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ROLE OF EMISSION UNIFORMITY IN THE SUSTAINABLE MANAGEMENT OF DRIP IRRIGATION SYSTEM

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Abstract- Sustainable management of drip irrigation system aims to the efficient use of different input resources like energy, water, and financial resources. This study was achieved to investigate the effect of the drip irrigation system emission uniformity (EU) on the water and energy use efficiencies besides studying its impact on crop profitability. The study took place in Al-Shahwan farm, Khatatba village, Menoufia governorate, Egypt in the successive season 2010 on squash crop. Split-plot designed experiment with two variables including four operating pressure heads 6, 8, 10, and 12m (main plot) as a variable that affects EU; and two types of emitters G and T (sub-main plot). The G type showed higher EU under all operating heads. The higher values of EU will result higher values of crop production, and water use efficiency (WUE). Operating pressure was the only factor that significantly affects EU and crop production. T type showed higher energy use efficiency (EUE) compared to G type values because of its high flow rate values that decreased the operation time which directly will result low values of energy consumption. G emitter showed higher Benefit-cost ratio (B/C) values than T type. The B/C ratio of G8 treatment was lower than values of T12 and T10 treatments despite the higher production of the two mentioned T emitter treatments. This was because of the higher power requirement which meant higher fuel consumption besides the higher capital price of T emitter laterals. Generally, the study pointed out that maximum possible EU value that result from well designed and managed and continuously evaluated drip irrigation system, is necessary to reach the goals of sustainable management including higher WUE, EUE, and higher crop profitability. In addition to keeping EU as high as possible, the study recommended to use higher flow rates emitters that gives high EU whenever available to avoid the decrease in EUE that may result due to higher operating time. The studies recommended to put the integration between system performance and network components' costs in consider for avoiding any possible decrease in crop profitability. There should be tries for using already existed low-cost energy sources to reduce the operation costs or trying to use non- traditional sources.

Keywords- Drip irrigation, Emission uniformity, Sustainable, System management

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Introduction

Sustainable management of a system expresses the efficient use of environmental and financial resources without compromising the future generations to meet their needs of these resources. Rational and effective use of natural resources like energy and water in agriculture is one of the principal requirements for sustainable development. It will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system [1]. Making this efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, the economic viability of farm operations to enhance the quality of farmers' life and society as a whole [2]. Consequently, all factors that control the efficiency of the use of energy, water, and financial resources should be well studied for the design, operation, and management of agricultural systems considering sustainability of these resources. Irrigation operations are the major user of energy in agricultural production [3,4]. Modernization of irrigation systems led to increased consumption of energy [5]. Energy needs for water pumping may be several times greater than those for all other agricultural field operations. When water usage becomes inefficient, the total energy requirements for agricultural production will increase [6]. Khan, et al. [3] investigated the energy inputs for different grain crops production under different irrigation systems in Australia. They concluded that improving energy use efficiency (EUE) and crop- water productivity are the two possible pathways for reducing the environmental footprints of water and energy inputs. On the average, drip irrigation saves about 70 to 80% water when compared to conventional flooding or furrow irrigation methods [7]. This means that well managed and high-performance drip irrigation system will lead to higher water use efficiency (WUE). This water conservation is only possible when water is uniformly discharged through emitters. Irrigation uniformity is the most important indicator for evaluation of the irrigation system performance [8]. Uniform distribution of water means that all the plants have equal access to water [9]. All emitters in the system should discharge equal amounts of water, but flow rate differences between two supposedly identical emitters may exist due to some factors including pressure differences and emitters' sensitivity to pressure changes [10]. The modeling of crop response to water application indicated that more uniform application of water leads to higher crop yield [11-15]. Solomon [16] related expected yield to several uniformity measures, including Christiansen's uniformity coefficient, statistical uniformity [17,18] and distribution uniformity [19]. El Nemr [20] recommended moving away from the use of emitters that shows low values of uniformity parameters because of the negative impact on crop production. EU uniformity expresses the uniformity of emitters under constant pressure [21]. Low EU will necessitate applying more water to satisfy the need of plants receiving less than their water requirements. EU as a uniformity parameter has the advantage of including other uniformity parameters through its calculation process which are manufacturing coefficient of variation (CV) and emitters' flow rate variation [22, 23]. Sepaskhah, et al. [24] studied the combination of irrigation uniformity, system efficiency, and deficit irrigation on the crop production and crop profitability of winter wheat, spring barley, maize, and sorghum in an arid region. They concluded that combining system uniformity with low system efficiency and deficit irrigation will result a higher benefit- cost ratio as it reduces their negative effect on crop production. López-Mata, et al [15] used the uniformity coefficient to express the uniformity of applied water on soil. They indicated that increasing drip irrigation uniformity will decrease the gross margin (GM) of maize crop. Operating pressure head is one of the most important factors for successful drip irrigation system management. It affects the drip system uniformity parameters, besides affecting the power requirement for system operation. Irrigation power requirement plays an economic role in system management because it does control the cost of pumping beside the cost of energy consumption. Thus, we should study the suitable operating pressure for different types of emitters that give higher uniformity parameters, and its effect on the expected increase of crop yield, which may mean higher WUE and EUE putting the power and fuel needs and its economic impact on crop profitability in consider. The main objective of this study was to investigate the role of the designed emission uniformity of drip irrigation system in the sustainable system management by the meaning of obtaining the efficient use of different resources including water, energy, and financial resources through the following points:-

- Observing the effect of operating pressure as a factor directly affects power requirement and energy consumption on the emission uniformity.
- Evaluating the role of emission uniformity on increasing water and energy use efficiencies.
- Studying the effect of emission uniformity variation on crop profitability.

Methodology

Experimental Area.

The field experiment was carried out in Al-Shahwan Farms, Khatatba village, Menoufia governorate (30° 19\ L N- 30° 40\ E). Squash crop *CA2707* was irrigated using drip irrigation system with 72 hours interval during the successive summer season 2010 in sandy soil [Table-1].

The cultivated area was graded to the slope of zero level. The soil chemical analysis showed that soil pH was 7.85. Therefore 95.2 kg ha^{-1} of sulfur was added to reduce alkalinity effect. Electrical conductivity of water was 0.8 dS/m while SAR (Sodium absorption ratio) was 2.55, so the irrigation water can be used without any expected problems for salinity or infiltration [25]. After germination, the following amounts of fertilizers in kilograms per hectare were injected to the network 3 times weekly for 4 weeks 4.76 $CO(NH_2)_2$, 4.76 NH_3, 1.19 H_3PO_4. Also 11.9 NH_4NO_3, 14.28 K_2SO_4, and 1.19 H_3PO_4 were added 3 times weekly and stopped fifteen days before the end of harvesting period. A pesticide 2.5% Mefenoxam, and 40% Copper with concentration of 1500 g/m^3 of water was used to defend plants against fungus infections. Crop was planted in 5/8/2010 with 3 seeds per pore (50 cm spacing) at 15 cm depth and after germination it was thinned to one plant / pore. Harvesting started at 2/10/2010 till 24/11/2010 with a total 112 days growing season.

Table 1- Some physical characteristics of the experimental area soil

Depth, cm	Particle size distribution, %			Texture	F.C, %.	W.P, %.
	Sand	Silt.	Clay.			
0-15	89.69	0.47	9.84	Sandy	9.8	4.6
15-30	90.62	0.45	9.93	Sandy	10.4	5
30-45	88.5	3.21	8.25	Sandy	10.9	5.1

F.C = Field capacity, and W.P= Wilting point.

Irrigation Network Installation

The layout of irrigation network is shown in [Fig-1]. Laterals 30 m long, 16mm inner diameter, and 1.5 m spacing were used with two types of emitters 0.5 m spacing along lateral. [Fig-2] shows the different types of the used emitters G and T.

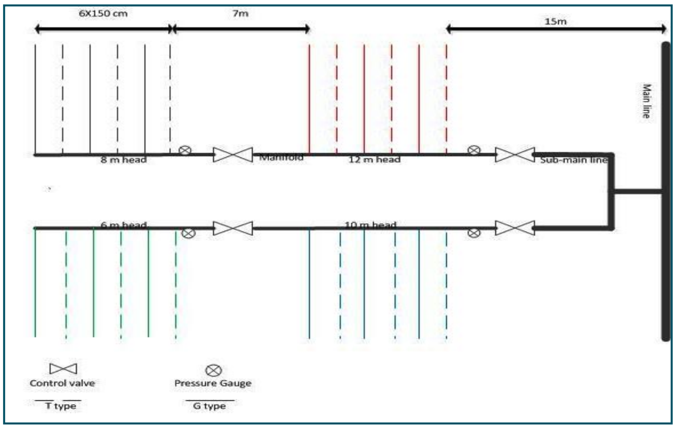

Fig. 1- Schematic diagram for the irrigation network layout.

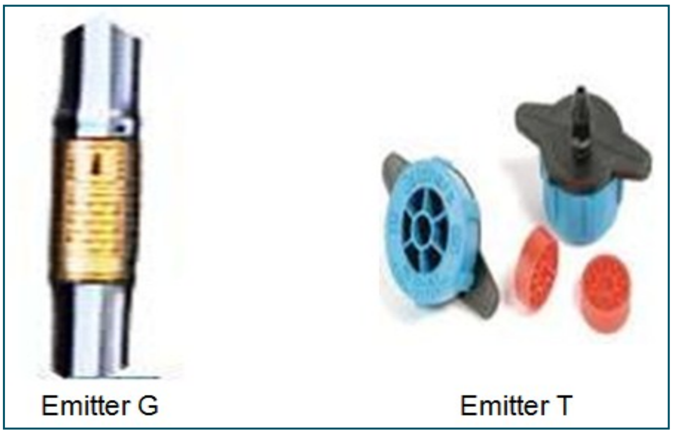

Fig. 2- Emitter types- G and T

The inner diameters of main line, sub-mains and manifolds were 12.7, 7.62 and 5.08 cm respectively.

Variables and Statistical Design

Split-plot design was used to study the significance of experimental variables effect on crop production and EU. Four operating pressure heads (main plot) 6, 8, 10, and 12 meter of water were used in the irrigation network that contains two types of emitters (sub-main plot) G, and T. Three replicates of each treatment were used for statistical analysis of crop production values [Fig-1].

Emitters' Specifications.

[Table-2] lists some manufacturing specifications of the used emitters.

Table 2- Some emitters' manufacturing data.

Emitter symbol	Manufacturer name	Classification	Country of made
G	Euro drip	Built-in	Egypt
T	Arab drip	Long path	Jordan

[Table-3] shows the values of emitters' flow rates under the different used pressure heads and the emitter exponent(x). The emitter flow rate-pressure relationship was described with the [Eq-1] [26].

$$q = kH^{x} \quad (1)$$

where q= emitter flow rate l h^{-1}, and H is the emitter operating head, m.

Table 3- Emitters' flow rates, l/h under different pressure heads

Emitter type	Operating pressure head, m				Flow rate-pressure relationship
	6	8	10	12	
G	2.26	3.05	3.2	3.79	$q=1.02H^{0.25}$
T	2.74	3.5	4	4.06	$q= 0.83H^{0.34}$

Both G and T emitters according to the values of their exponent are considered pressure compensating emitters [27].

Measurements

- **Emission Uniformity**

Wu, et al. [22] and Barragan, et al. [23] used the [Eq-2] to calculate EU.

$$EU = \frac{q'_{lq}}{q'} = 1 - \sqrt{[1 - \frac{q_{min}}{q'}]^2 + [\frac{1.27CV}{\sqrt{N}}]^2} \quad (2)$$

Where: $q`$= Average of emitters' flow rate, l $h^{-1}$, $q`_{lq}$= mean of lowest one-fourth of emitter flow rates, l h^{-1}. CV = emitter coefficient manufacture of variation, and N = number of emitters per plant which was 1 under the experiment conditions. CV was calculated referring to [28].

$$CV = \frac{S_q}{q} \quad (3)$$

Where: and S_q = standard deviation of emitters' flow rate. Lateral length was divided into four fake quarters. Five emitters from each quarter were chosen randomly to form 20 emitters' flow rates samples. Discharged water was collected in graded bottles which were put all at once for 2 minutes under the emitters to obtain emitter flow rate. The previous steps were replicated three times on one lateral from each treatments replicates considering being the same lateral each time to unify measuring conditions.

- **Irrigation Water Requirements**

Crop water requirements were calculated according to Sepaskhah, et al. [24]. Crop reference evapotranspiration monthly values (ET_o, mm/day) were cited from CLIMWAT computer program [29] for El-Tahrir meteorological station which covers the experimental area.

$$ET_c = ET_0.K_c.K_r \quad (4)$$

Where: Kc = crop factor which took the values 0.45, 0.7, 0.9 and 0.75 for the initial, development, mid, and late growing periods of crop, [30].

$$K_r = \text{reduction factor} = \frac{\text{Space between plants} \times \text{Space between Laterals}}{0.85} \text{ or 1 which is less} \quad (5)$$

By applying [Eq-5] K_r=0.88.

- **Crop Production**

The total weight of squash fruit produced in every replicate was weighed on 10 g accuracy scale. The whole fruits under each replicate were picked when cucumber fruit reached the accepted market size (10-15 cm long).

The average of the three replicates was multiplied to 222.2 to get the crop yield per hectare for each treatment.

- **Water Use Efficiency (WUE)**

WUE has been used to describe the relationship between squash crop production and the total amount of water used. It was determined in kg m^{-3} by applying the [Eq-6] [31].

$$WUE = \frac{Y}{W_a} \quad (6)$$

Where: Y = total yield, kg ha^{-1} and W_a = total applied water, m^3 ha^{-1}.

- **Power Requirements**

In order to calculate the energy consumption of the irrigation network under the experimental conditions. The water pumping power requirement has to be calculated. The pump brake power was calculated as shown in [Eq-7].

$$BP_E = \frac{P_w}{\eta} \quad (7)$$

Where: BP_E= engine brake power in hp, P_w= water power, hp and η= decimal pump efficiency that was assumed 0.7.

$$P_W = QxH_t x\omega \quad (8)$$

Where:

Q= required discharge at the network m^3 h^{-1}, H_t= total head m, and ω = water specific weight kg m^{-3}.

$$H_t = H_f + H_s + H_e \quad (9)$$

H_f=friction loss, H_s =static head, and H_e =emitter operating pressure head in m.

The suction static head was 125m. Hazen Williams formula was used to calculate the friction loss for main, sub-main, manifold, and laterals. The constant C value was 150. [32].

$$H_f = \frac{10.67xQ^{1.85}}{C^{1.85}Xd^{4.87}} \quad (10)$$

Where: d = inside pipe diameter in m. The friction loss in connectors and valves was assumed 10% of the total friction loss [33]. The fuel consumption, l/h was calculated using the [Eq-11] [34, 35] for diesel engines.

$$F_c = 0.12.BP_E \quad (11)$$

Where: F_c=fuel consumption, l h^{-1}.

- **Energy and Energy Use Efficiency (EUE)**

Energy consumption was calculated by multiplying the calculated power requirement in the total operation time per season for each treatment. EUE indicator was used to express the crop produced from a consumed energy unit according to [Eq-12].

$$EUE = \frac{\text{Total yield, kg}}{\text{Water pumping energy, kW.h}} \quad (12)$$

- **Crop Profitability**

The total annual cost per hectare for the growing season was calculated referring to Buchanan, et al. [36] based on the Egyptian market information for the year 2010. The total cost is equal to the summation of total annual fixed and variable costs. Fixed costs included depreciation of network components, interest, and taxes and insurance costs. The depreciation costs of the different irrigation network components were calculated as shown in [Eq-13].

$$\text{Annual depreciation} = \frac{\text{Capital price - price at the end of life duration}}{\text{Life duration}} \quad (13)$$

The variable costs included fuel, oil and lubricants, labor, repair and maintenance, and additive costs including pesticides, fertilizers, seeds, and transportation. The end life price of an object was assumed 10% of the capital price. Life duration of the pump and network components was assumed 10 years. The interest value was 10% while taxes and insurance were 2% of the main price of an object. Fuel cost (0.15 US$/ l) was calculated referring to [Eq-11]. Oil and lubricants were assumes 15% of total fuel costs [37]. Labor fees were 1.82 US$/day/person for 8 hours working day. Repairs and maintenance costs were assumed to be equal to the depreciation cost. The summation of seasonal additive costs was 311.61 US$. Cost of G type laterals was 9.56 US$/100m while it was 15.94 US$/100m. The main objective of comparing two pressure compensating emitters that are supposed to show high uniformity is the variation in laterals cost. This variation is supposed to impact the cost of network which will affect the total profitability of crop production process. Consequently, this enables the economic side of system evaluation to be taken in consider. The return earned by the farmer for selling squash crop was 0.15 US$ kg^{-1}. The benefits- cost ratio (B/C) was used to describe the final crop profitability for the farmer.

Results

- **Emission Uniformity**

[Table-4] shows that the operating head had a highly significant effect on the EU values. Neither emitter type nor interaction between emitter type and operating pressure had a significant effect on EU. G emitter had the higher values for EU if compared to emitter T under all operating pressure heads. The highest EU for the G type was 97.10% under 10m operating pressure head while it was 89.35% for T type. The variation between maximum and minimum value of EU due to the variation in pressure reached 13.7, and 16.45% for the G and T types respectively of the maximum obtained EU of both types. The values of EU and the means comparison are listed in [Table-5]. There was no significant difference between the EU values of G10 and G12 treatments. In addition there was no significant difference between G10 and the rest of treatments except T6 which had the lowest value of EU and was significantly different from all other treatments.

Table 4- Analysis of variance for the experiment variables effect on EU

Source of variation	DF	SS	MS	F Ratio
REPLICATES (R)	2	59.25	29.63	1.28 ns
PRESSURE (P)	3	624.33	208.11	9.00**
ERROR a	6	90.42	15.07	
EMITTER (E)	1	112.67	112.67	4.87 ns
P*E	3	78.33	26.11	1.13 ns
ERROR b	8	185	23.13	
TOTAL	23	1150	50	

*ns= not significant **= significant at 0.01 level*

Table 5- Means of EU values, % for G and T emitters under different operating pressure heads

Emitter type	Operating head, m			
	6	8	10	12
G	83.80 b	88.81 b	97.10 a	91.00 ab
T	74.65 c	88.51 b	88.89 b	89.35 b

L.S.D= 7.313 at 5% level

- **Crop Production and Water Use Efficiency**

[Table-6] shows that operating head was the only variable that had a significant effect on the crop production. [Table-7] shows the values of squash crop production and water use efficiency for all the experimental treatments. The highest value of crop production (16.92 Mg ha^{-1}) was obtained at G10 treatment. The lowest value of crop production (10.15 Mg ha^{-1}) was at T6 treatment. The variation in crop production for G emitter was 31.02% of maximum production while it was 35.19% of maximum production for T emitter. The results revealed that the obtained production will increase by increasing EU for all treatments. Means comparison of crop production values which are shown in [Table-7], indicates that there was no significant difference between G10 treatment and the rest of experiment treatments except T6 treatment. The amount of applied water was 3476 m^3 ha^{-1}. WUE increased by increasing crop production. Thus, the highest and lowest values of WUE for G emitter (4.87 and 3.36 kg m^{-3}) were at 10 and 6m head, respectively while they were 4.51 and 2.92 kg m^{-3} at 12 and 6m for T emitter.

Table 6- Analysis of variance for experiment variables effect on crop production

Source of variation	DF	SS	MS	F Ratio
REPLICATES (R)	2	79.19	39.59	1.31 ns
PRESSURE (P)	3	587.58	195.86	6.47*
ERROR a	6	68.48	11.41	
EMITTER (E)	1	112.67	112.67	3.72 ns
P*E	3	59.25	19.75	0.65 ns
ERROR b	8	242.33	30.29	
TOTAL	23	1149.5	49.98	

**= Significant at 0.05 level*

Table 7- Means of crop production, Mg and WUE, kg m^{-3} of the experimental treatments

Operating head, m	Crop production, Mg/ ha		Water use efficiency, kg/m^3	
	G	T	G	T
12	15.74 ab	15.66 ab	4.53	4.51
10	16.92 a	14.55 ab	4.87	4.19
8	13.37 ab	13.20 ab	3.85	3.8
6	11.67 ab	10.15 b	3.36	2.92

L.S.D= 5.3 at 5% level

Power Requirements, Energy and EUE

The calculated power requirements and operation time for the irrigation network with G and T emitters under different operating heads are shown in [Table-8]. It was observed that by increasing the operating pressure head, the power requirements for both emitters have increased. Increasing operating head from 6 to 12 m led to increase the power requirements by 33.67% and 35.81% of maximum obtained power requirement respectively for G and T emitters. The operation times of T emitter's laterals were less than these of G emitter if compared to the same operating head for all the values of pressure heads. Increasing the operating head from 6 to 12m will result a decrease in operation time by 40.37% and 32.51% of the highest operation time for G and T emitters, respectively.

Values of energy listed in [Table-9], showed that the highest value of consumed energy was 522.15 kW h ha^{-1} at G10 treatment while the lowest one 361.85 kW h ha^{-1} at T6. Variation in energy values reached 10.09 and 4.7% Of maximum consumed energy for both emitters G and T, respectively. Maximum obtained EUE was 33.53 kg/kW h at G12 while the lowest was 22.35 kg/kW h at G6 treatment. T type showed higher EUE values if compared to G type treatments for the corresponding values of operating head.

Table 8- Power requirements and network operation time per hectare for different operating pressure heads

Operating head, m	Power requirement, kW/ha		Operation time, h/season	
	G	T	G	T
12	6.83	5.92	68.78	64.21
10	6.36	5.75	81.46	65.17
8	5.67	4.95	85.48	74.49
6	4.53	3.8	115.35	95.14

Table 9- Energy consumption and EUE values of experimental treatments

Operating head, m	Energy kW.h ha^{-1}		EUE kg kW^{-1} h^{-1}	
	G	T	G	T
12	469.42	379.8	33.53	41.23
10	517.95	374.84	32.67	38.82
8	484.67	368.48	27.59	35.82
6	522.15	361.85	22.35	28.05

Crop Profitability

The obtained results showed three ranges of power requirements that can be compatible with the commercially available pumps. Commercially available pumps in the market which are suitable for the calculated power were 5, 7 and 10 hp (1hp= 0.746 kW). [Table-10] lists the ranges of calculated power requirements resulted from the treatments, and the capital price which was used to calculate the pumps' cost.

Table 10- Prices of the commercially available pumps used in costs calculation

Calculated power range, hp	Suitable commercially available pump power, hp	Capital price, US$
>5-7	7	637.52
>7	10	910.75

[Table-11] shows the total costs of squash cultivation process. Increasing the operating pressure head will increase the total costs of all treatments. The highest benefits-cost ratio was 2.57 with G type at 10m operating pressure head while the lowest was 1.49 at T6. It was noticed that the B/C ratio for T emitter at 10 and 12m head was less than B/C for G emitter at 8 m head though the higher crop production obtained for the previously mentioned treatments of T type.

Table 11- Total seasonal costs and B/C ratio per hectare of the experimental treatments

	G				T			
	6	8	10	12	6	8	10	12
Depreciation	159.02	159.02	183.61	183.61	197.21	197.21	221.8	221.8
Interest	97.18	97.18	112.2	112.2	120.52	120.52	135.55	135.55
Taxes and insurance	35.34	35.34	40.8	40.8	43.83	43.83	49.29	49.29
Total fixed costs	291.53	291.53	336.61	336.61	361.56	361.56	406.64	406.64
Fuel	5.57	7.38	9.15	12.07	5.38	7.12	9.45	12.47
Oil and lubricants	0.83	1.11	1.37	1.81	0.81	1.07	1.42	1.87
Labor	118.4	118.4	118.4	118.4	118.4	118.4	118.4	118.4
Repairs and maintenance	159.02	159.02	183.61	183.61	197.21	197.21	221.8	221.8
Additives	311.61	311.61	311.61	311.61	311.61	311.61	311.61	311.61
Total variable costs	595.42	597.51	624.13	627.49	633.41	635.41	662.68	666.15
Total annual costs	886.95	889.04	960.75	964.1	994.97	996.97	1069.32	1072.79
Benefits	1700.55	1948.27	2465.57	2293.62	1479.05	1923.5	2120.22	2281.97
B/C ratio	1.92	2.19	2.57	2.38	1.49	1.93	1.98	2.13

Discussion

The lower value of G emitter exponent compared to the T emitter's value clarifies that the G type has better ability to reduce the variation in emitters' discharges along lateral which resulted the higher values of EU than those of the T emitter under the used operating heads. This was in agreement with Yun-Kai, et al. [38] who mentioned that emitter exponent should be as low as possible to obtain a uniform water flow along laterals. Merriam, et al. [39] introduced a general criteria for evaluating the EU. According to this evaluation the EU values were excellent for G type at 12 and 10m heads and good at 6 and 8m head. For T type EU was good at 12, 10, and 8m while it was fair at 6m head. This classification can point out the ability of G emitter to keep EU in acceptable ranges at different operating pressure heads when compared to T emitter. There was a proportional relationship between the EU and crop production for both emitters in agreement with Wu [40], Bhatnagar, et al [41]. The non-significant effect of emitter type on EU and crop production may be due to that the two emitters' types has the same classification as pressure compensating emitters which means they have close response to pressure variation that was also shown in the non-significant difference between EU values in most of treatments. The variation in crop production for G emitter under different operating pressure heads was lower than it was for T emitter. This may be due to the higher uniformity for water application with G emitter which was less affected by pressure variation than T emitter. This higher production with a constant amount of applied water under all treatments led to a higher WUE for G emitter if compared to T emitter. These results agreed with Rodrigues, et al [42] that irrigation uniformity will lead to higher production and WUE. The higher EU will lead to efficient use of energy and water to achieve increase in crop production [43, 44] for each emitter individually. The EUE values of T emitter treatments were higher if compared to G emitter. This can be a result for the higher flow rate of T emitter which impacted on the seasonal irrigation time. In this case there is disagreement with Ozkan, et al. [43], Singh, et al. [44] that higher EU was not the only variable that may lead to obtain higher EUE. In general, the lower variation in emitters discharge as affected by pressure difference for G type, led to lower variation for G type in crop production and power requirements. Variation in energy consumption for T type was less than G type as the energy value depends on the operation time which depends mainly on the value of the flow rate and not directly related to how uniform is the flow. The B/C ratio had increased by increasing the EU for both types. Despite the increase in crop production for T emitter under 10 and 12m head, if compared to G emitter at 8 m head, which has also a lower value of EU than the two previously mentioned treatments of T type, the B/C ratio for G8 was higher. This may be due to the increase in power requirement for T12 and T10 which resulted from the increase of pressure head. This increase of B/C ratio may also was due to the higher capital price of T emitter laterals which caused higher cost per lateral if compared to G type laterals.

Conclusion

Results showed that the higher EU will give an impact on the increase of crop production under drip irrigation system. This will result a parallel increase in the benefits of water and energy consumed units. Consequently, the well designed and managed drip irrigation system with a continuous evaluation for system performance will lead to reach the objectives of sustainable drip irrigation system management regarding efficient use of different resources specially water and energy. On the other hand, low flow rate of an emitter may reduce the EUE because of the more time it takes for operation which will result a higher values of energy followed by lower values of EUE even if the emitter shows high EU. The results showed also that the increase in crop profitability was not just related to the EU of the drip irrigation system. It was also related to the cost of network components. From previous, for the sustainable management of drip irrigation system, well designed and managed drip irrigation system that gives excellent EU is necessary for higher benefits of water, energy, and financial resources. System designers, operators, and managers should put in consider, the integration between system performance and network components' costs to avoid any possible decrease in crop profitability. It is recommended also to use higher flow rates emitters that gives as high EU as possible not less than excellent, to avoid the decrease in EUE that may result due to higher operation time. It is recommended also there should be tries for using already existed low-cost energy sources to reduce the operation costs or trying to use non- traditional sources.

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