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Drip Emitter Flow Rate Effect on Soil Moisture Content at Different Depths

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Abstract

This study was conducted in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat, on a total area of 15 m×35 m during October 2017 to March 2018. The objectives of the study were to determine the impact of emitter flow rate on soil moisture content at different depths (0-30, 30-60, 60-90 cm) of the soil profile and the wetted diameter at the soil surface under drip irrigation. The soil type of the site is heavy clay. Two flow rates of 8 and 16 liters/hours were used. The operating pressure was 1.5 bar. Eighteen basins were prepared for the citrus transplants. A drip irrigation system was designed and installed in the field. Six laterals were connected to the submain (25 mm in diameter) of the system. Each lateral line applied irrigation water to three basins. The diameter of the basin was 2 m and the spacing between basins was 5 m. Three laterals were provided with emitters to apply 8 L/h and the other three laterals were provided with emitters to provide 16 L/h, the amount of water applied to each basin was equal. The completely randomized design was used, and treatments were replicated three times. The data was analyzed using Statistical Package for the Social Sciences (SPSS), and the variations among means were checked by the analysis of variance (ANOVA). The findings concluded that the flow rate of 1 6L/h in comparison with the flow of 8 L/h recorded the highest moisture content to a depth of 30 cm. While moisture content values were not significantly different at the depth of 60 and 90 cm. There were no significant differences in wetted diameter values on soil surface for both discharges. Emitter discharge is an important factor in drip irrigation system design and management. In this study significant differences in soil moisture content due to emitter discharge were found near the soil surface (0–30 cm depth), while such differences were not found at depth 30–90 cm.

Keywords

Drip Irrigation, Flow Rate, Emitters, Moisture Content, SPSS

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1. Introduction

Water is an essential key to development and social welfare as it is the gate to agricultural, industrial, and domestic activities. Water resources in Sudan are rather limited despite the fact that they are comprised of rainfall, surface flows and groundwater [1]. Sudan is an agricultural country, rich in natural resources, but land and water need to be utilized efficiently for self-satisfaction in food, fiber and with excess for export. Sudan cultivable land is estimated to amount up to 105 million hectares of which only 7.4 million hectares are under rainfed agriculture and about 1.3 million hectares are under irrigation. River Nile and its tributaries are the main conventional source of water for reliable agricultural development. However this source is governed by international agreements. Approaches to conserve water can be adopted through improving and/or modernizing water application techniques at the farm level. The traditional

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irrigation method adopted in Sudan is the surface mainly with low efficiencies but there are serious efforts for improvement. These include precision levelling by the laser technology coupled with long furrow irrigation whereas the use of the hydro flume proved its success in Kenana sugar plantations. Irrigation modernization is accepted as a strategic option to improve water use efficiency and increase the total production and economic output. The overhead systems, particularly the center pivot systems have shown good success under Sudan conditions. On the other hand, the use of drip irrigation system is still confined to mainly glass houses, small private farms, shelter belts and landscaping [2]. Irrigation is the artificial application of water to the soil or plant, in the required quantity and at the time needed. Irrigation is widely carried out through surface and pressurized systems, characterized by the mode of transport of the water onto the point of application. Irrigation efficiency is an essential component of any irrigation system management due to its relationship with the energy and the labor required for implementing a sustainable irrigation scheme. Under several rules and conditions, the soil should be planted with plants at any age from seeds to harvest, that the process of adding water by human barb protrusion, whether by installing devices such as sprinklers and emitters, or digging channels for water movement [3].

Drip irrigation (trickle irrigation) is a type of micro-irrigation that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation. Drip irrigation systems distribute water through a network of valves, pipes, tubing, and emitters depending on how well designed, installed, maintained and operated. Trickle irrigation only wets part of the soil root zone, unlike surface and sprinkler irrigation. This may be as, low as 30% of the volume of soil wetted by the other methods. The wetting patterns which develop from dripping water onto the soil depend on discharge and soil type [4]. Drip irrigation is considered to be the most efficient irrigation method because it can distribute water uniformly, control the amount of water applied precisely, reduce evaporation and deep percolation, minimize salinity effects [5], and water is applied at frequent intervals in controlled quantities as per the requirements of plant. The knowledge of moisture distribution pattern helps in the effectiveness of drip irrigation. The extent of soil wetted volume in an irrigation system determines the sufficient amount of water needed to wet the root zone [6].

The objectives of this study under drip irrigation were to determine soil moisture content down the profile (30, 60, and 90 cm) and determining the wetted soil surface, both under tow flow rates of 8 and 16 L/h.

2. Materials and Methods

2.1. The Experimental Site and Layout

This study was conducted during October 2017 to March 2018 to assess moisture content at various depths and wetted surface for a drip irrigation system. The experimental work was carried out in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat (longitude 32° 32́ E, latitude 15° 40́ N and altitude 380 m amsl) [7]. The soil of the site belongs to the Central Clay Plain of the Sudan which has been formed by alluvial deposit of the Nile, primarily of basaltic origin, and it is considered as Vertisols [8]. The experimental area was of 15 m×35 m. A drip irrigation system was designed and installed. A number of 18 basins were constructed in the field. The diameter of each basin was 2 m, while the spacing between basins was 5 m. The basins were set in 6 rows each one had 3 basins while 8 L/h and 16 L/h discharges were used under operating pressure of 1.5 bar.

A completely randomized design with three replications was used. The data was analyzed using Statistical Package for the Social Sciences (SPSS). The variations among means were checked by the analysis of variance (ANOVA).

The materials used were Soil containers, Pressure gauge, Meter tape, Catch cans, Auger, Measuring cylinder and Stop watch.

2.2. Time Required for Motor Operation

To calculate the time required for motor operation the following equation [9] was used:

$$T = (\Pi\frac{d^2}{4} \times ETc \times \text{Irrigation interval})/\text{Emitter discharge} \quad (1)$$

d: basin diameter (m).

ETc: Water requirement (mm/day).

For 8 l/h discharge emitters $T = (\pi\times(2^2/4)\times8\times1)/8 = 3.14$ h.

For 16 l/h discharge emitters $T = (\pi\times(2^2/4)\times8\times1)/16 = 1.57$ h.

2.3. Determination of Soil Moisture Content

Before starting the experiment the soil was irrigated to field capacity, then the system operated for 3.1 h for 8 L/h discharge and 1.57 h for 16 L/h discharge.

Soil samples were collected in containers from 30, 60 and 90 cm depths, and sent to the laboratory to be dried for 24 hours at 105°C in the oven.

The following equation [10] was used to determine the soil moisture content:

$$Mc\% = \frac{W1 - W2}{W1}\times100 \quad (2)$$

Mc%: moisture content.

W1: weight of fresh soil sample (g).

W_2: weight of oven dry soil sample (g).

2.4. Drip System Performance

Before starting the experiment, the drip system was tested to verify its proper operation within the acceptable performance.

2.5. System Components

2.5.1. Pump Station

Two electrical pumps were used, the first one to withdraw water from the main line to the tank with a maximum head of 32 m. While the second pump (1.5 hp) was used to withdraw water from the tank into the system.

2.5.2. Water Tank

Water was stored in a plastic tank with capacity of 7.5 m^3. The tank was raised on an iron platform 1.5 m high with square base of 2 m×2m.

2.5.3. Main Line

A PVC plastic pipe with diameter of 25 mm was used as a main pipe line. One end of the line was connected to the pump outlet and the other end was connected to a main valve.

2.5.4. Lateral Lines

Six plastic pipes with diameter of 13 mm were used as a lateral lines. One end of the lines were connected to the mainline.

2.6. Wetted Diameter of the Soil Surface

The measuring tape was fixed at two points on the basin perimeter passing through the center, the average values of diameter were calculated for both discharges (8 and 16 L/h).

3. Results

As shown in Table 1 and Figure 1, the results revealed that the highest value of the average of moisture content (31.6%) was found in the depth of 30 cm, while the average of moisture content values were decreased in 60 and 90 cm depths for the discharge of 8 L/h.

For 16 L/h flow rate the maximum value of moisture content occurred in the depth of 30 cm (36.4%), while the moisture content values were decreased in 60 and 90 depths (19.8 and 18.9% respectively), as demonstrated in Table 2 and Figure 1.

According to the results presented in Table 3 and Figure 2, the average of wetted diameter of 16 L/h and 8 L/h discharges were 129.4 and 125.7 cm respectively.

4. Discussion

For the discharge of 8 L/h, significant differences ($P \leq 0.05$) were found in the values of moisture content under 30 cm depth, the depth 0 - 30 cm indicated the highest value of moisture content (31.6%). On the other hand, there were no significant differences in moisture content at 60 and 90 cm depths. The average amounts of moisture content were decreased in 60 and 90 cm depths (Table 1 and Figure 1). The wetted patterns were affected by the application rate when the soil is uniform [11]. The wetted radius and depth increased with increasing the irrigation time at the same emitter discharge and initial water content, and with increasing the emitter discharge at the same irrigation time and initial water content [12].

Table 1. Average of moisture content (MC%) for discharge 8 L/h.

Depth (cm)	Average of MC% replicates			Average of MC%
	1	2	3	
30	35.3	30.1	29.3	31.6
60	21.1	18.7	16.3	18.7
90	16.3	20.3	17.6	18.1

Tables 1 and 2 illustrated that the average of moisture content values for discharge 16 L/h was higher than moisture content of flow rate 8 L/h for depth of 30 cm, but the average moisture values for depths of 60 and 90 cm seem close to each other for the two flow rates. Significant differences ($P \leq 0.05$) were found in the average values of moisture under 30 cm depth, and there were no significant differences in 60 and 90 cm depths for the discharge 16 L/h. As presented in Table 2 and Figure 1, The highest value of moisture content occurred in the depth (0-30cm), while the moisture content values were decreased in 60 and 90 depths. The results were in conformity with the results obtained by Zhang and others [13], who compared single emitter wetted patterns with multi emitters and it was noticed that wetted depth was significantly greater in multi emitters than single emitter. Soil moisture content was relatively higher by volume near the emitter and it was decreasing as the distance from the emitting point increased [14].

The wetted diameter for both 8 L/h and 16 L/h discharges in the beginning of lines were higher than the others which reference to the high pressure at the beginning of the line because the distance from the source of water is short. The analysis showed that there were no significant differences in the wetted diameter values. Similarly, Acar and others obtained that, different water applications had significant effect on only vertical wetting front advance but had no significant effects on lateral wetting front advance within the soil profile and at the surface [15]. According to the results presented in Table 3 and Figure 2, the average of wetted diameter of 16 L/h was little higher than 8 L/h. The volume of applied water increases the wetted surface area [16].

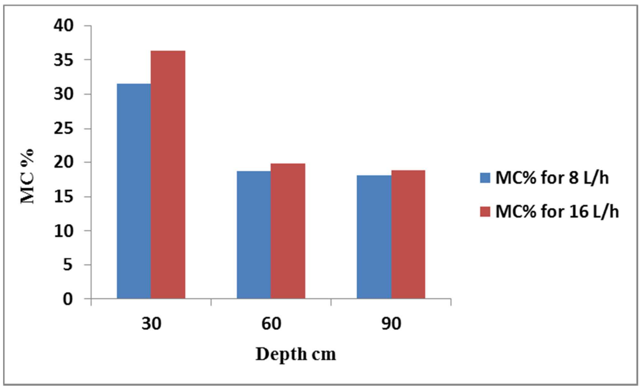

Figure 1. Average of moisture content for 8 and 16 L/h discharges.

Table 2. Average values of moisture content (MC%) for discharge 16 L/h.

Depth (cm)	Average of MC% replicates			Average of MC%
	1	2	3	
30	37.8	33.6	37.8	36.4
60	22.0	18.5	19.0	19.8
90	18.1	18.6	19.9	18.9

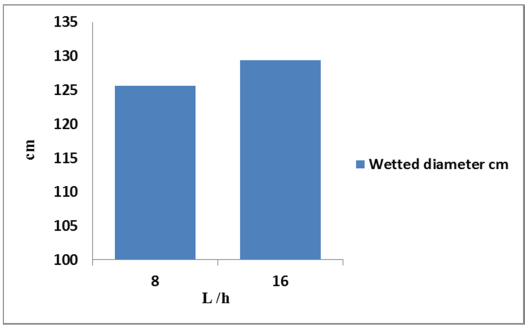

Figure 2. Wetted diameter for 8 and 16 L/h discharges.

Table 3. Average of wetted diameter for 8 and 16 L/h discharges.

Discharge (L/h)	Wetted diameter of basins (cm)									Average of wetted diameter
8	130	128.5	127	131	125	120	123	126	120	125.7
16	137	140	145.5	126	120	120	136	120	120	129.4

5. Conclusions

This study was conducted in a heavy clay soil to determine the impact of emitters discharge on soil moisture at different depths (30, 60 and 90 cm) of the soil profile and the wetted diameter at the soil surface under drip irrigation. Soil moisture values were determined for the two flow rates (8 and 16 L/h) and analyzed using analysis of variance (ANOVA). From the results of this study it can be concluded that for the two different flow rates tested, soil moisture content increased near the soil surface (0 –30 cm depth) with increasing emitter flow rate at the same amount of water applied. There were no significant differences in moisture content values of soil for depths of 60 and 90 cm. Significant differences were found in the values of moisture content under 30 cm depth. The highest values of moisture content occurred in the soil depth of 30 cm for both discharges. For discharge of 16 L/h the moisture content was higher for depth of 30 cm than moisture content value for 8 L/h discharge. The wetted diameter for 16 L/h was little higher than 8 L/h. The study results will be very useful for providing adequate amount of water in the root zone depth, decreasing the period of irrigation time and saving energy.

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