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Evaluation of hydraulic performance of three different emitters in drip irrigation systems for small vegetable farms, Gezira state, Sudan

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Abstract
Drip irrigation system is the most efficient economical method for irrigation vegetable production. The objective of this study was to evaluate the hydraulic performance of three different types of emitter's namely Regular gauge (RG), Compensating pressure (CP) and non-Compensating pressure (NCP) using eggplant (*Solanum melonga* L.) as a test of a crop. The experiment was conducted in a Faculty of Agricultural Science, University of Gezira during the period of October 2021 to march 2022. Parameters of hydraulic performance of drip emitters were average discharge (Qavg %), discharge variation (Qvar), coefficient uniformity (CU %), coefficient of manufacture variation (CV), emission uniformity (EU %) and statistical uniformity (US %). The treatments were laid out in a randomized complete block design (RCBD) with four replicates. The result showed that the values of (CU%), (CV), (EU%), (US%) and percentage emitters clogging (Pclog%) were 97.9%, 0.38, 40.7%, 58.6%, 1.9% and 96.4%, 0.43, 52.1%, 57.7%, 1.8% and 96.4%, 0.6, 28.3%, 47.5%, 1.3% for regular gauge (RG), compensating pressure (CP) and non-compensating pressure (NCP) respectively. It is considered coefficient uniformity (CU %), was excellent and found to be within the acceptable range while discharge variation (Qvar %), emission uniformity (EU %), coefficient of manufacture variation (CV), and statistical uniformity (Us %) were found to be within the range of poor and unacceptable. Result also showed significant differences among types of emitters on plant height, applied water, yield and water productivity of eggplant. The highest yield was obtained non-compensating pressure (NCP) (13279 kg/ha) while the lowest yield was obtained by regular gauge (RG) (8180 kg/ha). The highest water productivity was obtained by regular gauge (RG) (7.7 kg/m^3), while the lowest value was obtained by compensating pressure (CP) (4.8 kg/m^3). The study recommends that the best type of emitter was non-compensating pressure (NCP), because it produced the highest yield of eggplant.

Keywords: Drip irrigation, hydraulic performance, emitter clogging, water productivity, uniformity

Introduction

Drip irrigation sometimes referred to as trickling irrigation, micro-irrigation, or low-volume irrigation, is the ideal technique since it offers a high degree of regularity. Compared to conventional irrigation systems, drip irrigation systems typically consume 30 to 50 percent less water since they supply (Almajeed and Alabas, 2013) [2]. In drip irrigation, dripper emitters deliver small, frequent doses of water to each plant individually. It has the highest application efficiency of any irrigation technique (Phocaides, 2001) [15]. When it comes to high-value cash crops like greenhouse plants, ornamentals, and fruit, drip irrigation technology is gaining popularity and playing a significant role in agricultural output (Pescod, 1992) [14]. The most effective and cost-effective form of irrigation for vegetable production is drip irrigation (Sharu and Abrazak, 2020) [16]. The Advantage of drip irrigation system include: less water, fertilizer and nutrients can be used with high efficiency, reduction in weed growth, reduced labor requirement, less soil erosion. While its disadvantage includes: clogging of drip holes, high initial investment requirement, soil salinity hazard and easy damage of drip lines (Gruban and Denton, 2004) [8]. At the plant, field, farm, system, and basin levels, water productivity can be examined. Its worth would fluctuate with the analysis's scale (Molden *et al*, 2003) [12].

When calculating irrigation efficiency, water engineers traditionally ignored economic considerations and compared real evapo-transpiration (ET) to the total amount of water diverted for crop production (Kijne *et al*, 2003) [10]. Agriculture has a substantially lower economic value of water than other industries, including manufacturing (Xie and Walther, 1993) [19] (Barker *et al*, 2003) [3]. Researchers were concerned with increasing the productivity of water use in agriculture in order to get the most production or value out of every unit of water used as a result of the growing physical shortage of water on the one hand, and the scarcity of economically accessible water due to increasing cost of production and supply of the resource on the other (Kijne *et al*, 2003) [10]. However, little information is available on hydraulic performance of different types of emitters in Somalia. The main objective of this research work is to evaluate of hydraulic performance of three different emitters in drip irrigation systems for small vegetable farm in Gezira sate, Sudan.

Material and Method

The experiment was carried out Agricultural Experiment farm owned by the University of Gezira Faculty of Agricultural Science, at latitude 14°21' N, longitude 29°33' E and altitude 405 m above mean sea level. The experimental site is clay, dark brown, deep cracking with very low permeability (Soil Survey Staff, 1999) [17]. The experiment started at the beginning of (fall) season during October 2021 up to the (Winter) season March 2022. The area of the experimental plot was 170 m^2 with dimensions of 17m*10m. Four replications of a randomized complete block design were used to set up the experimental plot. Three treatments were used which were regular gauge (RG), compensating pressure (CP) and non-compensating pressure (NCP).

Methods

Discharge of emitter

Average discharge rate was measured using graduated measuring cylinder, catch cans and stopwatch. The model was lifted to work until one of the catch cans was filled stopped the watch and then the collected water in catch cans measured. To determine the average capacity in liters, the test was conducted three times. To calculate the discharge, divide the average volume by the passage of time.

$$q = V/t$$

Where:
q = Discharge (L/h)
V = Volume collected (ml) t = Time taken (hours)

Discharge variation (Qvar)

Emitter flow variation (qvar) was calculated using the following equation:

$$Q_{var} = (Q_{max} – Q_{min})/Q_{max}$$

Where:
Qvar = Flow variation
q max = maximum emitter flow rate (L/h) q min = minimum emitter flow rate (L/h)

Coefficient of uniformity (CU %)

According to the equation established by Christiansen (1942) [6], the coefficient of uniformity was calculated as follows:

$$CU = 100 - (80*Sd/V_{avg})$$

Where:
CU = Uniformity coefficient (%)
Sd = Standard deviation of observation
Vavg = Average volume collected.

Coefficient of manufacture variation (CV %)

The Coefficient variation can be computed using the formula below (Burt and Styles, 200 Coefficient of manufacture variation (CV %)
The Coefficient variation can be computed using the formula below (Burt and Styles, 2007) [5].

$$CV\% = 100 * SD/q$$

Where:
CV= the coefficient of variation of emitter discharge. SD = standard deviation of emitter discharge.
q = average discharge in the same lateral lines (L/h).

Emission uniformity (EU %)

According to (Keller and Blaisner 1990) [21] the emission uniformity is defined as follows:

$$EU (\%) = (q_{avg25\%}/q_{avg})*100$$

Where:
Qavg 25% = mean of the lowest 0.25 of emitter discharge.
q avg = average discharge rate of all the emitters checked in the field (L/h).

Statistical Uniformity (%)

The statistical uniformity was computed according to the following equation by (Bralts and Kesner, 1987) [4].

$$U_s = 100 (1 - S_q/q)$$

Where:
Us = Statistical Uniformity (%)
Sq = Standard deviation of emitters discharge (l/h).
q = Discharge of emitters (l/h).

Percentage of Clogging emitters (Pclog %)

The following equation was used to calculatethe percentage of clogged emitters Where

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

Pclog = Percentage of clogging emitters (%).

Nesclog = Numbers of clogged emitters.

Nestotal = total numbers of emitters.

Statistical analysis

Using an appropriate randomized complete block design analysis of variance MSTAT programme.

Results and Discussion

Discharge (l/h): The emitters discharges were measured and calculated and the Table 1 presents the findings. It's observed based on Table (1) that the average discharge rates of emitters were 1.8l/hr, 2.2 l/h and 3.7 1/h for Regular gauge (RG), compensating pressure (CP) and non-compensating pressure (NCP), respectively. The highest value was obtained by the non- compensating pressure emitter (3.7 1/h) while the lowest value was obtained by the regular gauge (1.8 l/h).

Table 1: Emitter discharge (l/h)

Emitter type	Q l/hr
RG	1.8
CP	2.2
NCP	3.7

Discharge variation (Q var)

The emitter variation discharge were measured and calculated and the results are displayed in Table (2).

The mean measured discharge variations of emitters were 28.5, 31.7, and 33.8 for the regular gauge emitter (RG), the compensating pressure emitter (CP) and the non-compensating pressure (NCP), respectively. The highest mean value was obtained by the compensating pressure emitter (33.8) while the lowest value was obtained by the regular gauge emitter (28.5). According to the maximum drip irrigation standard of 20 to 30 for the discharge variation recommended by FAO (1984) the results obtained by the regular gauge emitter were acceptable, while the results from the other two types of emitters were generally unacceptable.

Table 2: Discharge variation of emitter's type (Qvar)

Emitter type	Means	Criteria
RG	28.5	20 – 30
Classification	Acceptable	Acceptable
CP	31.7	More than 30
Classification	Unacceptable	Unacceptable
NCP	33.8	More than 30
Classification	Unacceptable	Unacceptable

Uniformity Coefficient (CU %)

Table (3) present the effect of the different three types of emitters on coefficient uniformity. The average coefficient of uniformity values of 97.9%, 96.4% and 96.4% were excellent for regular gauge (RG), compensating pressure (CP) and none compensating pressure emitter (NCP), respectively. The highest mean value was obtained by the regular gauge emitter (RG) (97.9%) while the lowest value was achieved by the non-compensating pressure emitter (NCP) (96.4%). This result agrees with (Kirnak *et al.* (2014) [9] who reported that the coefficient of uniformity Hydraulic design has an impact on drip irrigation system, although manufacture's variation. Bralts *et al.* (1987) [4] reported that the coefficient of uniformity greater than 90% is excellent.

Table 3: Coefficient uniformity of emitters type (CU %)

Emitter type	Means	Criteria
RG	97.9	Above 90%
Classification	Excellent	Excellent
CP	96.4	Above 90%
Classification	Excellent	Excellent
NCP	96.4	Above 90%
Classification	Excellent	Excellent

Coefficient manufacture variation (CV %)

Table (4) displays effect of the three types of emitters on coefficient of manufacture variation of drip irrigation system. The coefficients of manufacture variation of flow rates were acceptable. The coefficient of manufacture variation values was 0.38, 0.43 and 0.6 for the regular gauge emitters (RG), compensating pressure emitters (CP) and none compensating pressure emitters (NCP), respectively. The highest mean value (unacceptable) was obtained by the non-compensating pressure emitters (0.6) while the lowest value (low) was achieved by the regular gauge emitters (0.38). Similar results were obtained by Alabas (2014) [11] and Soccol *et al.* (2002) [13] who found that the mean coefficient of variation was 0.28 for drip irrigation systems.

Table 4: Coefficient of manufacture variation (CV)

Emitter type	Means	Criteria
RG	0.38	0.3− 0.4
Classification	Low	Low
CP	0.43	More than 0.4
Classification	Unacceptable	Unacceptable
NCP	0.6	More than 0.4
Classification	Unacceptable	Unacceptable

Emission uniformity (EU %)

The emission uniformity was measured and calculated and the results are shown in Table (5). It's observed from the Table (5) that the average emission uniformity of emitters was 40.7%, 52.1 and 28.3 for regular gauge (RG), compensating pressure (CP) and non- compensating pressure (NCP), respectively. The highest value was obtained by the compensating pressure emitter (52.1%) while the lowest value was obtained by non-compensating pressure emitter (28.3%).

Table 5: Emission uniformity (EU %)

Emitter type	EU%	Criteria
RG	40.7	Less than70%
Classification	Poor	Poor
CP	52.1	Less than70%
Classification	Poor	Poor
NCP	28.3	Less than70%
Classification	Poor	Poor

Statistical uniformity (Us %): The statistical uniformity were measured and calculated and the results are shown in Table (6). It's observed from the Table (6) that the average statistical uniformity of emitters were 58.6%, 57.7% and 47.5% for Regular gauge (RG), compensating pressure (CP) and non- compensating pressure (NCP), respectively. The highest value was obtained by the non-regular gauge emitter

(58.6%) while the lowest value was obtained by the non-compensating pressure (47.5%). This result agrees with by Soccol *et al.* (2002) [13] who reported that the statistical uniformity values less than 60% is unacceptable.

Table 6: Statistical uniformity (Us %)

Emitter type	Means	Criteria
RG	58.6	Less than60%
Classification	Unacceptable	Unacceptable
CP	57.7	Less than60%
Classification	Unacceptable	Unacceptable
NCP	47.5	Less than60%
Classification	Unacceptable	Unacceptable

Percentage of emitter clogging (pclog %)

Table (7) shows the impact of various emitter types on the percentage of emitters clogging of the drip irrigation system. The percentage of emitters clogging values of 1.9%, 1.8% and 1.7% were obtained by the regular gauge emitter (RG), compensating pressure emitter (CP) and none compensating pressure emitter (NCP), respectively. The highest mean value was obtained by the regular gauge emitter (1.9%) while the lowest value was obtained by non- compensating pressure emitter (1.7%).

Table 7: Percentage Emitters Clogging (Pclog %)

Emitter type	Means
RG	1.9
CP	1.8
NCP	1.7

Wetted diameter (cm)

Table (8) shows the effect of hydraulic performance on wetted diameter of drip irrigation. The result obtained shows that the average wetted diameter of emitters was 8.9 cm, 8.8 cm, and 9.6 cm for Regular gauge (RG), compensating pressure (CP) and non-compensating pressure (NCP), respectively. The highest value was achieved by the non-compensating pressure emitter (9.6 cm) while the lowest value was obtained by the compensated pressure (8.8 cm).

Table 8: Effect of emitter's type on wetted diameter (cm)

Emitter type	Wetted diameter (cm)
RG	8.9
CP	8.8
NCP	9.6

Applied water (m^3/ha)

The findings showed that the differences were highly significant differences ($p \leq 0.01$) in applied water between treatments of drip irrigation system. The results of the applied water obtained by the regular gauge emitter (RG), compensating pressure emitter (CP) and non-compensating pressure emitter (NCP). were1172.5 m^3/ha, 151s1.7 m^3/ha and 2165.6 m3/ha, respectively. The significantly highest applied water was obtained by the none-compensating pressure emitter (2114.7 m^3/ha), while the lowest was achieved by the regular gauge emitter (1122.2 m^3/ha).

Water productivity (kg/m^3)

The water productivity associated with the different emitter's types is presented in Table (9). The results showed that there were significant differences ($p \leq 0.05$) between the different types of emitters. The range for water productivity (kg/m^3) for the emitter's type (RG, CP, NCP) was 7.75 kg/ m^3, 4.81 kg/m^3 and 6.41 kg/ m3, respectively. The significantly highest water productivity was obtained by the emitter regular gauge pressure. (7.7516 kg/m^3) while the lowest was achieved by the compensating pressure emitter (4.81kg/m^3).

Similar results were obtained by Yagoub (2018) [22] who reported that water productivity under full irrigation treatment was 7.5 kg/m^3.

Yield (kg/ha)

The results indicate that there was a significant difference ($p \leq 0.05$) between treatments under drip irrigation system. The yields obtained by the regular gauge emitter (RG), compensating pressure emitter (CP) and non-compensating pressure emitter (NCP) were 8627 kg/ha, 9313 kg/ha and 13477 kg/ha, respectively. The findings of the statistical study showed that were significant differences ($p \leq 0.05$) in yield between the different irrigation treatments. The highest crop yield was obtained by the non-compensating pressure emitter (13279 kg/ha), while the lowest yield was achieved by the regular gauge emitter (8180 kg/ha). There was a reduction in yield of 20, 29 and 44%, by the drip irrigation treatments compared to fully irrigated treatments. These results agree with the findings Karam *et al.*, (2009) [20] and Topcu *et al.*, (2007) [18].

Table 9: Effect of emitters' type on yield, applied water and water productivity

Treatment	AW(m3/ha)	WP(kg/m3)	Yield (kg/ha)
RG	1122.2 c	7.7516 a	8180 a
CP	1745.7 b	4.8138 b	8342 b
NCP	2114.7 a	6.4105 ab	13279 a
SE±	67	0.73	1255.9
CV	8.66	16.31	17.88
Sig. level	**	*	*

* = means are significant at $P \leq 0.05$ level
** = means are highly significant at $P \leq 0.01$ level

Conclusion and Recommendation

Conclusion

Evaluation of drip irrigation system performance is required periodically to ensure that the right emitter discharge is maintained. Results of this study on the hydraulic performance in three types of emitters were conducted and can be drawn as the following points: The average discharge varied from 1.8 to 3.7 l/hr. The values of hydraulic performance of drip irrigation system under three types of emitters, including: coefficient uniformity (CU %), was quite good and found to be within the acceptable range while discharge variation (Qvar %), emission uniformity (EU %), coefficient of manufacture variation (CV), and statistical uniformity (Us %) were found to be within the range of poor and unacceptable. Regular gauge (RG) is the best one for all parameters of hydraulic performance except on average discharge, emission uniformity and clogging percent. The highest yield of eggplant was obtained by non-compensating pressure (13279 kg/ha), while the highest water productivity was obtained by regular gauge (7.75 kg/m^3).

Recommendation

Hydraulic performance of this result was recommended as the following: The best one emitter type is the regular gauge (RG) because it has the highest water productivity as compared to other emitters, non- compensating pressure emitters (NCP) and compensating pressure emitters (CP). It's still necessary to have more studies studies for better understanding of eggplant respond to drip irrigation.

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