Assessment Of Field Performance Of Three Types Of Non-Pressure Compensating Drip Irrigation Emitters

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***Abstract*— A drip irrigation system was designed and installed to evaluate the performance and uniformities of three types of emitters. The emitters tested have the trade names of Turbo, Octa and Burrell. The performance factors studied were uniformity coefficient, uniformity of distribution, scheduling uniformity, manufacturer's coefficient of variation, emission uniformity, wetted diameter and depth of soil profile. Results indicated that the Turbo and the Octa types of emitters are better than the Burrell type of emitter under the three operating pressures.**

Keywords—performance, uniformities, coefficient, emitters, discharge, distribution.

I. INTRODUCTION

Water maintains life for every creature in this planet. Therefore, water supplies should be conserved to meet the high demand of water, especially that new sources of water supplies are becoming less. Because water is becoming scarce, people thought of how they can preserve water supplies while irrigating plants, especially when there are no natural sources of water supplies. In Sudan, water sources are mainly from rain, ground water, permanent and seasonal rivers, which are governed by international agreement.

Drip irrigation (trickle or micro irrigation) is an ideal irrigation system for economizing on the available irrigation water. It is also necessary to manage the available water efficiently for maximum crop production. Drip irrigation can apply water both exactly and uniformly at a high irrigation frequency compared with furrow and sprinkler methods of irrigation, thus potentially increasing yield, reducing subsurface drainage, providing better salinity control and better disease management since only the soil is wetted whereas the leaf surface stays dry (Shaker, 2004; Ayars et al., 2007). Drip irrigation distributes water uniformly while controlling the amount of water applied exactly, thereby reducing evaporation and deep percolation (Elfving, 1982; Batchelor et al., 1996). In this type of irrigation method, the volume of soil wetted at a particular water application is controlled by the volume of water added, the discharge rate of the dripper and the soil water content (Aujla et al., 2005). Thus, the method is best suited to semi-arid and arid areas where water is scarce, and where low water consuming high value crops can be grown. These systems can have a wider use for production of field and vegetable crops to contribute in food security. Drip irrigation systems have many advantages compared with the other irrigation systems with the result of high efficiencies, good uniformities, when properly designed. The system can irrigate lands with irregular topography with minimum of leveling. This will limit large quantities of irrigation water loss by evaporation, deep percolation seepage and surface run-off in the conveying system or at the on-farm level. In drip irrigation system, there is the possibility of supplying water separately to each plant in small, frequent and precise quantities through small devices called drippers or emitters, that is, water is applied continuously in drops at the same point and moves into the soil and wets the root zone vertically by gravity and laterally by capillary action. The objective of this study is to evaluate three types of emitters under Sudan condition based on flow rates (discharge).

Material and Methods

Experimental Site:

A drip irrigation system with three types of emitters was designed and installed at the open field of the Demonstration Farm, University of Khartoum, Faculty of Agriculture, Shambat, Sudan (Plate 1). The experimental site lies on the eastern bank of the River Nile at longitude 32° 32´E and latitude 15° 40´ N and 380 m above mean sea level. The experiments were conducted during November 2013. The mean air temperature, evaporation, relative humidity and wind speed during the study period were 27.7oC, 32%, 15.1mm/day and 3km/h (respectively), and wind direction was north.

Experiment layout and description:

The layout of the experiments was made basically for attaining high efficiency with low cost and easy to operate. The system included a water tank (7.5m3) raised on a platform 2m above the ground surface. A centrifugal pump (1hp) was used to draw irrigation water from the storage tank to supply the system. The pump discharged water through a main (PVC) line 16 m long and 50.8 mm inside diameter. The main line was joined to a sub main (PVC) line of 25.4 mm inside diameter, 4m long. The sub main was connected to six lateral lines each 13 mm in diameter and 10 m in length made of black linear low density polyethylene. The spacing between lateral lines was 0.8 m and 0.8 m between emitters. The fittings were made of polyethylene materials. Three types of emitters were fixed in the system, one type of emitters for each lateral. The three types included turbo with model turbo–key Drip Emitters code 1014004 discharge (10l/h), the second type was Octa with model shrubber (R) (Combo Dripper / sprayer) (A4) and the third type is Burrell shape Model ADJ (16l/h). A control valve and a pressure gauge (10bar) were fixed at the head of the main line. Each lateral had a control valve and was blocked at the end.

System calibration and evaluation:

Volumetric calibration of the emitters was made with graduated cylinders and a stop watch. This was carried out at three operating pressure (0.75, 1.00, and 1.25 bar). The position of check point was the first, third, sixth, ninth and twelfth emitters for each lateral. Each measurement was repeated at least three times for each pressure and then the mean value was recorded.

System uniformity:

The mean discharge rate of the emitters was measured and recorded. The absolute deviation and the lowest one-fourth (¼) mean discharge of each treatment was determined and recorded. The coefficient of uniformity of each treatment was calculated using Christiansen (1942) equation.

The wetted diameter:

The wetted diameter in the soil surface for each treatment was measured.

Wetted depth determination:

Pits were dug for measuring the wetted depth of the soil profile. Three random pits were dug for each treatment. The experimental layout adopted in this study was the split- split plot design. The results were statistically analyzed and tabulated.

Results and Discussion:

Tables (1-2) and figures (1-7) show the results of the evaluation of the three types of emitters of drip irrigation system (Turbo, Octa and Burrell) under three operating pressures of 0.75, 1.00 and 1.25 bar.

Uniformity coefficient (Cu%):

Table (1) and Fig (1) show the Cu for the three types of emitters under three different operating pressures. The Cu was calculated using Christiansen's (1942) equation. The Cu under 0.75 and 1.00 bar were for Turbo (88%) and Octa (88%) types of emitters and considered good whereas for Burrell type was (68%) was considered acceptable. But under 1.25 bar for Turbo (91%) and Octa (90%) types of emitters were excellent whereas for Burrell (80%) type was good, using the criteria specified by Keller and Bailer (2003). Table (1) and Fig (1) also show the results of statistical analysis for the effect of the three different pressures on the Cu. The analysis of data showed that significant differences were found, also showed that the highest Cu was obtained under pressure 1.25 bar whereas the lowest one was obtained under 0.75 bar and these may be due to the sensitivity of emitter to pressure as Mizyed and Kruse (1989) stated. Through a properly designed drip system, a Cu of at least 85% is considered appropriate for standard design requirements. Such a high Cu is only possible through properly designed emitters that provide steady discharge to all emission points (Al-Amound, 1995).

Uniformity of distribution (Du%):

Tables (1) and Fig (2) show the Du for the three types of emitters under three different operating pressures. The Du for Turbo and Octa types of emitters for the three different operating pressures (77% or more) fell within the acceptable range but the uniformity of distribution for Burrell type (70% or less) fell within the unacceptable range as specified by Michael (1978).

There were significant differences ($P \leq 0.05$) among the treatments (Table 1 & Fig 2). The highest value of Du for Turbo and Octa (82%) was obtained under pressure 1.25 bar and the lowest one for Turbo and Octa (80% and 78%) was obtained under 0.75 bar, whereas the highest Du for Burrell (70%) was obtained under pressure 1 bar. The lowest Du for Burrell (66%) was obtained under 1.25 bar, and these may be due to sensitivity of emitters to pressure. The results are in agreement with those obtained by Mizyed and Kruse (1989). In a poorly designed system, the operator may not able to get Du of water which may result either in under irrigation or over irrigation. Under both cases, plants will either suffer the dry stress or experience wet stress (Al-Amound, 1995). However, the Du is a function of several factors including hydraulic head and slope of lateral and sub-main lines. The Du substantially decreases at slopes steeper than 30% (Ella et al., 2009).

Scheduling uniformity (Su):

The scheduling uniformity was found to be inversely proportional to the uniformity of distribution as shown in Table (1) and Fig (3).

The analysis of variance (Table 1) showed that there were significant differences ($P \leq 0.05$) among treatments. Table (1) shows the SU for Turbo and Octa types of emitters for the three different operating pressures (1.3 or less) fell within the acceptable range but the SU for Burrell type (1.5) fell within the unacceptable range as specified by Michael (1978).

Manufacturer's coefficient of variation (Cv%):

For Turbo and Octa types the CV were found to be less than 20 % as shown in Table (2) and Fig (4). For Burrell type the CV were found to be more than 20 %.

An emitter flow variation of less than 20% is considered acceptable; and more than 20 % is unacceptable as stated by Michael (1978). Table (2) revealed that there were significant differences ($P \leq 0.05$) in the CV among treatments due to the operating pressure. Solomon (1979) and Mizyed and Kruse (2008) reported that manufacturing variations, pressure differences, emitter plugging, aging, frictional head losses, irrigation water temperature changes, and emitter sensitivity result in flow rate variations even between two identical emitters.

Emission uniformity (EU%):

Table (2) and Fig (5) show the EU for the three types of emitters under three different operating pressures. The EU of all emitters under all pressures fell within the acceptable level as stated by Michael (1978). The analysis of data showed that no significant differences were found under pressure 1.25 bar among treatments whereas there were significant differences among treatments under 0.75 and 1 bar operating pressures.

Wetted depth of the soil profile:

Table (2) and Fig (6) show the wetted depth of the soil profile for the three types of emitters under three different operating pressures. The largest depth of the soil profile was obtained under Turbo type, whereas the shortest one was obtained under Burrell type. This result can be attributed to the effect of soil type and discharge rates of emitters. Also Table (2) and Fig (6) show that the wetted depth of the soil profile increased as pressure increased. The wetted area in the soil surface for each treatment was measured and was found to be different and this difference was due to the type of the soil which has some cracks and also may be due to the different discharge rates of emitters under different operating pressures.

Table (2) shows the results of statistical analysis for the effect of the three different operating pressures on the wetted depth of soil profile. The analysis of data showed that there were significant differences ($P \leq 0.05$) among treatments under 0.75 and 1 bar operating pressures. Whereas no significant differences were found under operating pressure 1.25 bar.

The effect of emitter zones on the emitter discharges:

Fig (7) shows the highest discharge was obtained for the three emitters under zone B whereas the lowest one was obtained under zone C for Burrell and Octa and these may be due to manufacturing variation in emitters, pressure variation caused by elevation changes, friction head losses of emitter to pressure and the degree and extent of emitter clogging. The result is in agreement with results obtained by Mizyed and Kruse (1989). Appendix E shows there are highly significant differences between zones and also show that the interaction between zones and emitter have significant effect.

Conclusion

From the results of this study the following conclusions can be drawn:

1. The uniformities and performance of emitters were affected with different operating pressure.

2. The operating pressure of 1.25 bar gave the highest efficiencies for the three types of emitters used in this study.

3.The values of Cu% and Du% for the Turbo emitters were 91% and 82%, respectively under 1.25 bar operating pressure, whereas for Octa emitters Cu% and Du% were 90% and 82% respectively, under 1.25 bar operating pressure. For the Burrell type the values of Cu% and Du% under 1.25 bar operating pressure were 80% and 66%, respectively.

4. The wetted areas and depths for the three types of emitters under the three different operating pressures were not regular.

Recommendations:

From the results obtained and conclusions drawn from this study the following recommendations can be made:

1. It is more efficient to use Turbo and Octa types of emitters in drip irrigation systems especially under 1.25 bar operating pressure than the Burrell type of emitters.

2. The performance of pressure compensating and non-pressure compensating emitters should be tested under field conditions in large systems.

Acknowledgement

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Plate 1: Plan view of the system layout

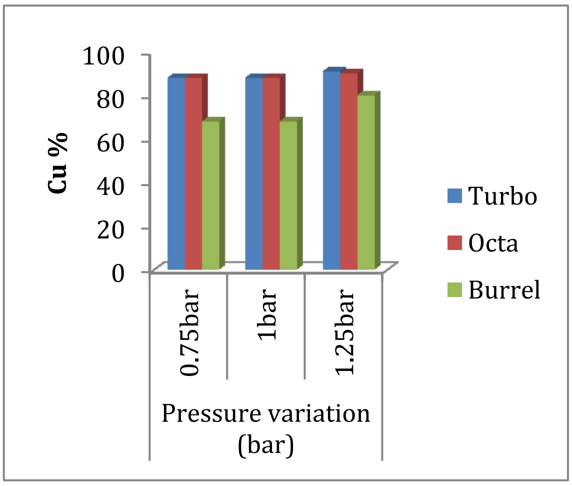

Fig. 1: Effect of operating pressures on Cu %

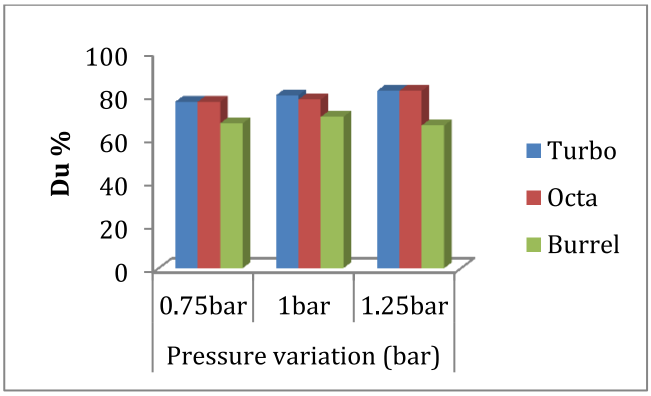

Fig. 2: Effect of operating pressures on Du %

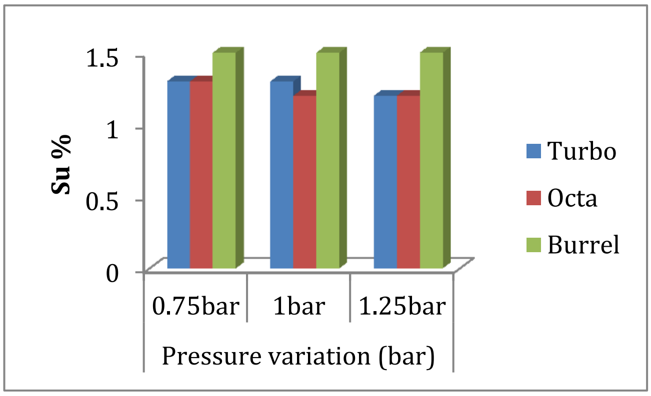

Fig. 3: Effect of operating pressures on Su

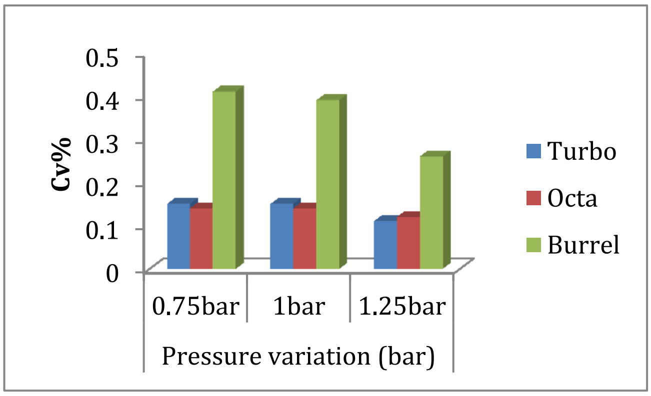

Fig. 4: Effect of operating pressures on Cv%

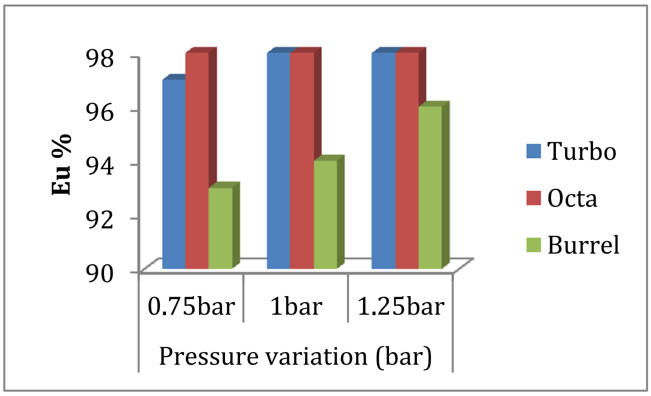

Fig. 5: Effect of operating pressures on Eu %

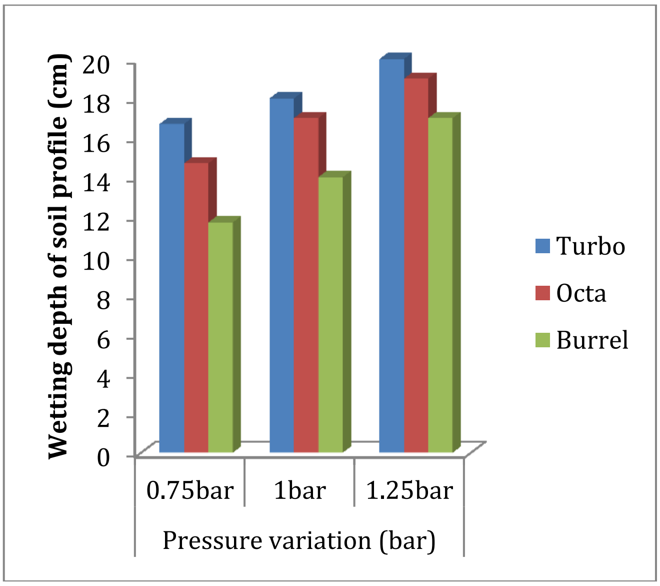

Fig. 6: Effect of operating pressures on depth of soil profile

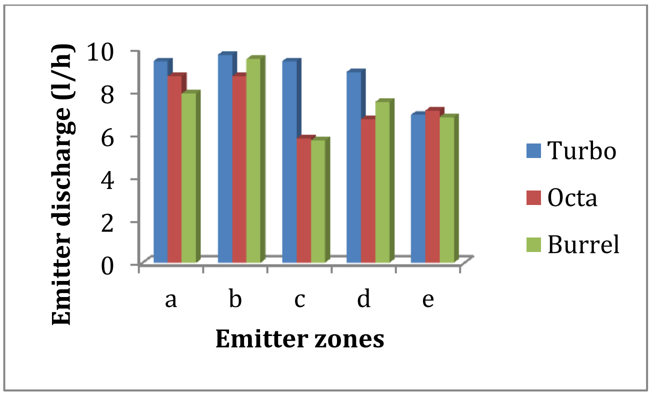

Fig. 7: Effect of emitter zones on emitter discharge

Table (1): Comparison of tested emitters based on Uniformity of Coefficient (Cu%), Uniformity of distribution (Du%) and Scheduling uniformity (Su%) according to different operating pressures.

Type of emitter	Operating pressure (bar)								
	0.75	1.0	1.25	0.75	1.0	1.25	0.75	1.0	1.25
	Uniformity of Coefficient (Cu%)			Uniformity of distribution (Du%)			Scheduling uniformity (Su%)		
Turbo	88[a]	88[a]	91[a]	77[a]	80[a]	82[a]	1.3[b]	1.3[b]	1.2[b]
Octa	88[a]	88[a]	90[a]	77[a]	78[b]	82[a]	1.3[b]	1.3[b]	1.2[b]
Burrel	68[b]	68[b]	80[b]	67[b]	70[c]	66[b]	1.4[a]	1.5[a]	1.5[a]
LSD	2	2.4	2.6	2.6	1.8	2.6	0.22	0.15	0.15

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

Table (2): Comparison of tested emitters based on Manufactures coefficient of variation (Cv%), Emission uniformity (Eu%) and Wetted depth of the soil profile according to different operating pressures.

Type of emitter	Operating pressure (bar)								
	0.75	1.0	1.25	0.75	1.0	1.25	0.75	1.0	1.25
	Manufactures coefficient of variation (Cv%)			Emission uniformity (Eu%)			Wetted depth of the soil profile		
Turbo	0.15[b]	0.15[b]	0.11[b]	97[a]	98[a]	98[a]	16.7[a]	18[a]	20[a]
Octa	0.14[b]	0.14[b]	0.12[b]	98[a]	98[a]	98[a]	14.7[a]	17[a]	19[a]
Burrel	0.14[b]	0.39[a]	0.26[a]	93[b]	94[b]	96[b]	11.7[b]	14[b]	17[a]
LSD	0.03	0.02	0.03	2.4	3.2	2.4	2.6	2.7	2.4

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