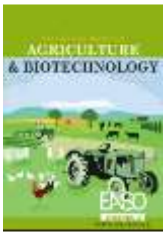

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Original Article

Impact of Different Drip Emitter Types on Hydraulic Performance and Wetted Zone Characteristics in Okra Cultivation

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Keywords:

Drip Irrigation, Hydraulic Performance, Emitter Clogging, Water Productivity, Uniformity.

ABSTRACT

Drip irrigation system is the most efficient and economical method for irrigation vegetable production. The study aimed to design and evaluate the hydraulic performance of three different types of emitter namely Regular gauge (RG), Compensating pressure (CP) and non-compensating pressure (NCP) using okra as a test of a crop. This study was conducted at the experimental farm of the Faculty of Agricultural Science, Zamzam University in 2023. The treatments were laid out in a randomized complete block design (RCBD) with three replications. 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 results showed that the values of (CU%), (CV), (EU%), (US%) and percentage emitters clogging (Pclog%) were 99.52%, 0.49, 68.01%, 74.14%, 2.8% and 99.32%, 0.36, 52.06%, 63.47%, 1.65% and 99.09%, 0.26, 40.07%, 51.05%, 0.85% for non-compensating pressure (NCP), compensating pressure (CP) and regular gauge (RG respectively. It is considered coefficient uniformity (CU %), was good and found to be within the excellent range while discharge variation (Qvar) was found to be within the desirable range, emission uniformity (EU %), coefficient of manufacture variation (CV), and statistical uniformity (Us %) were found to be within the range of poor, low, acceptable and unacceptable. Thus, the study recommended the best type of emitter was regular gauge (RG), because it has the highest crop yield and water productivity as compared to other emitters, non-compensating pressure emitters (NCP) and compensating pressure emitters (CP).

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INTRODUCTION

> *Agriculture accounts for about 70-80% use of available water in the world (Duhrkrop et al, 2009). Shortage of irrigation water has made it necessary to develop water-saving management technology in order to make it available to farmers through the season and ensure food security (Kumasi and Asenso, 2011). A system called drip irrigation, sometimes referred to as trickle irrigation, is intended to precisely and uniformly irrigate a plant's root.*

(Hisham *et al*, 2022). Drip irrigation is the most efficient and economical method for irrigation in vegetable production (Sharu and Abrazak, 2020) so that reduced wetted area, less water is lost to evaporation. Drip irrigation systems typically use 30 to 50% less water than other irrigation systems as they provide only the water needed by plants (Almajeed and Alabas, 2013). The Advantage of drip irrigation system include: less water 'fertilizer and nutrients can be used and 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 (Grubben and Denton, 2004).

Okra or 'lady's finger' or 'bamia pod' is a perennial flowering plant belonging to the Malvaceae family. It is a plant of the tropical and warm climates and the plant is highly valued due to its green pods. Okra vegetable is used in many dishes and cuisines and is rich in nutritional content. There is, however, some debate regarding the origin of this vegetable. Okra contains a number of essential vitamins and minerals and so is beneficial for your health. In tropical countries, okra pods are one of the most widely used vegetables. They can be consumed in a variety of ways – chopped, sliced, stewed or fried. The leaves of this vegetable are also edible and they are often utilized raw in salads. Okra plant is cultivated in tropical, sub-tropical and warm temperate regions of the world but its origin is debatable. (D. Sathish, 2013). Okra demands continuous moisture but is susceptible to waterlogging. Okra plants get a consistent water supply through drip irrigation, which minimizes water stress and encourages strong plant growth. Uniform and superior quality pods, as well as improved fruit set and yields, are the results of consistent soil moisture levels (Patel & Rajput, 2008).

The main objective of this research is to study the effects of three emitter types on hydraulic performance of drip irrigation system in wetted and depth diameter for okra production.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Experimental and Research center, Faculty of Agriculture at Zamzam University of Science and Technology, which locates around Garasbaley area which administratively comes under Benadir Region. Garasbaley lies on longitude 45.16°E and latitude 2. 04°N.Garasbaaleey geographically locates the West direction of Mogadishu-Somalia. The experiment was carried out in 2023 the area of the experimental plot was 140m^2 with dimensions of 14 m x 10 m. The experiment was laid out in a randomized complete block design

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(RCBD) with three replications. Three treatments were used which were regular gauge (RG), compensating pressure (CP) and non-compensating pressure (NCP).

Discharge measurement

The average discharge rate was measured using graduated measuring cylinder catch cans and a stopwatch. The model was lifted to work until one of the catch cans was filled, stopped the watch was, then the collected water in catch cans beneath each emitter compensating pressure emitter (CP), non-compensating pressure (NCP) and Regular gauge (RG) was measured by a 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.

$$Q = V/T \qquad (1)$$

Where:

Q =Discharge of emitters (Lh^{-1})

V =volume collected (L)

T = time taken (hrs)

Discharge variation (Qvar)

Flow variation is also a design parameter to evaluate trickle lateral design. The defining equation for flow variation was calculated using the following (Guguloth, 2016) equation

$$Q_{var} = (Qmax – Qmin)/Qmax \qquad (2)$$

Where:

Q_{var} = Flow variation

Qmax = maximum emitter discharge rate in system (L/h)

Qmin = the lowest emitter discharge rate in system (L/h)

Coefficient of uniformity (CU %)

One of the widely used CU is Christiansen uniformity coefficient. Uniformity coefficients of emitters were tested using the Christiansen (1942). It gives information on how efficiently water is distributed in the field

$$CU=100 – (80*Sd/V_{avg}) \ldots\ldots (3)$$

Where:

CU = Uniformity coefficient (%)

Sd = Standard deviation of observations

V_{avg} = Average volume collected.

Coefficient of manufacture variation (CV %)

The Coefficient variation can be calculated using the following formula (Michael, 1990).

$$CV= Sq /q_{avg} \qquad (4)$$

Where:

CV= the coefficient of variation of emitter discharge.

Sq = standard deviation of emitter discharge (L/h)

q_{avg} = average discharge rate of all emitters checked in the field (L/h)

Emission uniformity (EU %)

Emission uniformity was computed according to (Keller and Blaisner, 1990) the emission uniformity is defined as follows:

$$EU (\%) = (qavg25\%/ qavg) *100 \qquad (5)$$

Where:

qavg25% = 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, 1983).

$$Us (\%) = 100 (1 – Sq/q\ q_{avg}) \qquad (6)$$

Where:

Us = Statistical Uniformity (%)

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Sq = Standard deviation of emitters discharge (l/h).

q_{avg} = average Discharge of emitters (l/h).

Percentage of Clogging emitters (Pclog %)

The clogging emitter's percentage was determined using the following equation:

Where:

$$P_{c\log\%} = 100\left[\frac{Nes_{c\log}}{Nes_{total}}\right] \quad (7)$$

Pclog = percentage of clogging emitters (%)

Nesclog = numbers of clogged emitters.

Nestotal = total numbers of emitters.

Wetted diameter (cm)

The wetted diameter in the soil surface for each emitters type was measured, using a ruler.

Wetted depth (cm)

Pits were dug to measure the wetted depth of the soil profile. Nine random pits were dug for each emitters type

RESULT AND DISCUSSION

Emitter discharge (l/h)

The emitter's discharges were measured and calculated and the results are shown in Table (1) it's observed from the Table (3.1) that the average discharge rates of emitters were 3.2 l/hr, 2.35 l/hr and 1.1.351/hr for non-compensating pressure (NCP), compensating pressure (CP), and Regular gauge (RG) respectively. The highest value was obtained by the non-compensating pressure emitter (3.2 1/hr) while the lowest value was obtained by the Regular gauge emitter (1.135 l/hr)

Table 1. Emitter discharge (l/hr)

	Q l/hr		
Emitter type	**Test1**	**Test2**	**Means**
NCP	3.0	3.4	3.2
CP	2.2	2.5	2.35
RG	1.2	1.07	1.135

Emitter discharge variation (Q_{var})

The emitter variation discharge was measured and calculated and the results are shown in Table (2) the mean measured discharge variations of emitters were 0.91, 0.77, and 0.60 for the none compensating pressure (NCP), the compensating pressure emitter (CP), and the regular gauge emitter (RG) respectively. The highest mean value was obtained by the non-compensating pressure (NCP) emitter (0.91) while the lowest value was obtained by the regular gauge emitter (0.60). According to the Middle East J. Agric. Res.,2022 general criteria for Qvar values are 10% or less (desirable) and 10 to 20% acceptable and greater than 25%, not acceptable (Guguloth, 2016). The results obtained by all types of emitters were generally unacceptable.

Table 2. Discharge variation (Qvar)

	Q var			
Emitter type	**Test1**	**Test2**	**Means**	**Criteria**
NCP	0.87	0.96	0.915	Less Than 10%
Classification	Desirable	Desirable	Desirable	Desirable
Cp	0.57	0.98	0.775	Less Than 10%
Classification	Desirable	Desirable	Desirable	Desirable
RG	0.32	0.88	0.6	Less Than 10%
Classification	Desirable	Desirable	Desirable	Desirable

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Coefficient Uniformity (CU %)

Table (**3**) showed that the effect of the different three types of emitters on coefficient uniformity. The average coefficient of uniformity values of 99.09%, 99.32% and 99.52% were excellent for none compensating pressure emitter (NCP), compensating pressure (CP) and regular gauge (RG), respectively. The highest mean value was obtained by the regular gauge emitter (RG) (99.52%) excellent while the lowest value was achieved by the non-compensating pressure emitter (NCP) (99.09%) excellent. This result agrees with (Kirnak *et al*. (2014) who reported that the coefficient of uniformity of drip irrigation system is affected not only by hydraulic design but also by manufacture's variation. Bralts *et al*. (1987) reported that the coefficient of uniformity greater than 90% is excellent.

Table 3. Coefficient uniformity (CU %)

		CU%		
Emitter type	**Test1**	**Test2**	**Means**	**Criteria**
NCP	99.4	98.79	99.095	Above 90%
Classification	Excellent	Excellent	Excellent	Excellent
Cp	99.64	99.01	99.325	Above 90%
Classification	Excellent	Excellent	Excellent	Excellent
RG	99.65	99.39	99.52	Above 90%
Classification	Excellent	Excellent	Excellent	Excellent

Coefficient manufacture variation (CV %)

Table (4) shows the 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 were 0.49, 0.36 and 0.26 for the none-compensating pressure emitters (NCP), compensating pressure emitters (CP) and regular gauge emitters (RG), respectively. The highest mean value (unacceptable) was obtained by the non-compensating pressure emitters (0.49) while the lowest value (Acceptable) was achieved by the regular gauge emitters (0.26). This classification of coefficient of variation represented by Keller and Bliesner (1990).

Table 4. Coefficient of manufacture variation (CV)

		CV		
Emitter type	**Test1**	**Test2**	**Means**	**Criteria**
NCP	0.33	0.65	0.49	Above 0.4
Classification	Low	Unacceptable	Unacceptable	Unacceptable
Cp	0.19	0.54	0.365	0.3-0.4
Classification	Very good	Unacceptable	Low	Low
RG	0.19	0.33	0.26	0.2-0.3
Classification	Very good	Low	Very good	Acceptable

Emission uniformity (EU %)

The emission uniformity was measured and calculated and the results are shown in Table (**5**) and It's observed from that the average emission uniformity of emitters were (40.07%, 52.06 and 68.01) for non-compensating pressure (NCP), compensating pressure (CP) and Regular gauge (RG), respectively. The highest value was obtained by the Regular gauge emitter (68.01%) while the lowest value was obtained by non-compensating pressure emitter (40.07%). The results obtained by the all types of emitters were generally Poor and This classification of emission uniformity represented by Merriam and Keller (1978).

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Table 5. Emission uniformity (EU %)

		EU%		
Emitter type	**Test1**	**Test2**	**Means**	**Criteria**
NCP	57.27	22.87	40.07	Less than70%
Classification	Poor	Poor	Poor	Poor
Cp	77.7	26.43	52.065	Less than70%
Classification	Acceptable	Poor	Poor	Poor
RG	75.87	60.15	68.01	Less than70%
Classification	Acceptable	Poor	Poor	Poor

Statistical uniformity (Us %)

The statistical uniformity was measured and calculated and the results are shown in Table (6) and It's observed that the average statistical uniformity of emitters were 51.05%, 63.47% and 74.14% for non-compensating pressure (NCP), compensating pressure (CP), and Regular gauge (RG) respectively. The highest value was obtained by the Regular gauge emitter (74.14%) while the lowest value was obtained by the non-compensating pressure (51.05%). This result of statistical uniformity is evaluated according to ASAE (2003).

Table 6. Statistical uniformity (Us %)

		US%		
Emitter type	**Test1**	**Test2**	**Means**	**Criteria**
NCP	67.4	34.7	51.05	Less than 60%
Classification	Poor	Unacceptable	Unacceptable	Unacceptable
Cp	80.59	46.36	63.475	60-70%
Classification	Acceptable	Unacceptable	Poor	Poor
RG	81.13	67.15	74.14	70-80
Classification	Acceptable	Poor	Acceptable	Acceptable

Percentage of emitter clogging (pclog %)

Table (7) shows the effect of the different types of emitters on the percentage of emitters clogging of the drip irrigation system. The percentage of emitters clogging values of 2.8 %, 0.85% and 1.65% were obtained by the non-compensating pressure emitter (NCP), compensating pressure emitter (CP) and regular gauge emitter (RG), respectively. The highest mean value was obtained by the non-compensating pressure emitter (2.8%) while the lowest value was obtained by compensating pressure emitter (0.85 %).

Table 7. Percentage Emitters Clogging (Pclog %)

	Pclog%		
Emitter type	**Test1**	**Test2**	**Means**
NCP	2.6	3	2.8
CP	0.7	1	0.85
RG	1.5	1.8	1.65

Wetted diameter (cm)

Table (8) showed that the effect of hydraulic performance on wetted diameter of drip irrigation. The result obtained shows that the average wetted diameter of emitters was 12.75 cm, 15.19 cm, and 13.07 cm for non-compensating pressure (NCP), compensating pressure (CP) and Regular gauge (RG), respectively. The highest value was achieved by the compensated pressure emitter (15.19cm) while the lowest value was obtained by the non-compensating pressure (12.75 cm). Similar result was reported by Farah, (2023)

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

Wetted diameter (cm)	
Emitter type	**Means**
NCP	12.75
CP	15.19
RG	13.07

Wetted depth (cm)

Table (9) showed that the effect of hydraulic performance on wetted depth of drip irrigation. The result obtained shows that the average wetted depth of emitters were 6.02 cm, 9.82 cm, and 8.9 cm for non-compensating pressure (NCP), compensating pressure (CP) and Regular gauge (RG), respectively. The highest value was achieved by the compensated pressure emitter (9.82cm) while the lowest value was obtained by the non-compensating pressure (6.02 cm.

Table 9. Effect of emitter's type on wetted depth (cm)

Wetted depth(cm)	
Emitter type	**Means**
NCP	6.02
CP	9.82
RG	8.69

Applied water (m^3/ha)

Table (10) shows the effect of the drip irrigation treatments on the applied water. The results indicated that there were no significant differences ($P \leq 0.05$) in applied water between treatments of drip irrigation system. The results of the applied water obtained by the non-compensating pressure emitter (NCP), compensating pressure emitter (CP) and regular gauge emitter (RG), were 2092.3 m3 /ha, 2101.9 m3 /ha and 3383.1 m3 /ha, respectively. The highest applied water was obtained by the regular gauge emitter (3383.1 m3/ha), while the lowest was achieved by the non-compensating pressure emitter (2092.3 m3/ha).

Table 10. Applied water of okra under different irrigation emitters

Treatments	**Applied water**
NCP	2092.3 a
CP	2101.9 a
RG	3383.1 a
CV%	46.91
SE±	684.09
Significant level	n.s

Water productivity (kg/m^3)

The water productivity associated with the different emitter's types is presented in Table (11). The results showed that 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 (NCP, CP, RG) was 1.64 kg/ m^3, 3.29 kg/m^3 and 6.24 kg/ m^3, respectively. The significantly highest water productivity was obtained by the emitter regular gauge pressure. (6.2463kg/m^3) while the lowest was achieved by the non-compensating pressure emitter (1.6427 kg/m^3). Similar result were obtained by Muse, 2018) who reported that water productivity under difference irrigation emitters.

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Table 11. Water productivity of okra under difference irrigation emitters

Treatments	Water productivity
NCP	1.6427b
CP	3.2910ab
RG	6.2463a
CV%	2.9586
SE±	0.7535
Significant level	*

Crop yield (kg/ha)

The results of the total yield of Okra under the different drip irrigation treatments are shown in Table (4.15). The results indicate that there was significant difference (P≤0.05) between treatments under drip irrigation system. The yields obtained by the non-compensating pressure emitter (NCP), compensating pressure emitter (CP), and regular gauge emitter (RG), were 3197kg/ha, 12321kg/ha and 11018kg/ha, respectively. The statistical analysis of the results indicated that there were no significant differences (P≤0.05) in yield between the different irrigation treatments. The highest crop yield was obtained by the regular gauge emitter (12321kg/ha), while the lowest yield was achieved by the non-compensating pressure emitter (3197kg/ha). There was a reduction in yield of 20, 29 and 44%, by the drip irrigation treatments compared to fully irrigated treatments. These results are in agreement with the findings Karam *et al.*, (2009) and Topcu *et al.*, (2007), also, similar results were obtained by (Farah, 2023).

Table 12. Crop yield of okra under difference irrigation emitters.

Treatments	Crop yield
NCP	3197 b
CP	11018 ab
RG	12321 a
CV%	41.74
SE±	3014.5
Significant level	*

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 1.13 to 3.2 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 Excellent range (99.52%) , while discharge variation (Qvar%) was found to be within the desirable range(0.91), emission uniformity (EU%) was achieved within poor range (68.01), coefficient of manufacture variation (CV) was found to be within acceptable (0.49), and statistical uniformity (Us%) was achieved within acceptable (74.14%). Recommendation

From the results obtained and conclusions drawn from this study the following recommendations can be made: the regular gauge (RG) is the best one of emitter's type because it has the highest crop yield and water productivity as compared to other emitters, non-compensating pressure emitters (NCP) and compensating pressure emitters (CP).

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