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Hydraulic Performance of Drip Emitters under Different Conditions and Water Qualities

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Abstract: The aim of this study was to investigate the hydraulic performance of the drip emitters under different environmental conditions and irrigation water qualities. Two experiments were carried out under different conditions in the demonstration farm of the Faculty of Agriculture, University of Khartoum, during May 2011 to February 2012. The first experiment was achieved under controlled condition (indoor) with different emitter types (Black on-line, Blue on-line and Inline) and levels of water salinity(0.20, 0.35, 3.5, 5.0, and 5.75 ds/m), while the second experiment was conducted under field (outdoor)condition and comprised different emitter types (Blue on-line and Inline) and interspacing (0.5 and 0.3 m). The emitters hydraulic performances were evaluated with reference to percentage of discharge reduction (R%), coefficient of discharge variation (CV%), Christiansen's uniformity coefficient (CU%), emission uniformity (EU%) and clogging percentage ($P_{clog\%}$). Analysis of variation showed that there were significant differences ($P \leq 0.05$) among the measured parameters. The results indicated that the black and blue pressure compensating emitters showed the highest performance in comparison with the inline emitters at $P \leq 0.05$, in both experiments. On the other hand, the blue pressure compensating emitters showed the lowest clogging percentage ($P_{clog\%}$) with regard to the five levels of water salinity 0.20, 0.35, 3.5, 5.0, and 5.75

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ds/m, respectively. While in the outdoor experiment the 0.5m emitter inter-spacing showed higher values of discharge (q) uniformity coefficient (CU)% and lower values of reduction of discharge (R)% as compared with 0.3m emitter interspace, and both emitter interspaces showed no significant differences ($P \leq 0.05$) in between for values of emission uniformity (EU)% and Clogging percentage (P_{clog}). The study concluded that the emitter type, water quality and emitter interspacing are the crucial factors affecting the hydraulic performance of drip irrigation systems.

Keywords: Irrigation system, clogging, emitter, water quality, inter-spaces

INTRODUCTION

Drip irrigation applies water and fertilizers directly and regularly to the plants root zone through a network of technically economically designed plastic pipes and low discharge emitters. The advantage of using a drip irrigation system is that it can significantly reduce soil water evaporation and increase water use efficiency by creating a low wet area in the root zone.

Due to water shortage in many parts of the world today, drip irrigation is becoming quite popular (Powell and Wright, 1998; Sahin *et al*., 2005). In addition, drip irrigation systems have the advantage of fitting difficult topography (Wei *et al.,* 2003).For obtaining high irrigation efficiency, drip irrigation is considered as one of the most convenient technologies in modern irrigation (Sharma, 2013).

Most of the recent studies showed that soil salinity profiles differ distinctly according to the irrigation systems. Moreover, drip irrigation has greater advantage in using saline water due to low salt accumulation in the root zone as reported by Singh-Saggu and Kaushal (1991) and Chartzoulakis and Drosos (1995).

Due to scarcity in fresh water for irrigation purposes, unconventional sources such as wastewater, drainage and brackish water are considered as alternative sources to be used in agriculture (Saad *et al.,* 2013).Irrigation with low quality water such as saline water requires more careful management than irrigation with fresh water (Boman and Stover, 2002).

Emitter Clogging is one of the most difficult problems facing users of drip irrigation systems. Clogging can seriously and adversely interfere with uniform application of irrigation water and system-applied fertilizers which leads to reduced crop yield and quality .The phenomenon of emitter clogging has been extensively studied (Taylor *et al*., 1995; Capra and Scicolone, 1998). Emitter clogging can be attributed to the three reasons: physical, chemical and biological (Bucks *et al*., 1979). The causes of clogging differ based on emitter's geometry (Ahmed *et al*., 2007) and position in lateral lines (Ravina *et al*., 1997). Ravina *et al.* (1997) found that fast flow can limit the biological growth on the pipe wall and thus lower the risk of clogging; emitters with high discharge rates clog less than those with low discharge rates over the same period. More clogged emitters are found at the tailing part than at the leading part of the drip lateral. This study aims to evaluate the hydraulic performance of the drip emitters at indoor and outdoor environmental conditions and under different water qualities.

MATERIALS AND METHODS

Two experiments were carried out under two different management conditions (indoor and outdoor) in the demonstration farm of the Faculty of Agriculture, University of Khartoum (15.6^{o}N, 32.53^{o}E, and 380 m above mean sea level) during May 2011 to February 2012. The indoor experiment included three emitter types and five levels of salinity. The emitters used were: Black on-line emitters of rated discharge 4 Lhr^{-1}, Blue on-line emitters of rated discharge 8 $Lh^{-1}$and Inline (built in) emitters of rated discharge 4 Lh^{-1}.

The salinity levels in ds/m, were 0.35 for well water (WWS), 0.2 for River Nile water (RNW), 3.5 (SW1) and 5 (SW2) for fresh water in which NaCl was intentionally added to Raw River Nile water and 5.75 for treated wastewater.

In outdoor experiment the emitters used were pressure-compensation (blue) and Inline-labyrinth for which emitter interspaces of 0.3m and 0.5 m were used.

Materials

The materials used in the experimental work included pressure gauge (2bar) of analogue type, meter tape, catch cans, measuring cylinder and stop watch

Methods

The discharge was calculated using the following equation as suggested by Keller and Karameli (1975):

Q= V/T………………………………… (1)

Where

Q = discharge (l/h)

V= volume of water collected by catch cans (liter)

T= operating time (h)

The reduction of discharge was calculated using the following equation according to Bralts and Kesner (1983):

$R_{reduction}$ = (V1 – V2) /V1 * 100 %............................(3.2)

Where:

$R_{reduction}$ = reduction of discharge

V1 = volume of water per liter in the first emitter of the lateral

V2 = volume of water of the last emitter in this lateral

Emission of uniformity (EU %) was calculated as defined by ASAE (1983):

$$EU = 100\left(1 - \frac{1.27cv}{\sqrt{n}}\right)\frac{q_n}{q_{ave}} \qquad (2)$$

Where:

EU = distribution of uniformity (%).

q_n = average rate of discharge of the lowest one-fourth of the emitters discharge readings (Lhr^{-1}).

q_{ave} = average discharge rate of all the emitters under test (Lhr^1).
n = number of observation
cv= Coefficient of variation

The operating pressure for this experiment was constant at 2 bar. The coefficient uniformity (CU %) was calculated as defined by Christiansen (1942) as follows:

$$Cu = 100\left(1 - \frac{\Delta q}{q_n}\right) \quad (3)$$

Where:
Cu = coefficient of uniformity (%)
Δq = mean deviation of individual emitters flow (lhr^{-1}).
q = emitters flow rate mean (lhr^{-1}).

The percentage of clogged emitters (P_{clog}%) was determined using the following equation as suggested by Liu and Huang (2009):

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

Where:
P_{clpg} = percentage of clogging (%)
Nes_{clog} = number of clogged emitters.
Nes_{total} = total number of emitters.

RESULTS AND DISCUSSION

Tables (1 and 2) show that the hydraulic performance of the emitters under investigation was highly affected by the water quality and emitter types at $P \leq 0.05$. It was apparent that the emitter discharge decreased with time. The highest discharge reduction was found with the water quality of 3.5 ds/m salinity (SW1), while the lowest value was recorded with River Nile water of salinity 0.2 ds/m (RNW). Generally, variation in the results of CV%, CU% and EU% with water quality were observed. The highest values of CU% and EU% were recorded with well water of salinity level 0.35 ds/m (WWS), and the highest value of clogging percentage was recorded with treated wastewater (TWW) and 5 ds/m saline water (SW2), while the lowest was observed with (RNW). These results may be due to the fact (TWW) and (WWS) have higher levels of impurities compared with the other water types. This result is supported by the findings of Bralts (1986) and Nakayama and Bucks (1991). In case of the emitter types, the blue compensating emitter under water quality TWWS and SW1, revealed greatest reduction in discharge rate followed by WWS and SW2, respectively. This result may be due to the fact that this emitter has higher discharge rate than the other emitters. These results are in accordance with the findings of Nakayama and Bucks (1991). Also may be attributed to the variation in pressure along the lateral as reported by Ravina *et al.* (1997).

Table 1. Hydraulic performance of drip irrigation systems under different irrigation water qualities

Salinity levels	**R%**	**CV%**	**CU%**	**EU%**	$\mathbf{P_{clog\%}}$
RNW (0.2)	0.14^{c}	0.18^{c}	77^{c}	57^{d}	22^{d}
WW S (0.35)	0.34^{a}	0.30^{a}	84^{a}	71^{a}	62^{b}
SW1 (3.5)	0.35^{a}	0.20^{c}	79^{b}	65^{c}	48^{c}
SW2 (5.0)	0.28^{b}	0.20^{c}	80^{b}	70^{ab}	73^{a}
TWWS (5.75)	0.36^{a}	0.24^{b}	80^{b}	67^{bc}	72^{a}
LSD	0.04	0.02	1.8	3.23	1.6

Means with same letters in same column are not significantly different at $P \leq 0.05$

Table 2. Hydraulic performance of drip emitters under indoor condition

Emitter Types	**R%**	**CV%**	**CU%**	**EU%**	$\mathbf{P_{clog\%}}$
Black	0.19^{c}	0.19^{b}	84^{a}	73^{a}	28^{c}
Blue	0.26^{b}	0.24^{a}	79^{b}	61^{c}	53^{b}
Inline	0.44^{a}	0.24^{a}	77^{b}	65^{b}	85^{a}
LSD	0.05	0.01	2	3	1

Means with same letters in same column are not significantly different at $P \leq 0.05$

The emitter types showed different response to clogging phenomenon, Fig. 1 exhibits that the percentage of partial clogging increased with time till reaching complete clogging. The black emitters showed the least clogging percentage, followed by blue emitters and the highest value was recorded with inline emitters (Tables 1-2). This result is supported by the finding of Capra and Scicolone (1998) who stated that the clogging percentage varied due to emitter type and water quality.

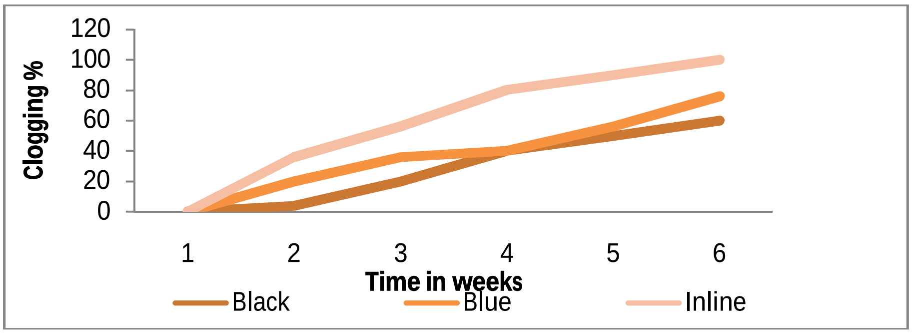

Fig. 1.The percentage of clogging in emitters with time

Under the outdoor condition, the emitter types showed no significant differences (P≤ 0.5) with regard to reduction of discharge, emission uniformity and clogging percentage, (Table 3). Nevertheless the blue pressure compensation emitters showed higher significant difference (P≤ 0.5) compared with the inline labyrinth emitters with reference to uniformity coefficient. This result may be attributed to the fact that the blue emitters compensated the losses in operating pressure and approximately gave uniformity in emitters discharges. These results were similar to those obtained by Ravina *et al*. (1997). On the other hand and as shown in Table 4, the 0.3m emitter inter spacing recorded higher significant differences than 0.5 m in values of reduction of discharge, while 0.5m emitter inter spacing revealed the highest values of CU% and no significant difference(P ≤ .05) was recorded between both interspacing in values of emission uniformity and percentage of clogging.

In Figs. (2 and 3), the clogging percentage (Pclog) increased with time in both emitter types and interspacing. Nevertheless, the blue emitter and 0.3 m interspacing revealed lower response to clogging in comparison with the inline emitter and 0.5 m interspacing, respectively. This may be due to the fact that the inline emitters precipitated the clogging materials more than the blue emitters. This result is supported by that of Ravina *et al*. (1992).

Table 3. Hydraulic performance of drip emitters under the outdoor condition

Emitter types	Hydraulic performance parameters %			
	R	CU	EU	Clogging
Blue	28[a]	91[a]	85[a]	14[a]
Inline	29[a]	90[b]	83[a]	16[a]
LSD	4.6	0.33	4.15	5.3

Means with same letters in same column are not significantly different at $P \leq 0.05$

Table 4. Effect of interspacing on hydraulic performance of emitters

Emitter inter-spaces (m)	Hydraulic performance parameters %			
	R	CU	EU	Clogging
0.5	21[b]	91[a]	84[a]	15[a]
0.3	36[a]	90[b]	83[a]	15.3[a]
LSD	5	0.3	4.14	5.3

Means with same letters in same column are not significantly different at $P \leq 0.05$

While the increase in precipitation with increasing in emitters interspacing may be due to the fact that interspacing allowed precipitation to take place. This result is supported by that of Taylor *et al.* (1995).

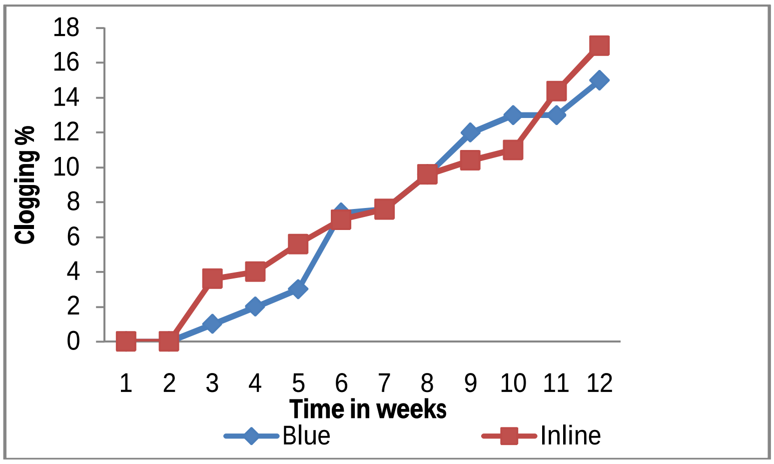

Fig.2. clogging percentage in emitters with time in outdoor condition

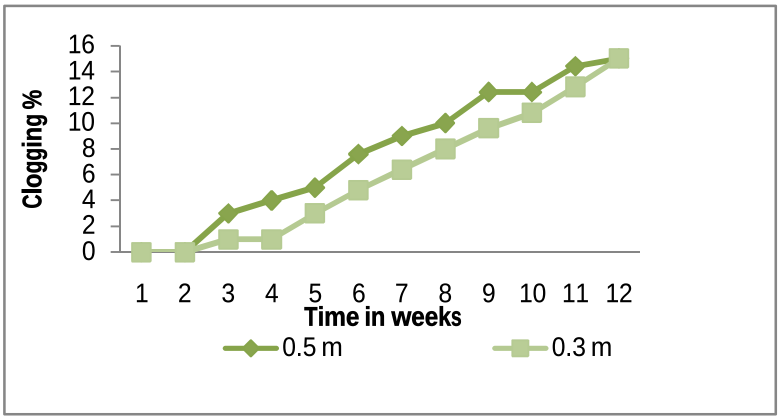

Fig.3. effect of emitter interspacing on clogging of emitter with time in outdoor condition

CONCLUSIONS

From this study it can be concluded that Blue and black (compensation emitters) resisted clogging more than inline emitters and gave high hydraulic performance. On the other hand the clogging phenomenon increased with increasing in salinity levels and emitters interspaces. Generally, the hydraulic performance of drip irrigation system was highly affected by emitter types, water quality and emitter interspacing

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الأداء الهيدروليكي للنقاطات تحت ظروف وخصائص مياه مختلفة

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مستخلص البحث: إن الهدف من هذه الدراسة هو تقيم الأداء الهيدروليكي للنقاطات في ظل ظروف بيئية مختلفة وخصائص مياه ري مختلفة. تم إجراء تجربتين في ظروف مختلفة في المزرعة التوضيحية لكلية الزراعة ، جامعة الخرطوم ، خلال الفترة من مايو 2011 إلى فبراير 2012. تم تنفيذ التجربة الأولى في ظل ظروف خاضعة للرقابة (داخل المعمل) مع أنواع نقاطات مختلفة (أسود وأزرق على الخط، و داخل مضمن في الخط) ومستويات ملوحة هي: (0.20 و 0.35 و 3.5 و 5.0 و 5.75 ds / m)، في حين أجريت التجربة الثانية تحت ظروف الحقل (الحقل المفتوح) باستخدام أنواع مختلفة من النقاطات (أزرقعلىالخطو مضمن داخل الخط) وبالإضافة للمسافات (0.5 و 0.3 م)., وقد تم تقييم الأداء الهيدروليكي للبواعث بالرجوع إلى النسبة المئوية لانخفاض التدفق (R %)، ومعامل تباين التدفق (CV %) ، ومعامل تجانس كريستيان (CU %) ، وتجانس التدفق (EU%)، ونسبة الانسداد (Pclog %). أظهر تحليل التباين وجود فروق ذات دلالة إحصائية ($P\leq 0.05$) بين المعاملات المقاسة. أشارت النتائج إلى أن نقاطات تعويض الضغط ذات اللون الأسود والأزرق أظهرت أعلى أداء بالمقارنة مع النقاطات المضمنة داخل الخطتحت مستوي المعنوية $P \leq 0.05$ ، في كلتا التجربتين. من ناحية أخرى ، أظهرت نقاط تعويض الضغط الأزرق أدنى نسبة انسداد (Pclog%) فيما يتعلق بالمستويات الخمسة لملوحة المياه 0.20 و 0.35 و 3.5 و 5.0 و 5.75 ds / mعلى التوالي. بينما في التجربة الحقلية ، أظهرت المسافة بين البواعث 0.5متر قيمًا أعلى للتدفق (q) ومعامل تجانس كريستيانسن (CU%) وقيم أقل لانخفاض التدفق (R %) مقارنةً بمسافة 0.3 م، والمسافات البينية للنقاط على حد سواء لم تظهر أي فروق ذات دلالة إحصائية ($P\leq 0.05$) لقيم تجانس التدفق (EU%) ونسبة الانسداد (Pclog%) وخلصت الدراسة إلى أن نوع النقاط ونوعية المياه والمسافات بين النقاطات هي العوامل الأساسية التي تؤثر على الأداء الهيدروليكي لأنظمة الري بالتنقيط.

الكلمات المفتاحية: نظام الري، انسداد، نقاط، جودة المياه، المسافات بين النقاطات

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