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Effect of different operating pressures on the hydraulic performance of drip irrigation system in Khartoum State conditions

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Abstract: The aim of this study was to investigate the effect of different operating pressures on the hydraulic performance of drip irrigation system (DIS). The experimental work was conducted at Nobles Company's Farm for Modern Systems, about 25 km south east of Khartoum, during two successive years of 2011 and 2012. The treatmentsused were two types of emitters (turbo pressure compensating and turbo non-pressure compensation emitters) under three operating pressures (1 bar, 1.5 bar and 1.75 bar). DIS was designed and installed to accommodate different treatments. The parameters tested were the hydraulic characteristics of the DIS which were Christiansen's coefficient of uniformity (CU%) distribution uniformity (DU %), scheduling uniformity (SU) and manufacturer's coefficient of variation (CV%). The results showed that, the hydraulic performance of DIS was significantly ($P \leq 0.05$) affected by the different types of emitters and different operating pressures. Turbo pressure compensating emitters with operating pressure of 1.5 bar gave the highest values of the hydraulic performance (CU = 91%, DU = 87%, SU = 1.14 and CV = 3%) as compared to the turbo non-pressure compensating emitters with operating pressure of 1bar (CU% = 88%, DU% = 84%, SU = 1.2 and CV% = 4).

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1. Introduction

Drip irrigation system can play a significant role in overcoming the scarcity of water mostly in water shortage areas to uniformly distribute water in agricultural fields especially where water is limited (Megersa and Abdulahi, 2015). Water shortage and water productivity significantly affected by the climate change especially in arid and semi-arid regions (Adam, 2014). Micro Irrigation systems are excellent management tool to meet the increasing demand of water for food production, and to the development, sustainability and productivity of the agricultural sector. The optimum use of irrigation water is a fundamental aspect to reach a sustainable agriculture (Ortega, 2002).

Irrigation water is managed to conserve water supplies, reduce impact on water quality and improve net economic returns of growers by applying less water than macro irrigation system (deficit irrigation), shifting to alternative crops or high yield varieties of the same crop that use less water, or adopting more efficient irrigation technologies (Patil et al., 2015). Playan and Mateos (2006) mentioned that, modernized irrigation systems at farm level implies selecting the appropriate irrigation system and strategy according to the water availability, the characteristics of climate, soil and crop, the economic and social circumstances, and the constraints of the distribution system.

Drip irrigation system (DIS) is widely recognized as potentially one of the most efficient irrigation methods (Darouich et al., 2014). However, potential efficiency is often not achieved. Mainly due to issues related to design or maintenance of DIS. Poor technical skills of farmers to assess the crop water requirements and to monitor the soil moisture conditions in the field are also limiting factors to wide adaptability of DIS. The causes of non-uniformity include unequal drainage and unequal application rates. Even where system uniformity is high, variation in soil properties, such as hydraulic conductivity, can affect drainage and lead to variation in water content (Bagarello et al., 1997; Raigonda et al., 2013). Application uniformity may be directly related to yield (Burt, 2004).

Non-uniformity in DIS potentially due to pressure differences, unequal drainage and unequal application rate also hinder to achieve full efficiency of system.Emitter plays a crucial role in system performance and the hydraulic performance significantly affected by the optimum selection of emitters, lateral diameter and length, ideal manufacturer's coefficient of variation (CV%), slope and pressure variations (Al-Amoud, 1995). Pressure compensating emitters for trickle irrigation systems are manufactured so that the discharge from each emitter is uniform at arrange of different operating pressures. When the system reaches its designed operating pressure, pressure compensation becomes effective and the discharge rate remains the same for all higher pressure up to the maximum operating pressure. The discharge for the non-pressure compensating emitter increases directly with an increase in pressure, while that for the pressure compensating emitters remains nearly the same for its operating range (Roll, 2000; Mohamed, 2013). Therefore, the objective of this study was to investigate the effect of different pressure variations on the hydraulic performance of drip irrigation system.

2. Materials and Methods

2.1 Experimental Area

The experimental work was conducted at Nobles Company's Farm for Modern Systems, located 25 km south east of Khartoum (longitude 32° 42′ E, latitude 15° 29′ N and altitude 377 m amsl), Sudan, during two years (September 2011 16th and September 26th 2012). Agroclimatic conditions of study area is semi-arid with low relative humidity and daily mean maximum and minimum temperature are 35.4 °C and 21.2 °C respectively. The soil of experimental site was sandy loam. During study period limited annual rainfall was recorded with short intense thunder storms. The mean annual rainfall is less than 300mm. This means that water is deficient and crop production must be based on irrigation.

2.2 Experimental Layout

The treatments used were two types of emitters (turbo pressure compensating and turbo non-pressure compensation emitters) under three operating pressures (1 bar, 1.5 bar and 1.75 bar). A DIS was designed and installed to accommodate different treatments.The treatments were arranged in split plot design with three replicates.The two emitters were allocated to the main plots and the three operating pressure were assigned to the subplots.

2.3 Description of Drip Irrigation System

DIS consisted of a head control unit, filter, pressure gauges, fertilizer injector, pressure regulators and polyvinyl chloride (PVC) distribution network. The distribution network consisted of a main line (16 cm diameter), sub main (6 cm diameter) and 10 laterals per sub main (2.5 cm diameter). Two types of drip distributors (turbo pressure compensating and turbo non-pressure compensation emitters) were installed in the laterals.

2.4 Parameters for Emitters Evaluation

Following parameters were used to evaluate DIS:

2.4.1 Uniformity of water application (CU%)

Christiansen's (CU %) valuates the mean deviation, which is presented in ASAE Standards (1999) as follows:

$$CU\ \% = 100\left[1 - \frac{1}{nqa}\sum_{i=1}^{n}|qi - qa|\right] \qquad [1]$$

Where qa is average emitter discharge rate (m^3h^{-1}), qi is flow rate of the emitter (m^3h^{-1}).

2.4.2 Distribution Uniformity (DU%)

Low quarter distribution uniformity DU% (Merriam and Keller, 1978) was applied to all types of irrigation systems can be expressed as follows:

$$DU = 100\frac{q_m}{q_a} \qquad [2]$$

Where qm is average flow rate of the emitters in the lowest quarter(m^3h^{-1}), qa is the average emitter discharge rate (m^3h^{-1}).

2.4.3 Scheduling Uniformity (SU)

Scheduling Uniformity (SU) was calculate by using formula

$$SU = \frac{1}{DU} \qquad [3]$$

Where DU is distribution uniformity (decimal).

2.4.4 Coefficient of variation of emitter flow

Coefficient of variation of emitter flow (CV%) evaluates the variability of flow and was computed by dividing the standard deviation by the average emitter discharge rate. Manufacturers usually publish the coefficient of variation for each of their products and the system designer must consider this source of variability (ASAE, 1999). CV can be expressed as:

$$CV = \frac{S_q}{q_a} \qquad [4]$$

Where: CV is the coefficient of variation of emitter flow, Sq is the standard deviation of emitter flow rate, qa is the average emitter discharge rate ($m^3\ s^{-1}$).

$$S_q = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(q_i - q_a)} \quad [5]$$

2.3. Data analysis

A computer program (SAS statistical package) was used to analyze the data. The variations among means were checked by the least significant difference (LSD).

3. Results and Discussion

The hydraulic performance was significantly ($P \leq 0.05$) affected by the two types of emitters (Table 1). The highest mean values were obtained with the turbo pressure compensating emitter as compared to turbo non-pressure compensating emitter. The superiority of turbo pressure compensating emitter over turbo non-pressure compensating emitter may be attributed to the fact that when the system reaches its designed operating pressure, pressure compensation becomes effective and the discharge rate remains the same for all higher pressure up to the maximum operating pressure.These results are in conformity with the results obtained by Al-Amoud (1995) and Provenzano et al. (2005) who reported that, emitter plays a crucial role in system performance and the hydraulic performance significantly affected by the optimum selection of emitters, lateral diameter and length, ideal manufacturer's coefficient of variation (CV%), slop, pressure variations and the minor head losses need to be taken into account in addition to frictional losses along the lateral in hydraulic analysis. The results also agreed with the results obtained by El-Nemr (2014) who revealed that uniformity of water application in DIS was significantly affected by emitter type.

As presented in Table 2, different operating pressure significantly ($P \leq 0.05$) affected the hydraulic performance. Operating pressure of 1.5 bar gave the highest mean values while operating pressure of 1 bar ranked the least. The results agreed with Mohamed (2013) who stated that, the discharge for the non-pressure compensating emitter increases directly with an increase in pressure, while that for the pressure compensating emitters remains nearly the same.

Table 1. Effect of different types of emitters on the hydraulic performance

Treatment	Hydraulic performance of DIS			
	CU%	DU%	SU	CV%
Turbo pressure compensating	91[a]	88[a]	1.14[b]	3[b]
Turbo non-pressure compensating	88[b]	85[b]	1.20[a]	4[a]
LSD	2.6	2	0.05	0.87
SE	1.01	1.34	0.03	0.58

Means followed by the same letter (s) in the same column are not significantly different at $P \leq 0.05$. Results are averages of two-years experiment.

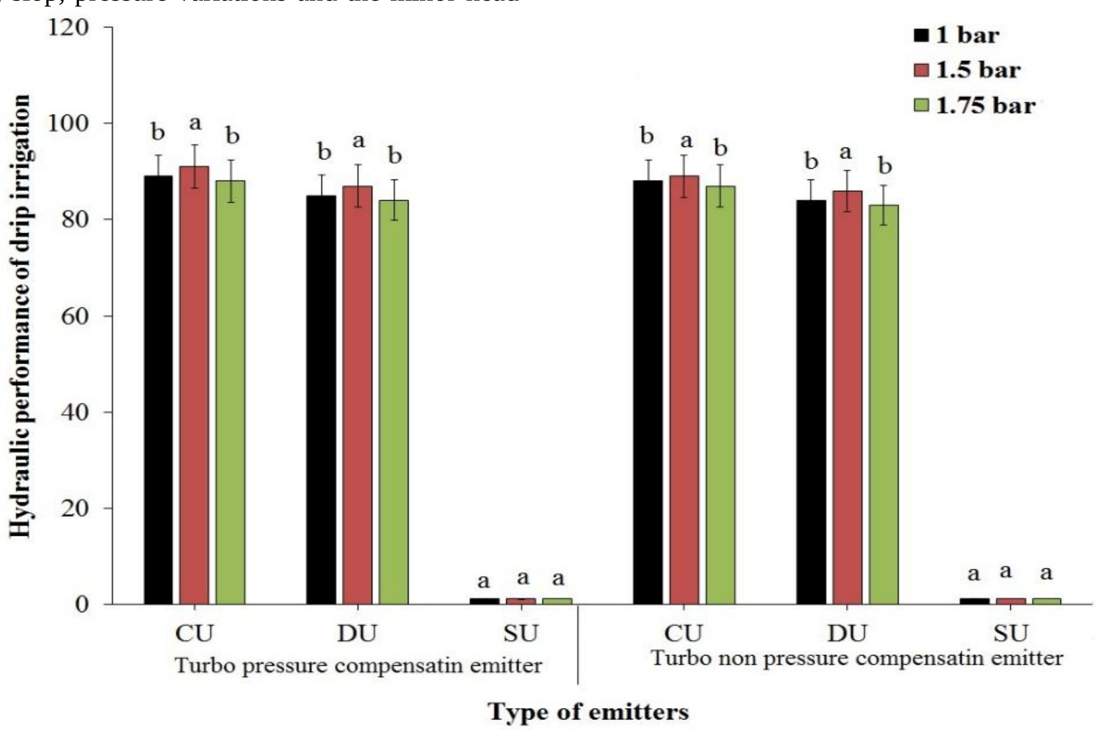

Fig.1 Effect of interaction on the hydraulic performance of drip irrigation system (average of two-years experiment). CU, Coefficient of uniformity; DU, Distribution of uniformity; SU, Scheduling uniformity.

Table 2. Effect of different pressure variations on the hydraulic performance

Treatment	Hydraulic performance of DIS			
	CU%	DU%	SU	CV%
1 bar	88[b]	84[b]	1.2[a]	4[a]
1.5 bar	91[a]	87[a]	1.1[a]	3[b]
1.75 bar	89[b]	85[b]	1.2[a]	4[a]
LSD	1.5	1.8	0.17	0.9
SE	1.00	1.21	0.11	0.60

Means followed by the same letter (s) in the same column are not significantly different at $P \leq 0.05$. Results are averages of two-years experiment.

The interaction between two types of emitters andthree operating pressures significantly ($P \leq 0.05$) affected the hydraulic performance (Fig. 1). Turbo pressure compensating emitters with operating pressure of 1.5 bar gave the highest mean values as compared to turbo non-pressure compensating emitters with operating pressure of 1 bar. The accurate design of laterals in DIS therefore needs to consider the following factors affecting hydraulic performance are emitter discharge variations along the lateral consequent to variation of hydraulic head due to both elevation changes and head losses along the lines; and emitter discharge variations at a given operating pressure, which depend on manufacturing variability, clogging, and watertemperature as stated by Provenzano and Pumo (2004). These results are in agreement with the findings of Mohamed (2013) who reported that, pressure compensating emitters are designed to discharge water at very uniform rate under a wide range of water pressure while, non-pressure compensating emitters are designed to discharge water at uniform rate, but the water pressure needs to remain relatively constant or the discharge will vary.

4. Conclusions

Emitter plays a crucial role in system performance and the hydraulic performance significantly affected by the optimum selection of emitters, lateral diameter and length, ideal manufacturer's coefficient of variation (CV%), and pressure variations. The superiority of pressure compensating emitters over non-pressure compensating emitters can be attributed to the fact thatpressure compensating emitters are manufactured so that the discharge from each emitter was uniformed at arrange of different operating pressures. Turbo pressure compensating emitter with operating pressure of 1.5 bar gave the highest values of the hydraulic performance of drip irrigation system as compared to turbo non pressure compensating emitter.

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References

Adam, H.S. 2014. Agroclimatology, Crop Water Requirement and Water Management. 2nd Edition. University of Gezira Press, Sudan.

Al-Amound, A. I. 1995. Significance of energy losses due to emitter connections in trickle irrigation lines. J. Agric. Eng. Res. 60 (1):1-5.

ASAE, Standards. 46th Ed. EP 458. 1999. Field evaluation of microirrigation system. St. Joseph, Mich.: ASAE.

Bagarello, V., V. Ferro, G. Provenzano and D. Pumo. 1997.Evaluating pressure losses in drip-irrigation lines. J. Irrig. Drain. Eng. 123(1): 1-7.

Burt, C. M. 2004. Rapid field evaluation of drip and microspray distribution uniformity. Irrig. Drain. Sys. 18(4):1-23.

Darouich, H.M., C.M.G. Pedras, J.M. Goncalves and L.S. Pereira. 2014. Drip vs. surface irrigation: A comparison focussing on water saving and economic returns using multicriteria analysis applied to cotton. Biosyst. Eng. 122:74-90.

El-Nemr, M. K. 2014. Adjusted operation time for poor uniformity drip irrigation networks. Misr J. Agric. Eng. 31 (3): 781 – 798.

Megersa, G. and J. Abdulahi. 2015. Irrigation system in Israel: A review. Int. J. Water Resour. Environ. Eng. 7(3): 29-37.

Mohammed, A. A. 2013. Evaluation the hydraulic performance of drip irrigation system with multi cases. Global J. Res. 13(2): 1-7.

Ortega, J.F., J.M. Tarjuelo and J.A. Juan. 2002. Evaluation of Irrigation Performance in Localized Irrigation System of Semiarid Regions (Castilla-La Mancha, Spain). Agric. Eng. Int. 5: 1-17.

Patil, V. C., Al-Gaadi, K., Madugundu, R., Tola, E. H., Marey, S., A. Aldosari and P. H. Gowda. 2015. Assessing agricultural water productivity in desert farming system of Saudi Arabia. IEEE J. Selected Topics Appl. Earth Observations Remote Sens. 8(1):1-14.

Playan, E. and L. Mateos. 2006. Modernization and optimization of irrigation systems to increase water productivity. J. Agric. Water. Manag. 80 (1): 100-116.

Provenzano, G. and Pumo, D. 2004. Experimental analysis of local pressure losses for micro irrigation lateral. J. Irrig. Drain. Eng. 130:4-(318).

Provenzano, G., D. Pumo, and P. Di Dio. 2005. Simplified procedure to evaluate head losses in drip irrigation laterals. J. Irrig. Drain. Eng. 131(6):525–532.

Raigonda, A., P. Balakrishnan, N.B. Mareppa and Shivanand. 2013. Evaluation of local head losses in drip irrigation laterals of inline emitters. Int. J. Agric. Eng. 6(1):105-110.

Roll, D. 2000. Irrigation Branch-Alberta Agriculture, Food and Rural Development. Source: Agdex 568-3. Revised December 2000.