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Hydraulic performance of drip irrigation system under different emitter types, and operating pressures using treated wastewater at Khartoum state

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Abstract

The experiment was carried out in the Faculty of Agriculture, University of Khartoum, during the period from May to September 2015. The objective of this study was to evaluate the hydraulic performance of drip irrigation system. The experimental work was held under laboratory condition, whereas a model for drip irrigation system was used. The treatments consisted of three types of emitters (turbo, Octa and barrel) with three operating pressures (P_1 (0.5), P_2 (0.75) and P_3 (1) bar). Treated wastewater with salinity 2.2 ds/m used as a source of the water supply. The uniformity parameters (coefficient uniformity (CU%), emission uniformity (EU%), coefficient of variation (CV%)) and clogging percentage (Pclog%)) were studied. The operating pressure kept constant during the experiment for each treatment. The SAS (statistical package) used for the data analysis. The results indicated that turbo emitter and P_3 (1 bar) revealed a significant differences ($P \leq 0.05$) in increasing CU% and EU% over the barrel and P_1 (0.5 bar), respectively. Therefore, barrel and P_1 (0.5 bar) recorded the highest values of coefficient of variation (CV%), while turbo emitter and P_3 revealed the lowest values. On the other hand, The emitter clogging percentage (Pclog%) of drip emitters is highly affected by emitter types and operating pressure. Whereas, the emitter clogging percentage decreased with increasing in operating pressure irrespective of emitter types. Nevertheless, turbo emitter showed the high resistance to clogging compared with the other emitters. This study concluded to that turbo emitter and operating pressure P_3 are more suitable to resist clogging and improving hydraulic performance of drip irrigation.

Keywords: Hydraulic Performance; Drip Irrigation; Emitter Clogging; Operating Pressure; Wastewater

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1. Introduction

Due to limited water resources and environmental consequences of common irrigation systems, drip irrigation technology is getting more attention and playing an important role in agricultural production, particularly with cash crops of high value such as greenhouse plants, ornamentals and fruit (Pescod, 1992). Drip irrigation is a system in which water is supplied directly to plant roots with a low pressure and flow rate to meet the crop water requirement. It is in extensive use around the world due it is controlling the applied water and easiest the irrigation management. Keller and Blaisner (1990) mentioned that drip irrigation is one of the most efficient irrigation methods. Therefore, this system is compatible for a wide range of crop varieties, soil types, climate and land surface despite of few potential constrains. Also it considered as the most effective and reliable method for reclaimed water irrigation (Pei et al., 2013).

Proper design and operating of drip irrigation system significantly minimize water use and energy consumption (Tyson and Curtis, 2009). Also stated that poor design may leads to under-watering many plants and over-watering the others rather than distributing water over the whole field.

Wastewater is domestic sewage, it refers to the liquid waste discharged from homes, commercial premises, agricultural drainage and industrial plants, which contains nutrient and hazardous impurities (Pescod, 1992). Sewage is an inevitable product of population centers and must be disposed off. Dumping of wastewater around cities and big towns is the current serious problem facing Sudan's municipalities, which may cause very serious pollution hazards. The volume of wastewater in town like capital Khartoum increases day by day due to the increase of population and developing of industrial sectors (Widaa et al., 2016). Due to the scarcity and unequal distribution of water resources in arid and semi-arid area, wastewater utilization appears to be the most suitable solution, which provides new- source of water and protects the environment. Furthermore, utilized wastewater increases crop yield and improved irrigation efficiency (Pescod, 1992).

The distribution uniformity of water is one of the important parameters to characterize drip emitters and design of a drip irrigation system. Clogging and emission non-uniformity, for a long time, have been the major obstacles in the development of drip irrigation. It would be a serious problem in areas with marginal water where the problems of precipitation of calcium carbonate, organic materials and suspended sands are severe. Emitter clogging can severely decrease the uniformity components of a drip irrigation system, especially when utilizing wastewater in irrigation. Therefore, precise assessment of emitters anti-clogging is important for selecting an appropriate emitter to address the required conditions (Zhou et al., 2017).

Emitters clogging causes classified into three general categories, viz: physical, chemical and biological or organic, such as sediment, bacteria and algae and scale, respectively (Zhou et al., 2017). Installation of filter equipment's before supply water to the system has solved a part of the problem, but could not eliminate it entirely so far and thus users have to be used difference methods to remove the precipitations by acid, which has adverse influences on soil and crops (Elobeid, 2006). In order to obtain the best emission uniformity (EU %) in uneven lands, the pressure regulators and pressure compensating emitters have been used. However, pressure compensating emitters tend to be more complex and costly than non-compensating emitters and are not easy to apply (Hezarjaribi et al., 2008). Many factors such as physical, chemical, biological, pressure, water temperature and construction changes, affecting the uniformity of water distribution. So the changes in any of the mentioned factors, particularly the pressure in the system that caused by poor design will bring tremendous changes in discharge and the uniformity of distribution and thus lowering the efficiency. The uniformity parameters are the main criteria for designing an efficient drip irrigation system.

Operating pressure is considered a very important in drip irrigation system design. Therefore, not accurate operating pressure leads to lack of performance and failure of the system (Valipour, 2012). Moreover, non-static operating pressure causes some problems such as defective pressure regulators, broken lines, and plugged emitters (Tyson and Curtis, 2009). Nevertheless, due to the lack knowledge of uniformity parameters, under varied operating pressures, this system is still facing problems of supplying water uniformly throughout the field. Therefore, this study aims to evaluate the hydraulic performance of drip irrigation system, under indoor conditions using treated wastewater, different emitter types (Turbo, Octa and Barrel) and three operating pressers (0.5, 0.75 and 1 bar).

2. Materials and methods

This study was conducted at the Faculty of Agriculture, University of Khartoum, Shambat (32°32′E, 15°40′N and 380 m above mean sea level), during May to September 2015, to assess the hydraulic performance of drip irrigation system under laboratory conditions, when treated wastewater is a source of the water used. The experiment was organized in split plot design, whereas the treatment was replicated three times. The emitter types were assigned to the main plot and the operating pressures were sub main plot.

2.1. Drip irrigation system layout

Small model of drip irrigation was used to evaluate the hydraulic performance of drip irrigation system. The emitters were spaced 50cm apart along the lateral lines, and the components of the model are:

1. A water tank of 1000 liter capacity was used to store treated wastewater
2. An electric motor 1/2 hp with a centrifugal pump used for pumping water from the tank
3. The control unit consisted of the following:
    a. Two valves, one before the pump and the other after it.
    b. Pressure gauge fixed before water entering the lateral line to maintain constant pressure throughout the system.
4. The mainline was a pipe of 4 m length, and 1 inch (2.54 cm) diameter, which made from polyethylene hose.
5. The lateral lines were made of black low density polyethylene (L.D.P.E) of 13 mm diameter and 5.85 m length. The distance between adjacent lines consecutive was 10 cm.

6. Emitters (Turbo (pressure compensating and 4 l/h discharge), octa (pressure compensating and 4 l/h discharge) and barrel (non-pressure compensating and 8 l/h discharge)) were fixed on with 50 cm spacing along the laterals.

Measuring cylinder, stopwatch and caught cans were used to measure the emitters' discharges.

2.2. Method

2.2.1. Discharge of emitter

The average discharge rate of 90 emitters, was measured using graduated measuring cylinder with 14 liter capacity, catch cans and stopwatch. The model was lifted to work for 2 hours, then the collected water in catch cans beneath each emitter, measured by graduate measuring cylinder. The method was repeated several times to get the average volume in liter. The average volume divided by time, to obtain the discharge (q) l/hr

2.2.2. Coefficient of uniformity (Cu %)

The coefficient uniformity was measured according to equation defined by (Christiansen, 1942) as follows:

$$Cu = 100\left(1 - \frac{\sum \Delta q}{q_n}\right) \qquad (1)$$

where:

Cu = Christiansen's uniformity coefficient in percentage

Δq = average deviation of individual emitters discharge (Lhr-1).

q = average discharge (Lhr-1).

n = number of observations.

2.2.3. 2.2.3 Emission uniformity (Eu %)

According to (Keller and Blaisner 1990) the emission uniformity is defined as follows:

$$EU\% = 100 q_n / q_a \qquad (2)$$

where:

Eu% = Emission uniformity

q_n = average rate of discharge of the lowest one fourth of the field data of emitter discharge readings (L/h)

q_a = average discharge rate of all the emitters checked in the field (L/h).

2.2.4. 2.2.4 The coefficient of variation of emitter flow (CV%)

The coefficient of variation of emitter discharge (CV%) was computed as follows:

$$CV\ \% = 100\ \frac{SD}{\bar{q}} \quad (3)$$

where:

CV= the coefficient of variation of emitter discharge.

SD = standard deviation of emitter discharge.

q- = average discharge in the same lateral lines (Lh^{-1}).

2.2.5. Percentage of Clogging emitters (Pclog%)

The clogging emitters percentage was determined using the following equation:

$$P_{c\log\%} = 100\left[\frac{Nes_{c\log}}{Nes_{total}}\right] \quad (4)$$

where

P_{clog} = percentage of clogging emitters (%).

Nes_{clog} = numbers of clogged emitters.

Nes_{total} = total numbers of emitters.

3. Results and discussions

The hydraulic performance of Drip irrigation System was assessed under controlled conditions. The common emitters used in Sudan (Turbo, Octa and Barrel) were selected with three operating pressures (0.5, 0.75 and 1 bar). The parameters of uniformity and emitter clogging percentage were evaluated. The results showed the types of emitters and operating pressures have a clear effect on the performance of drip irrigation system. Moreover, turbo emitter and P_3 (1 bar) revealed a significant differences ($P \leq 0.05$) in increasing CU% and EU% over the barrel and P_1 (0.5Bar), respectively. On the other hand, barrel and P_1 (0.5 bar) recorded highest values of coefficient of variation (CV%), while turbo emitter and P_3 revealed the lowest one (tables 1 and 2). From the other angle, the interaction between the emitter types and operating pressures, reflected that turbo under operating pressure P_3 has superiority over the other interactions in increasing the uniformity parameters (Figs 1, 2 and 3). The results supported by the finding of Mohamed (2013) who stated that, pressure compensating emitters are designed to discharge water at uniform rates under a wide range of water pressure, while non-pressure compensating emitters are designed to discharge water at uniformed rates, but the water pressure needs to remain relatively constant or the discharge will vary. The obtained values of uniformity parameters in this study were found acceptable according to Michael (1978), Bralts (1986) and Nakayama and Bucks (1991).

The clogging phenomena of drip emitters, is considered a serious problem affecting the performance of drip irrigation system. The results of this study revealed that the clogging percentage **(P_{clog}%)** of drip emitters affected by emitter types and operating pressure. Therefore, turbo emitter showed high advantages over acto and barrel emitters. From the other hand, emitter clogging problem tend to decrease with increasing in operating pressures. Whereas, P_3 (1 bar) recorded no clogging percentage, irrespective of emitter type, while the highest percentage of clogging was obtained with P_1 (0.5 bar), as shown in Fig 4. The results agreed with the findings of Capra and Scicolone (1998) who stated that the clogging percentage varied due to emitter type, pressure variations and water quality.

Table 1. Effect of emitter types on the uniformity parameters

Emitters	CU%	EU%	CV%
Turbo	94.6 ^{a}	92.6 ^{a}	0.03^{b}
Octa	91.6 ^{ab}	87.6 ^{ab}	0.13^{a}
Barrel	86.3 ^{b}	81 ^{b}	0.11^{a}
LSD	6.5	10.2	0.066

Means with the same letter (s) in the same column are not significantly different at $P \leq 0.05$.

Table 2. Effect of operating pressure on the uniformity parameters

Operating pressure (bar)	CU%	EU%	CV%
0.5	85.6 ^{c}	79.3 ^{c}	0.12^{a}
0.75	90.6 ^{b}	87 ^{b}	0.08^{ab}
1	96.3 ^{a}	95 ^{a}	0.02^{c}
LSD	4.98	6.83	0.05

Means with the same letter (s) in the same column are not significantly different at $P \leq 0.05$.

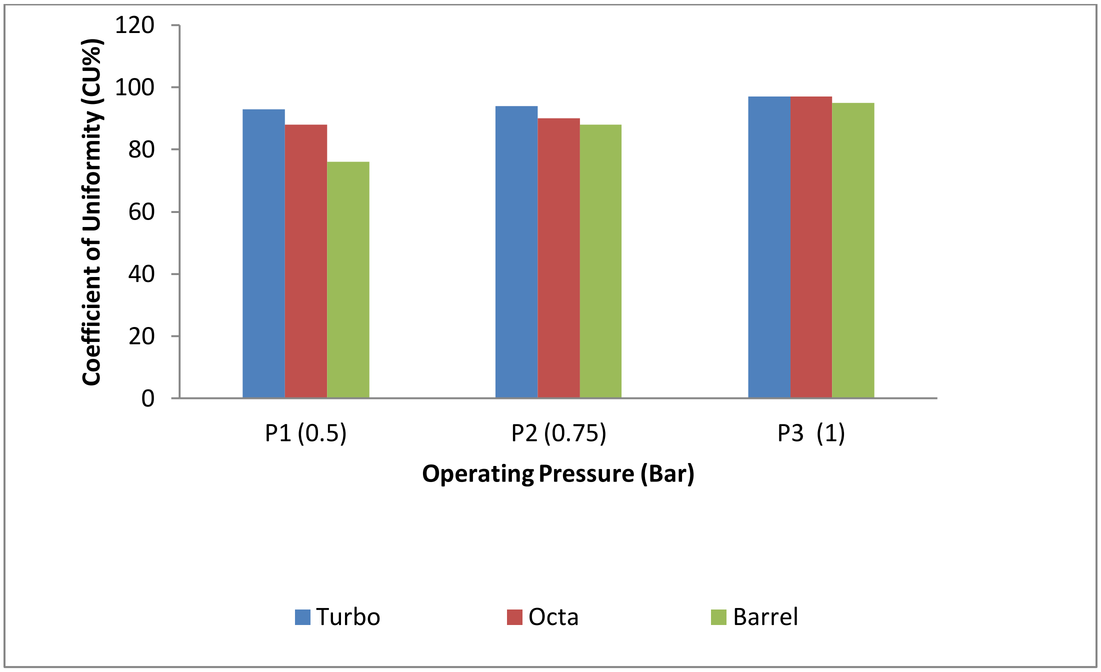

Figure 1. Effect of emitter types and operating pressure on Coefficient of Uniformity (CU%)

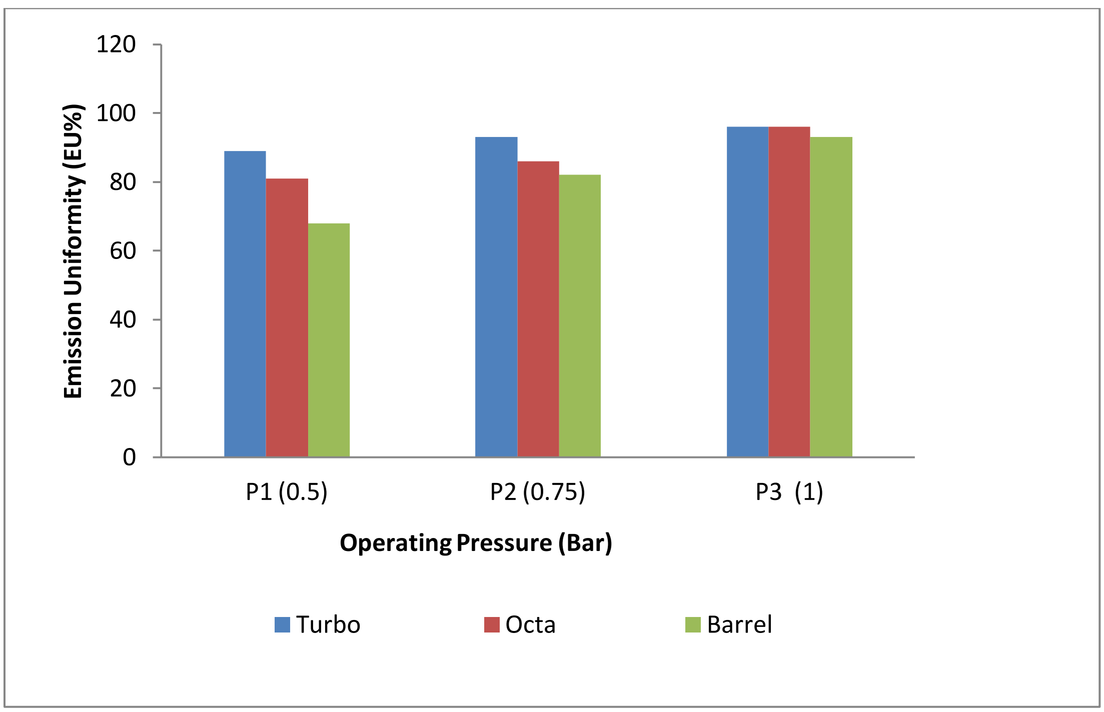

Figure 2. Effect of emitter types and operating pressure on Emission Uniformity (EU%)

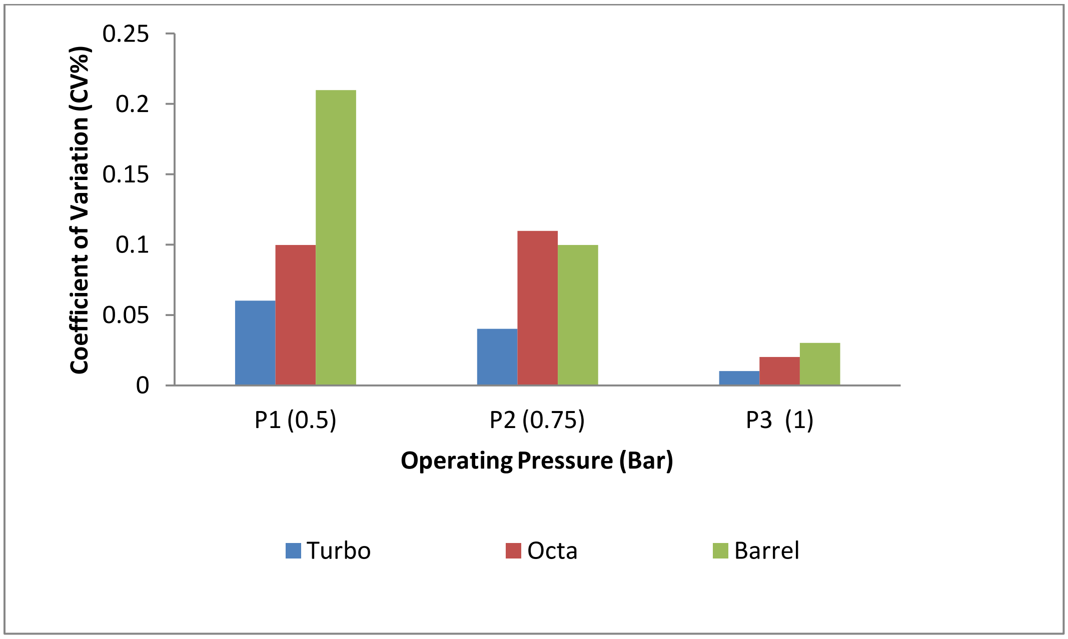

Figure 3. Effect of emitter types and operating pressure on Coefficient of variation (Cv%)

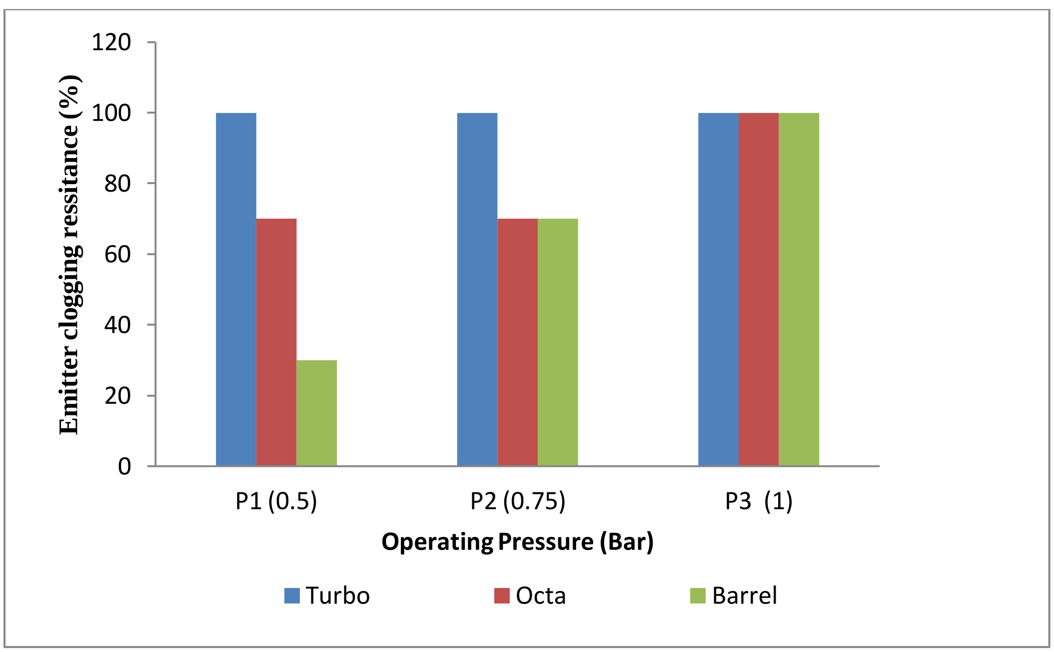

Figure 4. Effect of emitter types and operating pressure on Clogging percentage (P_{clog}%)

4. Conclusion

The conclusion that can be drawn from this study, is that emitter types and operating pressure have profound effect on the uniformity parameters of Drip irrigation system. Whereas, pressure compensating emitters (Turbo and Octa) showed higher values of CU% and EU% than non-compensating emitter (barrel).The same result was obtained with operating pressure, in which the system gave a high performance under 1bar operating pressure, followed by 0.75bar. Furthermore, pressure compensating emitters reflected higher resistance to emitter clogging than non-compensating emitter. While, increasing in operating pressure was work as anti-clogging in all stages of the experiment.

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