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Effect of Fertigation Methods on Hydraulic Performance of Drip Irrigation System under Greenhouse Conditions

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ABSTRACT: The experiment was conducted during 2018 in the greenhouse of the Horticulture Department of the Ministry of Production and Economic Resources, Kassala State, Kassala, to evaluate the effect of fertigation methods on hydraulic performance of drip irrigation system under greenhouse conditions. Drip irrigation system including fertigation units was installed. Four types of fertigators viz: ordinary closed tank, venturi, centrifugal pump and new method (simple way) were tested for efficiency and uniformity of drip irrigation system compared to drip irrigation without fertigation as standard method. Each type of fertigation was tested for 30 minutes. Treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications. The results showed that the highest values of field emission uniformity and absolute emission uniformity were recorded under centrifugal pump, the new method compared to venturi and closed tank. The best values of uniformity coefficient and distribution uniformity were recorded under new method and centrifugal pump compared to venturi and closed tank. The highest value of application efficiency was recorded under new method while the lowest under closed tank.

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KEYWORDS: Fertigation, emission uniformity, application efficiency, emitters.

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1. INTRODUCTION

Drip irrigation is a highly efficient system because the immediate root zone of each plant is wetted and also allows the application of water-soluble fertilizers and other agricultural chemicals. Under drip irrigation yield can be increased of up to 100%, beside water savings of up to 40-80% and labor savings over conventional irrigation systems (El-Habbasha, *et al*., 2015). In the Sudan, drip irrigation is very easy to design and install and has become very popular in the production of high value crops in large area in the open field and greenhouses. However, it was recommended for banana, onion and citrus by Khalifa, *et al.* (2013) and Khalifa, *et al.* (2014a; 2014b). They also reported that drip irrigation system scored higher net return and benefit cost ratio compared to the surface irrigation system.

Fertigation is a modern agro-technique combining water and fertilizer application through irrigation -provides an excellent opportunity to both maximize yield and minimize environmental pollution (Johnston, *et al*., 2003). It has also been found to increase the efficiency of the application of fertilizers besides reducing the quantity applied (Bharath, *et al*., 2015). The method of application plays an important role in the optimum utilization of a fertilizer as well as on improving its use efficiency (Malakouti, 2004). There are several advantages of fertigation as described by (Schumann, *et al*., 2009). Khalifa, *et al.* (2013) revealed that fertigation regimes had significant effects on number of fruits per plant and total yield. The highest yield and number of fruits per plant were obtained by 125% of urea recommended dose while the lowest was obtained by 50% of urea recommended dose in both years of grapefruit production.

Several techniques have been developed for applying fertilizers through the irrigation systems. For the greenhouse, there are two types available in the local market; ordinary closed tank and venturi type and both systems are operated by the drip irrigation pressure, which means it requires pressure loss in main irrigation (Phocaides, 2000). Some farmers use centrifugal pump to inject fertilizers into drip main-line behind the pump in the drip system.

The distribution uniformity of water is one of the important parameters to characterize drip emitters and design of a drip irrigation system (Zhou *et al*., 2017). Poor irrigation uniformity can leach nutrients out of the soil due to excess water being applied. This will increase fertilizer costs and pumping costs, and may have environmental impacts if the excess runoff and deep percolation are contaminated with nutrients (Solomon, 1983). In recent years, there has been tremendous interest in applying fertilizer nutrients through the irrigation system (fertigation) as a source of providing nutrients (Johnston, *et al*., 2003). The high efficiency of fertigation under greenhouse basically depends on drip irrigation uniformity and water distribution. Irrigation systems with poor distribution uniformity experience reduced yields due to water stress and or water logging (Clemmens and Solomon 1797). On the other hands, Solomon, (1983) reported that poor distribution uniformity also has increased financial and environmental costs. There is need to study the effect of different fertigation methods on the uniformity, water distribution and efficiency of drip irrigation system. Therefore, the objective this study was to evaluate the effect of fertigation method on the hydraulic performance of drip irrigation system under greenhouse conditions.

2. MATERIALS AND METHODS

The Experiment was conducted in the greenhouse of the Horticulture Department of the Ministry of Production and Economic Resources, Kassala State, Kassala, Sudan, during the year 2018 to evaluate the effect of fertigation methods on the hydraulic performance of drip irrigation system under greenhouse conditions. The greenhouse was a plastic tunnel and the area was 306 m^2 (34m×9m). The greenhouses directions are North-South, the temperature was 24-31°C and humidity was 80-90%. The drip line inside diameter was 13 mm and the dripper spacing was 40 cm with a nominal emitter discharge of 4l/h. The system was installed according to the recommended spacing of crops under greenhouses.

The Fertigation units: it consists of four different fertigation units as follows;

1. Ordinary closed tank:

This is a cylindrical pressurized metal tank (100liters) capacity and connected to the irrigation line by using a hose one inch diameter through two control valves (one at the inlet and the other at outlet) as shown in (Fig .1).

2. Venturi:

Venturi unit connected to the irrigation line by using 1″ diameter hose through two control valves (one at inlet and the other at outlet). It consists of a cylindrical entrance section 1″ diameter, cylindrical throat section 0.75″diameter and diffuser section 1″ diameter. The tank 50liters capacity connected to the venturi using a hose 0.75″diameter through control valve at absorption line (Fig .2).

3. Centrifugal pump:

The specification of the pump are; 0.75 kW (1HP), water discharge between 5 to 50l/min and pressure head from 28 to 51m (Fig .3).

4. New method (simple way):

It consists of a tank 50liters capacity with two control valves (one at the inlet and the other at the outlet). The inlet valve was placed on top of the tank and connected to 1″ diameter pipe, then the pipe was connected to the outside main pipe of drip irrigation pump. The role of this outlet pipe was to fill the tank by water for mixing the fertilizers and then closed. The outlet valve was placed on bottom of the tank and connected to 1″ diameter pipe, then the pipe was connected to main section pipe of drip irrigation pump. When the main pump is operated for irrigation, the outlet valve opens to allow the mixed fertilizer to be drawn from the tank to the main irrigation line by pump to the plant. The valve is closed when water and fertilizers were finished. The advantages of this method are cheap, easy and do not affect drip irrigation pressure (Fig .4).

The Four types of fertigation methods; ordinary closed tank, venturi, centrifugal pump and new method (simple way) were tested for efficiency and uniformity of drip irrigation system compared to drip irrigation without fertigation as standard method (control). Each type of fertigation was tested for 30 minutes and replicated three times. Treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications.

The hydraulic performance of the drip irrigation system was tested before and after the season. For computing uniformity, four laterals in the greenhouse were selected. Out of four; two were selected from middle and two from outside. Then these laterals were divided in 4 sections along the lateral length to give 16 parts. Two successive emitters from each part were selected to measure the discharge (liter per hour). The mean values of the two successive emitters were taken.

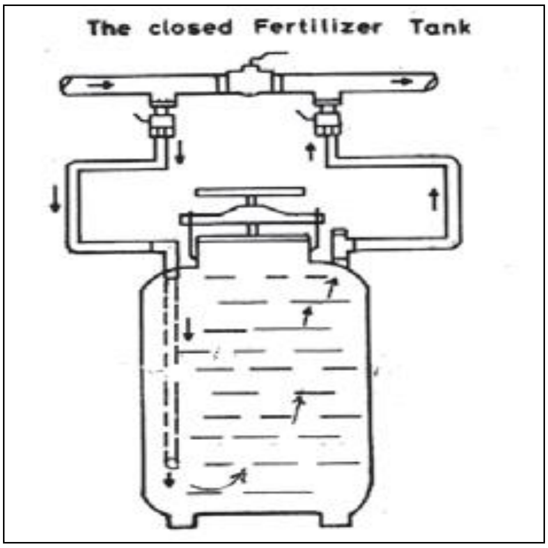

Figure 1. Ordinary closed tank

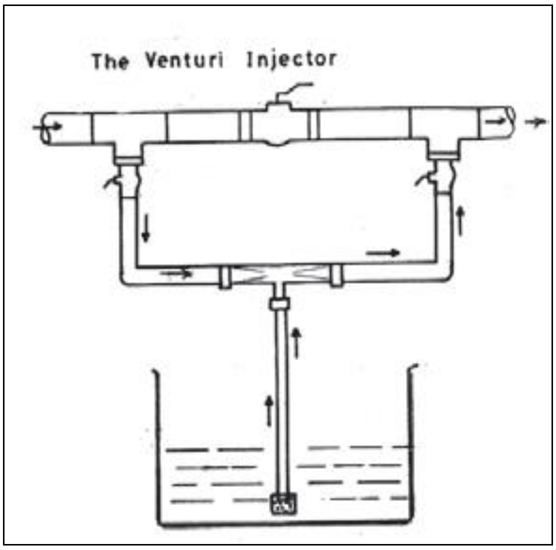

Figure 2. Venturi

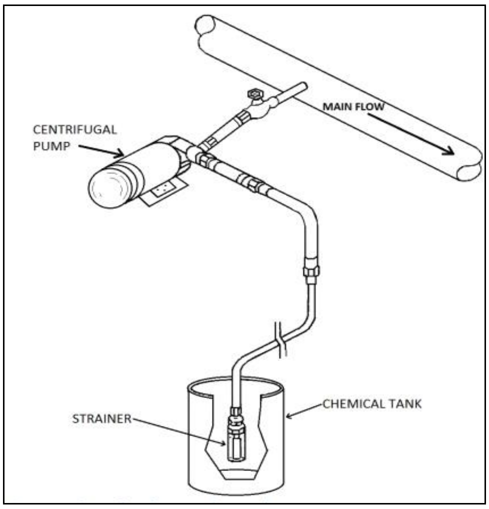

Figure 3. Centrifugal pump

Figure 4. New method (simple way)

Evaluation of the system was made by using the equations as suggested by different scientists.

1. **Field emission uniformity (EU_f)**

Field emission uniformity defines the uniformity of water application by drip irrigation method according to Choudhary and Kadam (2006) using the following equations:

$$EU_f = \frac{Q\ min}{Q\ avg} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

EU_f = field emission uniformity (%), Qmin = minimum emitter discharge (lph) and Qavg = average emitter discharge (lph).

2. **Absolute emission uniformity (EU_a)**

Absolute emission uniformity by the following equation according to Choudhary and Kadam (2006):

$$EU_a = \frac{1}{2}\left[\frac{Q\ min}{Q\ avg} + \frac{Q\ avg}{Q\ x}\right] \times 100 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where:

EU_a = absolute emission uniformity (%), Qmin = minimum emitter discharge, lph, Qavg = average emitter discharge, lph and Qx = average of highest 1/8th of emitter discharge, lph.

3. Coefficient of uniformity

The variation of emitter flow in a drip irrigation system was evaluated by using the uniformity coefficient deveined by Yildirim and Apaydin, (1999) as follows:

$$Cu = 100\left(1 - \frac{\Delta q}{q}\right) \quad \text{……………….……. (4)}$$

Where:

Cu = Christiansen's uniformity coefficient in percentage.

Δq = mean deviation of individual emitters flow from the mean (l/h).

q = mean flow rate from emitters.

4. Distribution uniformity

The efficiency of drip irrigation system depends on the uniformity with which water is discharged from emission devices (Solomon, 1983). In systems with drip tubing on soil surface, the uniformity can be evaluated by direct measurement of emitter flow rate as follows:

$$Du = 100\left(\frac{q_n}{q_{ave}}\right) \quad \text{……………………………….. (5)}$$

Where:

Du = distribution uniformity.

qn = average rate of discharge of the lowest one-fourth of the field data of emitter discharge readings (l/h).

q_{ave} = average discharge rate of all the emitters checked in the field (l/h).

5. Application efficiency (Ea)

The overall application efficiency of drip irrigation according to Vermeiren and Gobling (1990) was determined as follows:

Ea =Ks× Eu …………………… (3)

Where:

Ks = ratio between water stored and that diverted from the field. It expresses the water storage efficiency of the soil. It takes into account unavoidable deep percolation as well as other losses.

Eu = emission uniformity of drip irrigation system.

Table. 1. Water storage efficiency for different types of soil

Types of soil	Water storage efficiency (Ks)
Clay	100
Mixed silt, clay and loamy	95
Loamy	90
Sandy	87

Source: *Vermeiren and Gobling (1990)*

CropStat statistical package was used for data analysis and the least significant difference (LSD) test was used for mean separation at the probability level of 0.05.

3. RESULTS AND DISCUSSION

Effect of fertigation methods on field emission uniformity and absolute emission uniformity of drip irrigation system under greenhouse conditions:

There were highly significant differences in the field emission uniformity and absolute emission uniformity before and after the season (Table 2). The results showed that the closed tank and venturi methods were decreased field emission uniformity and absolute emission uniformity compared to control treatment (without fertigation) as shown in Table (2). Also there were no significant differences between centrifugal pump, new method and control treatment (without fertigation) (Table 2). The decrease in uniformity might by due to the effect of those methods in the pressure and emitters discharge because the operation of differential pressure tank and venturi depends mainly on the difference in pressure between the inlet and outlet of fertigators. These results are in agreement with those obtained by Abdallah, *et al*. (2006) who reported that the highest losses of head resulted when using differential pressure tank, while the lowest losses in the pressure head were obtained under the hydraulic injection pump. This is due to the fact that the operation of differential pressure tank and venturi depend mainly on the differential pressure between the inlet and outlet of fertigators. Moreover, Camp, *et al*. (1993) reported that if the water and fertilizer are to be applied together, it is crucial to evaluate emitter discharge uniformity and system performance.

Table 2. Effect of fertigation methods on field emission uniformity and absolute emission uniformity of drip irrigation system under greenhouse conditions.

Treatments	Field emission uniformity		Absolute emission uniformity	
	Before season	After season	Before season	After season
Closed tank	88.9c	88.6c	90.0d	89.8b
Venturi	91.3b	90.3bc	90.8c	90.4b
Centrifugal pump	92.9a	92.6ab	93.8ab	91.8ab
New method	94.2a	93.1ab	94.4a	94.4a
Control Without fertigation	94.4a	94.0a	93.3a	93.1a
Significance level	***	**	***	*
SE±	0.47	0.86	0.22	0.81
CV%	0.9	1.6	0.4	1.5

, **and* indicated significance at $P\leq 0.05$, 0.01 and 0.001, respectively.*

Effect of fertigation methods on uniformity coefficient and distribution uniformity of drip irrigation system under greenhouse conditions:

In the uniformity coefficient and distribution uniformity there were very highly significant differences before and after the season (Table 3). The highest values of uniformity coefficient and distribution uniformity were obtained with the control treatments (without fertigation) while the lowest were recorded under closed thank (Table 3). The best values of uniformity coefficient and distribution uniformity were recorded under new method and centrifugal pump compared to venturi and closed tank (Table 3). This may be due to the variation in emitters discharge and in the pressure head. The reason explained by Abdallah, *et al*. (2006) who found that the highest value of uniformity coefficient was 100%for the hydraulic pump injection method compared to 78% for pressure differential tank. Moreover, Letey *et al*. (1984) reported that the distribution uniformity of a system has an effect on the system application efficiency and on the crop yield.

Table 3. Effect of fertigation methods on uniformity coefficient and distribution uniformity of drip irrigation system under greenhouse conditions

Treatments	Uniformity coefficient		Distribution uniformity	
	Before season	After season	Before season	After season
Closed tank	91.7d	91.7d	90.7c	90.2d
Venturi	94.3c	94.1c	93.4e	92.8c
Centrifugal pump	95.3bc	95.4b	92.9d	92.7c
New method	95.9b	96.2b	94.7b	94.4b
Control Without fertigation	98.3a	97.7a	96.3a	96.8a
Significance level	***	***	***	***
SE±	0.33	0.42	0.14	0.33
CV%	0.6	0.8	0.3	0.6

**** indicated significance at $P\leq 0.001$.*

Effect of fertigation methods on application efficiency of drip irrigation system under greenhouse conditions

There were very highly significant differences in the application efficiency of drip irrigation before and after the season (Table 4). The highest value of application efficiency was recorded under new method while the lowest under closed tank (Table 4). Similar results were reported by Abdallah, *et al*. (2006) who observed the application efficiency was affected by both of fertigators device and lateral lengths. The values of application efficiency for lateral length of 40m were 99%, 98% and 92% for Hydraulic injection, pressure differential tank and venturi, respectively. Moreover, Pereira, (1999) found that distribution uniformity of an irrigation system depends both on the system characteristics and on the managerial decisions.

Table 4. Effect of fertigation methods on application efficiency of drip irrigation system under greenhouse conditions

Treatments	Application efficiency	
	Before season	After season
Closed tank	84.4d	84.2d
Venturi	86.8c	85.8c
Centrifugal pump	88.2b	88.0b
New method	90.0a	89.7a
Control Without fertigation	89.7a	89.3a
Significance level	***	***
SE$^{\pm}$	1.2	0.44
CV%	0.7	0.9

*** *indicated significance at P≤ 0.001.*

4. CONCLUSIONS

1. The highest values of field emission uniformity and absolute emission uniformity were recorded under centrifugal pump and new method compared to control treatment (without fertigation).
2. The best values of uniformity coefficient and distribution uniformity were recorded under new method and centrifugal pump compared to venturi and closed tank.
3. The highest value of application efficiency was recorded under new method while the lowest under closed tank.

Based on the findings, the fertigation methods by centrifugal pump and the new method is recommended for improving drip irrigation hydraulic performance under greenhouse conditions.

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