EFFECT OF OPERATING PRESSURE VARIATION ON UNIFORMITY PARAMETERS AND ITS IMPACT ON CROP PRODUCTIVITY AND POWER REQUIREMENTS OF TRICKLE IRRIGATION

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ABSTRACT

A field experiment was carried out in Al-Shahwan farms, Khatatba village, Sadat city, Menoufia governorate under sandy soil conditions with cucumber crop (F1-Faris). Uniformity parameters including emission uniformity, uniformity coefficient, distribution uniformity, manufacturing coefficient of variation, and emitter flow rate variation were measured for three types of emitters G, M, and T under 6, 8, 10, and 12m of water operating pressure head, in order to recommend an operating pressure head, that gives the best uniformity parameters which will be reflected on crop productivity. The power requirements for all treatments were calculated per unit area. The results showed that, better uniformity parameters will give better productivity. It is recommended to use 12m head for both M and T emitters, and 10m for G type. The T type gave the maximum crop productivity which reached 6.66 Mg/fed under 12m operating head. Increasing uniformity parameters led to increase the benefits of water unit as a result of increasing crop productivity.M type needed less power than the two other types but this affected the crop productivity. The maximum productivity gained under T emitter with 12m operating pressure head, compared with the maximum productivity of the other two types gave an increase of 6.7% and 12.5% compared to G and M types respectively. This will be faced by an increase of 63.8% of power requirement compared to M type, and a shortage of 6.9% of power requirement compared to G type. Increase of 6.7% of crop productivity and 12.5% for T type compared to the G and M types gave an increase in power source costs about 1.4% and 0.12%, respectively compared to the other two types. Electric power will save 63.6% of diesel fuel costs.

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INTRODUCTION

Water distribution on the soil surface is one of the key criteria that describe trickle irrigation performance. Trickle irrigation theoretically has high distribution uniformities and application efficiencies. Managing the system to obtain the best uniformity should be well studied before system operation starts. **Nakayama and Bucks (1986)** reviewed several widely used parameters, including uniformity coefficient, UC, emitter flow variation, qvar, and coefficient of variation of emitter flow, CV (Christiansen, 1942; Wu et al., 1979) mentioned that, it is expected that the more uniform was the water application, the more uniform will the yield be. All emitters in the system should discharge equal amounts of water, but due to manufacturing variations, pressure differences, emitter plugging, aging, friction head losses throughout the pipe network, emitter sensitivity to pressure and irrigation water temperature changes, flow rate differences between two supposedly identical emitters exist (Mizyed and Kruse, 2008). Solomon (1984) related expected yield to several uniformity measures, including Christiansen's uniformity coefficient, statistical uniformity (Bralts et al., 1981a, b), and distribution uniformity (Kruse, 1978). Operating pressure head is one of the most important factors affecting the trickle system uniformity parameters, as it affects the power requirement for system operation. So, we should study the suitable operating pressure for different types of emitters that gives best uniformity parameters, and its effect on the expected increase of crop yield, putting the power and fuel needs and its economic impact into consideration.

The objectives of this study were as follows:-

1- Testing uniformity parameters changes for different types of emitters under different operating pressure heads.

2- Calculating power requirements for obtaining the best operating conditions and the best productivity for different emitters.

3- Comparing the cost of power sources to the gain of crop productivity, in order to choose the most economic one.

MATERIALS AND METHODS

1. Preparation of experimental area

The field experiment was carried out in Al-Shahwan Farms, Khatatba village, Sadat city, Menoufia governorate. 30 m long(16mm inner diameter) trickle laterals with three types of emitters G, T, and M emitters 50 cm spacing along lateral and 150 cm between rows were used to irrigate cucumber crop (F1-Faris) with 48 hours interval during the successive summer season 2009 in sandy soil (Table 1). The field work was carried out in a 60 x 42 m^2 experimental area. The final cultivated area slope was zero level. The soil and water chemical analysis showed that soil pH was 7.85. Therefore 40 kg / fed of sulfur were added to control alkalinity of soil. 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 **(FAO, 1980).** Chisel plow (7 shares) hitched by a 48.49 kW (65 hp) tractor was used to remove residues of previous crop (Wheat) and weeds. Before planting amounts of 20 – 75-100 kg/ fed of N-P-K, respectively, were added during plowing operation. Cucumber crop was planted in 16/7/2009 with 3 seeds per pore (50 cm spacing) at 10 cm depth and after germination it was thinned to one plant / pore. A pesticide 2.5% Mefenoxam, and 40% Copper was used 150g/100 litres to defend plants against fungus infections. A pesticide contains active ingredient diethyl – trichloro- pyridyl phosphoriothioate 480 g/l were used to attack insects (Pachnoda fasciata) that attacked cucumber fruits.

Table.1: Some physical properties of the experimental 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	5.0
30-45	88.50	3.21	8.25	Sandy	10.9	5.1

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

2. Variables and experimental design

Three types of emitter M, T, and G types were used to be experimented as main plot. Four operating pressure heads 6, 8, 10, and 12 meter of water acted sub-main plot. Figure 1 shows the different types of used emitters a) G, b) M, and c) T types.

a b c

Fig.1: Types of used emitters.

Table 2 lists some manufacturing parameters for the use emitter.

Table.2: Some emitters' manufacturing data.

Emitter symbol	Manufacturer name	Classification	Country of made
a) G	Euro drip	Built-in	Egypt
b) M	Metalic plastic	Simple orifice	Egypt
c) 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 (q), l/h was described by a power law $q = kH^x$ where 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	
a) G	3.25	3.99	4.41	4.67	$q=1.189H^{0.196}$
b) M	1.79	2.07	2.3	2.48	$q=0.582H^{0.322}$
c) T	2.73	3.49	3.99	4.05	$q= 1.023H^{0.250}$

The emitters' exponent values show that, the M emitter flow rate will be the more affected by pressure variation followed by T emitter, while G emitter will be less affected. The flow through the three types is fully turbulent (**James, 1988**).

3. Measurements

3.1. Uniformity parameters

A sample of 20 emitters from each lateral was used to calculate the uniformity parameters including uniformity coefficient, manufacturing coefficient of variation, distribution uniformity, emission uniformity, and emitters' flow rate variation. Under different operating heads, cups were put under each emitter at the same time for 2 minutes, the collected water volume per emitter was used to calculate the emitter flow rate, l/h. The degree of emitter flow variation is expressed by the uniformity coefficient as defined by the following equation **(Christiansen, 1942):-**

$$\textbf{UC= 1-} \left(\frac{\sum_{i=1}^{i=n} \left| q_i - q^{`} \right|}{q^{`} \times n} \right) \times 100 \;\textbf{............1}$$

Where: -

n = number of observed emitter or cans, q_i = emitter flow rate ,l/h

$q^{`}$ = average of emitters flow rates , l/h.

The flow rate variation q_{var} was calculated using the following equation **(Wu and Gitlin, 1975).**

$$\mathbf{q_{var}}\textbf{=} \frac{q_{\max} - q_{\min}}{q_{\max}} \times 100 \;\textbf{....................2}$$

Where: -

q_{max}= maximum emitter flow rate l/h, and q_{min}= minimum emitter flow rate ,l/h.

The emitter manufacturing coefficient of variation was calculated as follows (**Keller and Karmeli, 1974):-**

$$CV = \frac{S_q}{q^{'}} \;\textbf{..................................3}$$

Where:-

S = standard deviation of emitters flow rate and

Distribution uniformity was calculated using the following equation **(kruse, 1978)**: -

$$\textbf{DU= 100 } \frac{q^{'}_{lq}}{q'} \;\textbf{...............................4}$$

Where: -

$q^{'}_{iq}$ =mean of lowest one-fourth of emitter flow rates, l/h.

The emission uniformity was calculated by the following formula:-

(Karmeli and keller , 1975):

$$Eu = 100(1 - \frac{1.27CV}{n^{0.5}}) \frac{q_{min}}{q_{avg}} \text{..........................} 5$$

Where:-

Eu = design emission uniformity, q_{min} = minimum discharge rate computed from minimum pressure in the system, l/h, q_{avg}= average of all the field data emitter discharge rate, l/h, CV = the emitter coefficient manufacture of variation, n = the number of emitters per plant and it was 1 under the experiment conditions.

3.2. Crop productivity

Four replicates along lateral (1m lengthx1.5m width) were taken from each treatment to find the crop productivity and replicated four times along lateral . Fruits were weighed on 10 g accuracy scale. The average of replicates was calculated, then it was multiplied in 2800 to get the crop yield per feddan (0.42 ha). Picking fruits started when cucumber fruit reached 12-14 cm long and/or 2cm diameter.

3.3. Water use efficiency.

Water use efficiency, has been used to describe the relationship between cucumber crop production and the total amount of water used. It was determined by applying the following equation **(Jensen, 1983):**

$$\mathbf{WUE} = \frac{Y}{W_a} \text{..........................} \mathbf{6}$$

Where:-

WUE = water use efficiency, kg/m^3, Y = total yield kg/fed and

W_a = total applied water, m^3/fed.

The climatic data were collected from Sadat weather station for the year 2008. Evapotranspiration for cucumber crop was calculated using CROPWAT computer program. Crop water requirements (mm/day).was calculated referring to (**FAO, 1980).**

4. Power requirements.

The pump brake power was calculated as follows:-

$$BP = WP / \eta_P \text{ .... } 7$$

Where:

BP= brake power, WP= water power, and $\acute{\eta}_P$ = decimal pump efficiency, assumed 0.6.

$$WP = Q \, x H_t \, x \, Ш \quad \ldots\ldots\ldots\ldots\ldots\ldots 8$$

Where:

Q= required discharge at the network, H_t= total head, Ш= water specific weight.

$$H_t = H_f + H_s + H_e \quad \ldots\ldots\ldots\ldots\ldots\ldots 9$$

H_f =friction loss, H_s =static head, H_e =emitter operating pressure head. The suction static head was 125m. Hazen Williams formula was used to calculate the friction loss for main, sub-main, manifold, and laterals. The c value was 150**. (Hazen and Williams, 1920)**:-

$$S = \frac{10.67 x Q^{1.85}}{C^{1.85} X d^{4.87}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 10$$

Where:

S = head loss (in m of water) per m of pipeline, Q = volumetric flow rate in m^3/s and d = inside pipe diameter in m.

The friction loss in connectors and valves was assumed 10% of the total friction loss (**El-Gindy *et al***. **2001**). Figure 2 shows a diagram for the area (4200m^2) assumed to calculate power requirements for different operating pressure heads. The inner diameters of main line, sub-main, and manifolds were 12.7, 7.62, and 5.08 cm respectively. These diameters were the same as the experiment area.

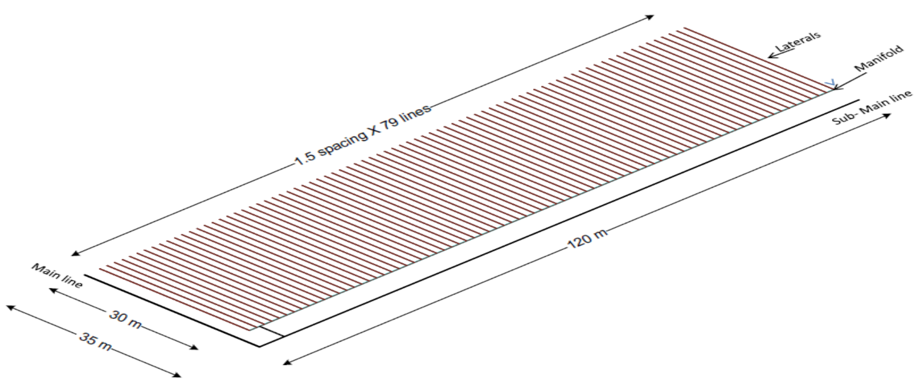

Fig.2: A diagram for an assumed network for power requirement calculations.

The fuel consumption, l/h was calculated using the following formula (**Culpin, 1976**) for diesel engines.

$$\mathbf{F_C = 0.12 * BP_E} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 11$$

Where:

$\mathbf{F_c}$=fuel consumption, l/h, and $\mathbf{BP_E}$= Engine brake power, hp.

3.5. Cost of power:

Two sources of power were assumed to be used in power cost calculations, electricity and diesel fuel. They were chosen as the most widely spread sources in Egyptian farms**.** The diesel fuel price at the experimental time period was 1.1 L.E/l while electricity cost was 0.24 L.E/kW.h for commercial properties. The fuel consumption for each treatment, l/h was multiplied by the total operating hours/season to find the diesel fuel cost/season. The calculated power, kW was multiplied by the total operating hours/season to find the total electricity cost. The US$= 5.72 Egyptian pound during the experiment time period.

RESULTS AND DISCUSSIONS

1. Uniformity parameters

Table 4 shows the values of uniformity measures for the different types of emitters. Results showed that for both M and T emitter, Increasing operating pressure head will lead to improve the uniformity measures, except UC of M type which was 68.41% under 12m head and 69.26% under 6m head. The UC any way under both heads for M emitter are classified as poor **(Bralts, 1986).** It can be recommend using 12m head for both types for the two previously mentioned types to get better Uniformity parameters than others used heads. For the G type the best uniformity parameters were under 10m head. The uniformity parameters of the recommended operating pressure head for each emitter show that the UC values for T, G, and M emitter were classified as Excellent, Excellent, and poor respectively **(Bralts, 1986)**. The EU values for G and T type were fair while it was poor for M emitter **(Merriam and Keller, 1978)**. For G and M emitters, the CV values were marginal while it was good for T emitter **(American Society of Agricultural engineers, 1985).**

Table.4: Uniformity parameters for the different emitters under different operating pressure heads.

Emitter type	Uniformity parameter, %		Operating head, m			
			6	**8**	**10**	**12**
	T	***UC***	85.26	91.83	92.40	93.22
		CV	6.94	5.91	4.85	3.83
		DU	74.65	88.51	88.89	89.35
		EU	47.52	62.66	73.23	79.00
		q_{var}	39.20	34.00	26.00	21.00
	G	***UC***	83.86	83.31	94.91	90.12
		CV	19.00	15.00	6.80	11.00
		DU	83.80	93.00	97.10	91.00
		EU	55.00	62.00	74.00	68.00
		q_{var}	45.00	39.00	25.00	29.00
	M	***UC***	69.26	59.63	65.43	68.41
		CV	28.15	26.90	21.24	13.93
		DU	42.65	36.5	50.69	51.64
		EU	13.87	12.08	17.67	19.79
		q_{var}	84.00	80.00	79.00	74.00

2. Crop productivity and water use efficiency.

Data listed in table 5 show the crop productivity and water use efficiency for experimented emitters under different operation pressure heads. It was noticed that the maximum crop productivity was for T emitter under 12 m operating head while the minimum was 3.62 Mg/fed for M type at 6m operating pressure head. The G type had its maximum productivity at 10m head. The crop productivity results followed the same trend of uniformity parameters. That may be due to the uniform distribution of water along lateral which will result a uniform product all over the field area. The applied water for all treatments was 1371 m^3/fed. Increasing uniformity parameters led to increase the benefits of water unit as a result of increasing crop productivity.

Table.5: Crop productivity and water use efficiency under the experimental treatments.

Operating head, m	***Crop productivity, Mg/fed***			***Water use efficiency, kg/m^3***		
	G	*M*	*T*	*G*	*M*	*T*
12	5.73	5.92	6.66	4.18	4.32	4.85
10	6.24	5.29	6.17	4.55	3.86	4.50
8	5.22	4.15	5.28	3.81	3.03	3.85
6	4.63	3.62	4.00	3.38	2.64	2.92

3. Power requirements:

Power requirements calculated for all treatments show that there is a proportional relationship between operating pressure head and operating power needed. For the unit of area (feddan) the M emitter has the lowest power requirement under all pressure heads followed by T type, while G emitter had the maximum needs because of its high flow rates compared to T and M types. The operating time per season show that M type has the maximum operating time followed by T type, while G emitter has the lowest ones. M type is neglected from the comparison despite the less power needs because of the bad uniformity parameters which led to productivity shortage. The previous data may be resulted from the values of emitters flow rate which affected the power values and operating time. The maximum productivity gained under T emitter with 12m operating pressure head, compared with the maximum productivity of the other two types will give an increase 6.7% and 12.5% compared to G and M types respectively. That will be faced by an increase of 63.8% of power requirement compared to M type for the recommended operating pressure heads of the two types. Comparing the recommended pressure heads for T and G emitters led to obtain a shortage of 6.9% in power requirement. The power requirements per fed (0.42 ha), are listed in table 6.

Table.6: Power requirements per fed for different operating pressure heads

Operating head, m	***Power requirement, kW/fed***			***Operation time, h/season***		
	G	*M*	*T*	*G*	*M*	*T*
12	2.46	1.30	2.13	52.42	98.72	60.45
10	2.29	1.19	2.07	55.52	106.44	61.36
8	2.04	1.06	1.78	61.36	118.27	70.15
6	1.63	0.90	1.37	75.33	136.77	89.86

4. Power costs

By comparing the minimum and maximum values of crop productivity for the experimented emitters individually, the increase in productivity for T type reached 66.5% followed by 4.7% increase in power costs. An increase of 34.7% in crop productivity for G emitter will be followed by 3.1% increase in power costs. For M emitter 63% increase in crop productivity will increase the power costs by 4.6%. Comparing maximum crop productivity for all emitters' types led to find that, an increase of 6.7% of crop productivity and 12.5% for T type compared to the G and M types gave an increase in power source costs about 1.4% and 0.12%, respectively. Using the recommended pressure head for the T type gave an increase in crop productivity more than the resulted cost increase of power sources. Electric power source if used will be cheaper than diesel fuel for all treatments. Comparing the recommended treatments showed that Using electricity as a source of power will save 63.6% from diesel costs.

Table.7: Power source costs of different power requirements per fed for both electricity and diesel fuel.

Operating head, m	***Electric costs, L.E/fed***			***Diesel costs, L.E/fed***		
	G	*M*	*T*	*G*	*M*	*T*
12	30.92	30.86	30.9	85.04	84.86	84.98
10	30.46	30.40	30.45	83.77	83.61	83.74
8	30.00	29.95	29.93	82.50	82.36	82.32
6	29.52	29.49	29.51	81.19	81.11	81.16

CONCLUSION

It is recommended to use 12m head for T emitters. The M emitter may not be recommended to be used under the experimental conditions referring to the uniformity parameters values it showed. G type is recommended to be used under 10m operating pressure head. From the side of uniformity parameters, better uniformity parameters will give better productivity. T type gave the maximum crop productivity compared to the other types, reached 6.66 Mg/fed under 12m operating head. The maximum crop productivity for G type treatment was under

10m operating head, while M emitter's maximum productivity was under 12m operating head. Increasing uniformity parameters led to increase the benefits of water unit as a result of increasing crop productivity. Despite M type needed less power but it is not recommended to use if compared to G and/or T type. The maximum productivity gained under T emitter with 12m operating pressure head, compared to the maximum productivity of the other two types, will give an increase of 6.7% and 12.5% in crop productivity compared to G and M types, respectively. That will be faced by an increase of 63.8% of power requirement compared to M type, and a shortage of power requirement compared to G type equals 6.9% of power requirement. Electric power will reduce the power source cost by 63.6% if compared to diesel fuel. It is recommended to use T emitter under 12m operating head for better uniformity parameters and higher productivity.

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المراجع العربية

الجندي،ع.م.؛أ.أ.عبد العزيز و ع.أ.سليمان.٢٠٠١. تصميم شبكات الرى والصرف.جامعة عين شمس.جمهورية مصر العربية.

الملخص العربي

تأثير اختلاف ضغط التشغيل على مؤشرات الانتظامية وانعكاسه على إنتاجية المحصول ومتطلبات القدرة لنظام الرى بالتنقيط

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أجريت تجربة حقلية بمزرعة واحة النجاه- قرية الخطاطبة- مدينة السادات- محافظة المنوفية في الموسم الصيفي ٢٠٠٩ على خطوط حقلية لنظام الرى بالتنقيط بطول ٣٠م وقطر داخلي 16مم. وقد هدفت الدراسة إلى: ١- اختبار تأثير اختلاف الضغط على مؤشرات الانتظامية لنظام الرى بالتنقيط. ٢- حساب متطلبات القدرة لوحدة المساحة لتوفير أفضل ظروف تشغيل ,والحصول على افضل انتاجية طبقاً للضغط الموصى به للنقاطات المختلفة ٣-مقارنة نسبة الزيادة في تكاليف مصادر القدرة إلى الزيادة المتوقعة في المحصول للتوصية بأفضل المعاملات. تم إجراء التجارب تحت ظروف التربة الرملية لمحصول خيار هجين فارس. تم استخدام ثلاثة أنواع من المنقطات M, G, T تحت اربعة ضواغط تشغيل ٦، ٨، ١٠، ١٢م. شملت مؤشرات الانتظامية معامل اختلاف التصنيع ، انتظام التنقيط، انتظام التوزيع، معامل الانتظام، واختلاف تصرف النقاطات. وقد أوصت النتائج باستخدام ضاغط تشغيل ١٠م للنوع G و١٢م للنوعين الآخرين لما حققه ذلك من تحسن في مؤشرات الانتظامية وانعكس على الإنتاج. ووصلت أعلى إنتاجية ٦,٦٦ طن/فدان باستخدام النوع T تحت ضاغط ١٢م. كما زادت كفاءة استخدام المياه بتحسن مؤشرات الانتظام وما تبع ذلك من تحسن في الانتاجية.في حالة مقارنة المعاملات الموصى بها لكل نوع من أنواع النقاطات للحصول على أفضل إنتاجية فان استخدام النقاط T سوف يؤدي الى النقص في احتياجات القدرة بنسبة ٦,٩% مقارنة بالنوع G وزيادة بنسبة ٦٣,٨% مقارنة بالنقاط M يقابلها زيادة ٦,٧ ،١٢,٥% في إنتاجية المحصول للنقاط T مقارنة بالنوعين G ،M على الترتيب. هذه الزيادة في الإنتاجية سوف تقابل بزيادة في تكاليف مصادر القدرة (الكهرباء- الديزل) بنسبة ١,٤ و ٠,١٢% على الترتيب مقارنة بالنوعين G،M على الترتيب. وأوضحت الدراسة ان استخدام الطاقة الكهربية سوف يؤدي إلى توفير قدرة ٦٣,٦% من تكاليف وقود الديزل. وقد أوصت الدراسة باستخدام النقاط T تحت ضاغط تشغيل ١٢م نظراً لتحسن مؤشرات الانتظام وكذلك الزيادة في الانتاجية كذلك عدم استخدام النقاط M تحت الظروف التجريبية لضعف مؤشرات الانتظام التي انعكست بدورها على الانتاجية.

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