (1997) who noted that a 5-10% plugging could produce CV(P) of 23-33%. On this premise, the CV(P) of the continuous flow system is within tolerable limits.

The overall discharge coefficient of variation CV(HMP) was evidently affected most by plugging. The overall CV(HMP) of 18.1-45.7% gave delightful spatial uniformity as shown in tables 3 and 4. From table3, the CUC and DU of the system were within 88.0-97.0%. This uniformity range is considered admissible. Therefore, the plugging condition of the system is not severe enough to attract more stringent corrective measures. The affordable continuous flow drip irrigation system is a contribution to existing Affordable Micro-irrigation Technologies (AMIT) targeted to the low income farmers of developing countries. This intimates that the systems capital and running cost must be maintained to the bearest minimum. Attempts to reduce the systems plugging further, would apparently attract additional cost that may be un affordable by peasant farmers, and so defeat the fundamental design objective of the system. Table 3 further reveals that the systems spatial uniformity ameliorates with increase in discharge. However, higher discharge implies more losses. In this dispensation where water economy is a sonorous global anthem, 9 drops/min could still be a reasonably safe discharge to use especially as it gave average CUC and DU of 92.3% and 89.7% respectively which are acceptable.

From Table 3 and 4, there is a clear reduction is systems spatial uniformity down the lateral, and with time. The reduction is due to accumulation of precipitates in the direction of flow which is towards the end of the lateral. This caused emitters supplied by the last lateral nodes to be severely vulnerable to plugging, contrary to those upstream. Therefore, to achieve a fairly constant uniformity through out the season, atleast a weekly cleansing of the terminal emitters in particular is obligatory.

4. Conclusion

The hydraulic design and component selection of the affordable continuous-flow drip system offer satisfactory hydraulic performance. Adoption of the medi-emitter in particular, contributes considerably in offering high spatial uniformity. Otherwise, precise landlevelling becomes crucial to achieving even water distribution. The pressure head required to activate the system is fairly low, often not more than 1m. A 1m pressure head at the distributary tank can supply up to 132 closely spaced vegetable crops with low continuous flow rates of 9-25drops of water a minute. This design therefore presents an attractive prospect for the advancement of Affordable micro irrigation technology. However, for proper functioning, the medi-emitters, especially those towards the end of the laterals require a weekly check against clogging.

Table 3:
Average seasonal performance parameters with respect to emitter position (Values are in percentages)

Emitter No.	Discharge (drops/min)															
	9				13				17				21			
	q_{var}	CVq	CUC	DU	q_{var}	CVq	CUC	DU	q_{var}	CVq	CUC	DU	q_{var}	CVq	CUC	DU
1	27.3	12.1	90.54	90.6	15.4	5.6	95.7	90.4	11.1	4.8	96.8	94.1	4.80	2.30	97.9	96.8
2	27.3	12.1	90.54	90.6	15.4	5.6	95.7	90.4	11.1	4.8	96.8	94.1	13.6	4.70	95.9	92.7
3	20.0	7.80	93.6	90.6	14.3	5.9	94.7	94.7	16.7	6.6	94.0	90.0	13.6	4.70	95.9	92.7
4	11.0	4.20	96.6	90.6	15.4	7.4	93.1	94.7	11.1	4.8	96.8	94.1	4.80	2.40	97.6	97.6
5	20.0	7.80	93.6	90.6	15.4	7.4	93.1	90.4	11.1	4.8	96.8	94.1	4.80	2.30	97.4	96.8
6	20.0	7.50	93.9	87.3	15.4	7.4	93.1	90.4	11.1	4.8	96.8	94.1	9.50	3.70	96.7	93.4
7	27.3	11.1	88.9	88.9	15.5	7.4	93.1	90.4	11.1	4.3	95.2	92.3	9.50	3.70	96.7	93.4
8	27.3	11.1	88.9	88.9	21.4	7.7	93.3	88.0	16.7	6.6	94.0	90.0	9.50	3.70	96.7	93.4
9	20.0	6.40	94.4	88.9	21.4	7.7	93.3	88.0	16.7	6.6	94.0	90.0	13.6	4.70	95.9	92.7
Avg	22.2	8.90	92.3	89.7	16.6	6.9	93.9	90.8	12.9	5.3	95.7	92.5	9.30	3.60	96.7	94.4
SE	0.24	0.30	0.30	0.01	0.15	0.12	0.01	0.03	0.20	0.17	0.01	0.02	0.39	0.27	0.01	0.02

Table 4:
Systems performance parameters reckoned with time (Values are in percentages)

Percent Growth Season	Discharge (drops/min)															
	9				13				17				21			
	q_{var}	CVq	CUC	DU	q_{var}	CVq	CUC	DU	q_{var}	CVq	CUC	DU	q_{var}	CVq	CUC	DU
10	11	4.2	94.4	91.5	15.0	5.5	95.7	94.0	10.0	4.8	98.0	95.0	4.5	2.5	98.0	97.0
20	19.3	7.0	95.8	91.0	15.4	5.7	95.6	91.2	11.5	5.0	97.0	95.0	4.8	2.5	98.0	97.0
30	19.3	7.8	95.6	90.6	14.5	6.0	94.8	90.0	11.5	5.0	97.0	94.0	4.5	4.5	97.5	96.5
40	20	8.0	93.5	90.5	16.0	7.4	95.0	90.0	11.1	5.5	96.2	94.0	9.5	4.0	97.5	96.5
50	19.8	6.8	93.0	90.5	15.5	8.0	93.0	92.0	11.1	5.5	96.0	93.0	10.0	5.5	98.0	96.0
60	21.5	11.1	90.0	91.0	15.4	7.2	93.0	91.0	12.5	5.0	96.5	93.0	10.0	5.0	96.0	96.5
70	26	11.0	88.3	87.0	16.0	7.2	93.5	91.5	12.5	5.0	95.0	92.0	13.2	5.0	96.5	94.5
80	27.3	11.5	88.0	90.0	20.2	7.3	93.0	90.0	12.0	5.5	94.0	91.1	10.5	5.0	95.5	95.0
90	27.3	12.1	88.0	88.5	19.8	7.5	93.5	88.2	17.0	6.0	93.1	90.5	13.5	5.5	95.0	93.0
100	28	12.2	88.5	88.5	21.0	7.7	92.0	87.7	18.5	6.0	93.0	90.0	13.5	5.5	95.0	93.5
Avg	22.0	9.17	91.51	89.91	16.9	7.0	93.91	90.54	12.8	5.3	95.6	92.8	9.4	4.5	96.7	95.6
SE	0.23	0.29	0.34	0.02	0.14	0.12	0.01	0.02	0.20	0.08	0.02	0.02	0.37	0.24	0.01	0.01

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