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Using Different Emitter Types on Corn Productivity as Affected by its Uniformity

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ABSTRACT

The influence of discharge uniformity was investigated experimentally for different emitter types and pressure on corn productivity and field water use efficiency (*FWUE*) under trickle irrigation system. Three emitters used in the study were pressure compensating "Em_{PC}", Turbulent flow "Em_{TF}" and Laminar flow "Em_{LF}" under five different pressures (0.25, 0.50, 0.75, 1.00 and 1.25 bar) with lateral lengths 50 m. Parameters of uniformity including uniformity emission, emitter flow rate variation and manufacture's coefficient were measured. The results indicated that the best parameters of uniformity will give the best crop productivity. The better uniformity was pressure compensating "Em_{PC}" emitter compared with turbulent flow and then laminar flow devices. The Em_{PC} device gave the best yield productivity which reached 3.856 $Mg\ fed^{-1}$ with 96.87% uniformity of emission (*UE, %*) at pressure 1.0 bar and the highest value of *FWUE* at 1.41 $kg\ m^{-3}$. The maximum yield with Em_{PC} device compared with the other devices increased an increase of 8.92% and 16.68% of Em_{TF} and Em_{LF} devices respectively. It was recommended to use Em_{PC} emitter at pressure of 1.0 bar for lateral lengths of 50 m, which gives the highest uniformity that will impact on corn productivity.

Keywords: Emitter, Uniformity, Corn Productivity.

INTRODUCTION

Emitters, or drippers, represent the most important element of a trickle irrigation system installation with respect to application water uniformity. These devices may vary from simple orifice to complex pressure compensating types. Ideally, all emitters within an irrigation system should deliver equal discharges (Keller and Bliesner, 1990). The emitter is classified according to their incorporation in the lateral (point and line source), flow rate (pressure compensating (*PC*) and (*NPC*)) non-pressure compensating and form of pressure dissipation and construction (long path, short path, orifice, vortex and multi-exit emitters) (Enciso *et al.*, 2007).

Mizyed and Kruse (2008) mentioned that, all device emitters in the irrigation method should flow rate the same water amount, but due to differences in pressure, variations manufacturing, emitter plugging, emitter classification, head losses friction of the network, device sensitivity to operating pressure and changes temperature of irrigation water, discharge variability between two devices exist.

Trickle irrigation systems are the slow application of water on above or below the soil by subsurface drip and surface drip devices. Water is applied as discrete or continuous drips, or tiny streams, through emitters, or porous tubing and then flows through the soil by capillarity and gravity to emphasize that only part of the soil volume is wetted (Dean *et al.*, 2002 and Sne, 2009). So, trickle irrigation could be recommended for corn farming, the corn yield always planted in the soil moisture distribution zones. The moisture distribution is affected by some elements, with application water uniform, emitter flow rate, different soil texture and emitter spacing (Shan *et al.*, 2011).

Distribution of water is one of the type criteria that express trickle irrigation assessment on the soil. Trickle irrigation in theory has the best uniformities and efficiencies of application compared with the other irrigation systems. Managing the trickle irrigation system to find the high water application must be well studied before the operation starts of irrigation system. The key factor for an efficient irrigation operation is the water. Hydraulic evaluation of trickle irrigation can be determined on the basis of parameters, such as discharge uniformity, flow variation (Q_v), discharge-pressure relationship, and coefficient of variation (V_m) (ASABE, 2008). The use of trickle irrigation in field crop production has become rather a communal practice in production of agricultural. It's being measured as a means to attain sustainable management of irrigation (Cote *et al.*, 2003).

The best parameters of uniformity will give the best productivity. It is suggested to use 12.0 m head for together simple orifice (*M*) and long path (*T*) emitters, in addition to 10.0 m for Built-in (*G*) type. The *T* device gave the maximum yield productivity which reached 6.66 Mg/fed in 12.0 m pressure head. Increasing uniformity led to increase the benefits unit of water as a result of increasing yield productivity. *M* device needed little power than the other emitter devices but this affected the yield productivity. The maximum yield with *T* device at 12.0 m pressure, compared with the other device types gained an increase of 6.7% and 12.5% compared to *G* and *M* types respectively El-Nemr (2010). The aim of this research is to investigate the influence of discharge uniformity for different device emitters on corn productivity and field water use efficiency (*FWUE*) under trickle irrigation system.

MATERIALS AND METHODS

The experimental was implemented at the hydraulic laboratory of Agricultural Engineering Department and the

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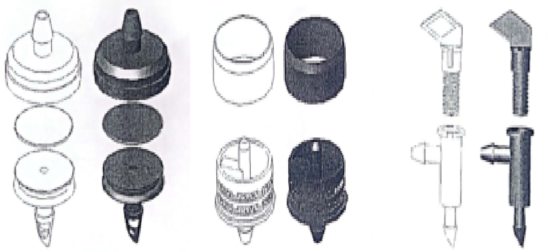
Research Farm of Agriculture Faculty, Suez Canal University, under sandy soil with corn crop. The hydraulic experiment was assessed for the purpose of device emitter calibration measuring flow rate and calculating manufacturing coefficient of variation for different device emitter. Three emitter devices were tested through this study pressure compensating (Em_{PC}), turbulent flow (Em_{TF}) and laminar flow (Em_{LF}) with nominal discharge 4.0 ℓh^{-1} with five pressures (0.25, 0.50, 0.75, 1.00 and 1.25 bar) as shown in figure (1).



a) (Em_{PC}) b) (Em_{TF}) c) (Em_{LF})

Figure 1. The tested emitter devices types.

The water was pumped from the tank by 0.75 kW (1 Hp) power. Flow rate was calculated by dividing the measured water volume using a gradually cylinder (temperatures of water i.e. 20-22°C) on specified time by stopwatch.

The pressure effect on device emitter discharge can be presented in two ways either, directly as the average of emitter discharge or flow variation (Q_v) that used to compare the minimum and maximum device emitter flow rates along a single lateral according to Jiang and Kang (2010) using the following function.

$$Q_v = \frac{Q_m - Q_n}{Q_m} x100 \quad (1)$$

Where; **Q_m and Q_n are maximum and minimum flow rate of emitter (ℓh^{-1}).**

Emitter flow Q (ℓh^{-1}) as a function of pressure (m) can be expressed as (Keller and Karmeli, 1974 and ASABE, 2008):

$$Q = k\ H^x \quad (2)$$

Where; ***k* is the constant of proportionality that describes emitter, and *x* is the device flow rate exponent that is described by the flow system.**

The suggested criteria for *x* values were expected and classified as pressure compensating equal 0.0, turbulent flow equal 0.5 and laminar flow equal 1.0. Coefficient of variation V_m can be computed as the standard deviation of all catch cans measurements divided by the average: On the other hand, the emitter manufacture's coefficient (V_m) was calculated by measuring the discharge from a sample (ASAE, 2003) as follows:

$$V_m = \frac{\sigma}{\overline{X}} \quad (3)$$

Where; $\overline{X}$ **; σ are emitters discharge average and deviation of standard**

In addition, the uniformity of emission (*UE, %*) was a better parameter for expressing the variation in discharge along lateral under different pressures. Li *et al.* (2012) investigated *UE*:

$$UE = \frac{\overline{Q_n}}{\overline{Q}} 100 \quad (4)$$

Where; $\overline{Q_n}$ **and** $\overline{Q}$ **are the lowest quarter mean and mean of emitter discharge (ℓh^{-1}).**

The setup of experiment consists of water source from canal Ismailia, unit of pump the farm with 15 *kW* (20 *Hp*) power supply, valves, flow meter, regulator of pressure was installed in series to regulate the supply pressure and pressure gauge. Pipes network of the main and the submain were *PVC* and lines of lateral which made from *PE* with nominal diameter of 18mm were connected with submain line. The three types of emitters were tested with pressure of 1.0 bar at length of 50 m to determine the best uniformity, corn productivity and field water use efficiency (*FWUE*).

The trickle irrigations system was connected in the corn field located elevation at 13m above sea level, 30° 58′ *N*, 32° 23′ *E*, Ismailia, Egypt. Local high yielding corn white single cross hybrid (2031) was planted as test crop. Corn crop was planted from 10/5/2023 to 8/11/2023 in the summer season, with 25 cm spacing. This corn crop was planted in soil sandy with 70 cm row spacing and distances between plants 25 cm spacing along lateral, at 50 m (18 mm inner diameter) lateral lengths with three devices (Em_{PC}, Em_{TF} and Em_{LF}) were used to irrigate corn crop. The Egyptian Agriculture Ministry's cultivation and fertilization guidelines were followed. Biological resistance to pests was established, no chemical pesticides were used and full water requirements. Sample of soil was collected to control some physical classified of soil depth layers to 45 cm according to Sparks (1996). The soil analysis indicated that at this layer of soil is considered to be homogeneous level as presented in Table (1). Soil texture was classified as sandy soil.

Table 1. Mechanical analysis of the test field soil.

Depth (cm)	Size of particle (%) Sand	Silt	Clay	Texture	ρ_b g/cm³	Moisture content (%) *W.P.*	*F.C.*	*A.W.*
0 - 15	95.2	1.9	2.9	Sandy	1.66	1.80	8.90	7.10
15 - 30	95.4	1.6	3.0	Sandy	1.63	1.77	9.00	7.23
30 - 45	95.4	1.8	2.8	Sandy	1.64	1.79	9.10	7.31

ρ_b: Dry bulk density, *W.P*: wilting point (- 15 atm), *F.C*: Field capacity (- 0.1 atm) and *A.W*: Available water.

The amount of applied irrigation water requirements IWR_a (*ℓ/Irri*) of corn through the growing season were calculated based on the determination of crop evapotranspiration ET_c (*mm/day*) by the Penman-Monteith (FAO-56) method used in CROPWAT (v.8) to determine the reference evapotranspiration (ET_o) and the crop coefficients (k_c) from climatic data formula which recommended by (Allen *et al.*, 2011):

$$IWR_a = ET_C\ A\ F_i \quad (5)$$

Where; ***A* is the plant area (m²) and F_i is the irrigation interval.**

The water application time t_a (*h*) was calculated from the following formula (Merriam and Keller, 1978):

$$t_a = \frac{IWR_a}{E_a\ q} \quad (6)$$

Where; **application efficiency E_a (decimal) equals 85% for this research and *q* is the emitter flow rate(ℓh^{-1}).**

The tested devices were operated under pressure of 1.0 bar during the test. The corn yield was harvested and the weight of the yield in each treatment was calculated and used to determine the field water use efficiency (*FWUE*) according to Abd El-Kader *et al.* (2010):

$$FWUE = \frac{Y}{W_T} \quad (7)$$

Where; ***FWUE* is the field water use efficiency (*kg m⁻³*), *Y* is the total corn yield (*kg fed⁻¹*) and W_T is the total applied of water ($m^3\ fed^{-1}$)**

RESULTS AND DISCUSSION

Impact of pressure on the emitter discharge

The general criteria of flow variation of device (Q_v, %) values were: desirable below 10%, acceptable between 10 to 20% and unacceptable above 20%, according to Wu and Barragan (2000) and Clark *et al.* (2007) as presented in figure (1). The mean value of Q_v at different pressures for Em_{PC} was desirable. Meanwhile the Q_v at pressures 0.50 and 1.0 bar for Em_{TF} emitter was acceptable, except at pressure 0.25, 0.75 and 1.25 bar were unacceptable Em_{TF} *device*. Also, Q_v of Em_{LF} emitter was unacceptable at all pressures, due to the low quality of Em_{LF}. Hence the flow variation of tested emitters could be stated in the following descending order ($Em_{PC} > Em_{TF} > Em_{LF}$).

The flow rate versus pressure correlation plays a vital role in the classification of emitter devices. It is one of the main influences in choosing a device and design of system. Figure (2) presents the relationship between pressure and flow rate for deferent emitters. It is apparent that the water discharge increased by increasing the pressure from 0.25 to 1.25 bar for Em_{TF} and Em_{LF} emitter. While, Q of Em_{PC} emitter was approximately constant with all pressure tested. Increasing pressure increased the discharge. Usually, the results illustrated that the water discharge of tested emitter device was highly affected by pressure but with different degrees depending on the emitter type.

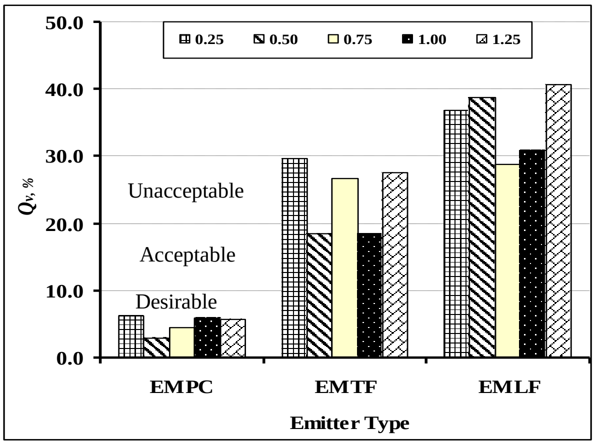


Figure 1. Influence of emitter type and pressure on Q_{var}.

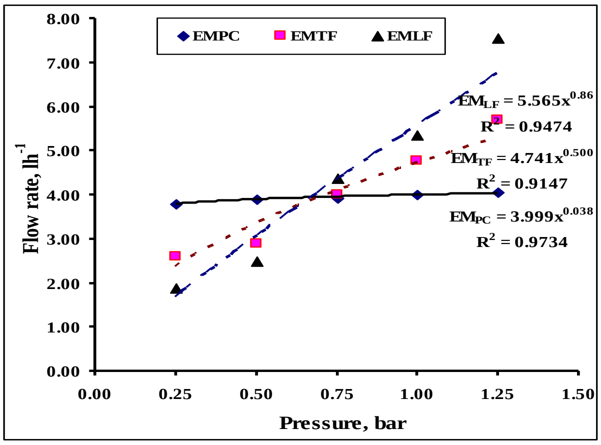


Figure 2. Effect of pressure and emitter devices on flow rate.

The tested devices flow regime characterization according to the exponent x as presented in figure (2) was laminar flow (Em_{LF}), turbulent flow (Em_{TF}) and pressure compensating (Em_{PC}). The statistical determination of coefficient for the pressure-flow rate relationship was recorded high values ($R^2 \geq 0.97$) with Em_{PC} and Em_{LF}. Meanwhile, Em_{TF} flow emitter had a relatively lower coefficient of correlation R^2 (0.91). These results are in agreement with those obtained by Kirnak *et al.* (2004). The exponent of emitter x indicated that its emitters classification laminar flow, turbulent flow and pressure compensating.

Figure (3) illustrated the characterization of the tested devices according to the emitter coefficient of manufacture's (V_m). The results showed that V_m values characterization of Em_{PC} was excellent (< 5 %). The V_m values for Em_{TF} were 7 to 11% at pressure 0.25 bar and then classified as marginal and V_m range was from 5 to 7% at pressure from 0.50 to 1.25 bar classified as average. Meanwhile, Em_{LF} was classified as marginal at pressure 1.0 bar, poor at pressure from 0.25 to 0.75 bar and unacceptable at pressure 1.25 bar. The low characterization of V_m for manufactured device Em_{PC} compared with Em_{TF} and Em_{LF} is due to its best quality of manufacturing and materials of these devices than others type.

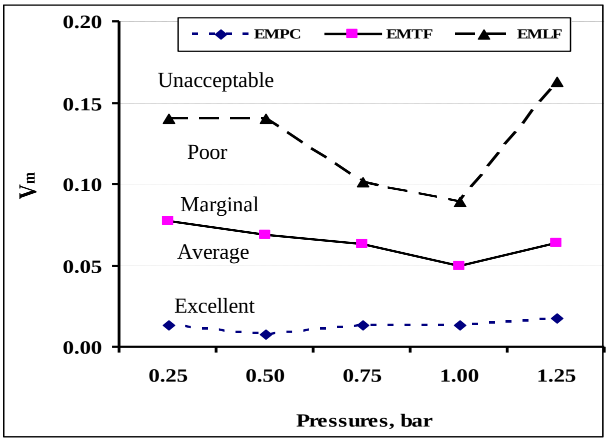


Figure 3. Influence of pressure and emitter devices on V_m.

Emission uniformity of emitter discharge

Uniformity of emitter discharge along the lateral length was expressed by uniformity of emission (*UE*). The *UE* is calculated as a procedure in the trickle irrigation design. The *UE* value measured from *Eq.* (4) was described as water uniformity on the soil. The emission uniformity was determined with three devices at variation pressures from 0.25 to 1.25 bar. The relationship between pressure and *UE* for all tested device types as presented in figure (4). On the other hand, for tested emitters, the pressure increasing from 0.25 to 1.0 bar led to *UE* increase for different emitter. In contrast, by increasing the operating pressure from 1.0 to 1.25 bar led to *UE* decrease for emitter, generally it was an inverse relationship between *UE* and the pressure. The highest values *of UE* were noticed to pressures of 1.0 bar for different devices. This result .is in agreement with suggested pressure provided through manufacturer of devices. Generally, maximum value of water uniformity was obtained with Em_{PC} device, while minimum value was found with Em_{LF} emitter. The results showed that water uniformity was a variable influence with emitter device types, due to the differences in V_m characterization, it showed that *UE* was increased by advanced V_m characterization agreed with (Tagar, *et al.*, 2010).

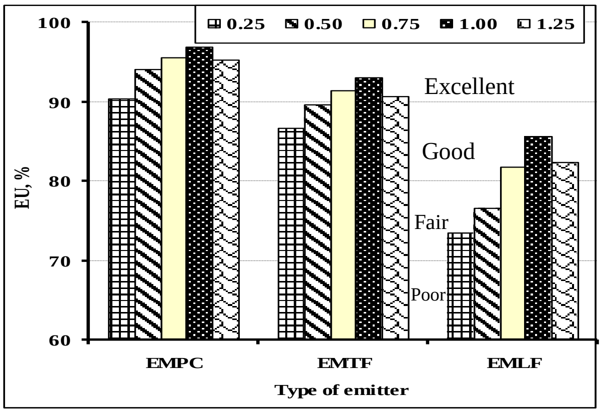


Figure 4. Impact of pressure and emitter devices on emission uniformity.

Yield and field water use efficiency

The corn was planted on 10th May to 8th September in the summer season of 2023 at 25 cm distances of plant, and the grain yields and straw under different emitters with 70 cm row spacing were weighed and illustrated in figure (5). The higher values of corn straw of 5625 *kg fed*$^{-1}$ and yield of 3856 *kg fed*$^{-1}$ were recorded for device Em_{PC}. Meanwhile, the lower values of 4220 *kg fed*$^{-1}$ and 3305 *kg fed*$^{-1}$ for straw and grain crop of Em_{LF} emitter. The maximum yield with Em_{PC} device at 1.0 bar pressure, compared with the other devices increased an increase of 8.92% and 16.68% compared to Em_{TF} and Em_{LF} devices respectively El-Nemr (2010).

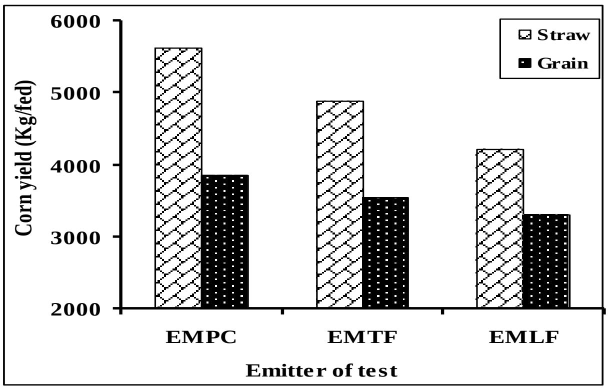


Figure 5. Different emitters and corn yield at pressure of 1.0 bar.

Generally, field water use efficiency (*FWUE*) is the ratio of total yield to the total applied of water. The results showed that *FWUE* were 1.41, 1.30 and 1.21 *kg m*$^{-3}$ for Em_{PC}, Em_{TF} and Em_{LF} devices, respectively as present in figure (6). It is clear from the found results that the best value of *FWUE* was achieved at Em_{PC} emitter type. In addition, the value of *FWUE* increasing trend with increasing the emission uniformity of devices. It was recommended to use Em_{PC} emitter at pressure of 1.0 bar for lateral lengths 50 m, which gives the highest uniformity that will be impact on *FWUE* and corn productivity.

The best parameters of uniformity will give best productivity. It is clear from the obtained results that the better values of uniformity were achieved at pressure 1.0 for manufactured emitters of Em_{PC} as presented in figure (4) and the highest values of yield. Also, the value of yield for Em_{TF} emitter was higher than that of Em_{LF} emitter. Concerning the relationship between the yield and the uniformity of water application, figure (7) shows that the uniformity plays an important role on corn yield. The data indicated that the yield increased by increasing the uniformity and this result is in agreement with the found by El-Sherbeni (1994). The highest straw and grain yield was found for Em_{PC} due to increase the water distribution uniformity; while the lowest yield was found for Em_{LF}. The Em_{PC} device gave the maximum yield productivity which reached 3.856 *Mg fed*$^{-1}$ with 96.87 *UE* in 1.0 bar pressure. Increasing uniformity led to increase the benefits unit of water as a result of increasing yield productivity. Em_{PC} emitter needed little power than the other emitter devices but this affected the yield productivity.

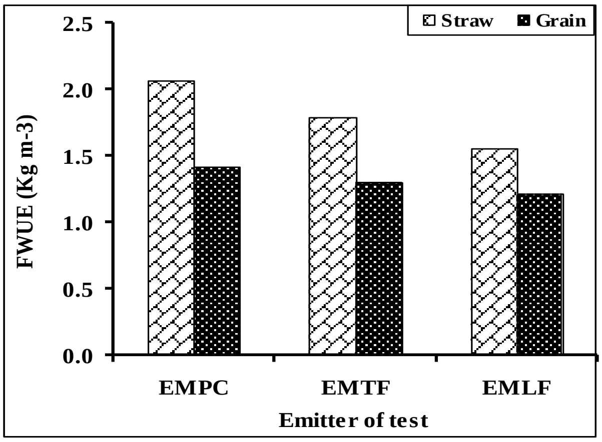


Figure 6. Emitters and field water use efficiency at pressure of 1.0 bar.

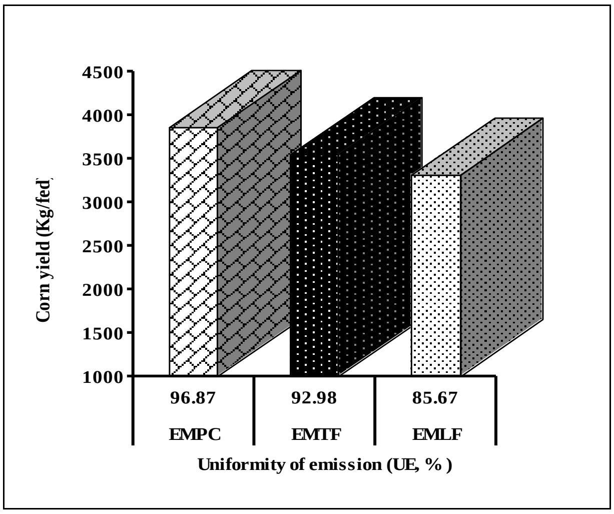


Figure 7. The relationship between uniformity and corn yield under different emitters at pressure of 1.0 bar

CONCLUSION

Emitter types had a great impact on discharge uniformity and corn productivity. Also, the used operating pressure had appositive correlation with uniformity and corn yield. The maximum yield with Em_{PC} device compared with the other devices increased an increase of 8.92% and 16.68% of Em_{TF} and Em_{LF} devices respectively. The Em_{PC} device gave the best yield productivity which 3.856 *Mg fed*$^{-1}$ with 96.87% *UE* at pressure 1.0 bar. The best value of *FWUE* was achieved at Em_{PC} emitter. The ample conditions were using pressure compensating "Em_{PC}" at pressure 1.0 bar with lateral lengths of 50 m to get the highest parameters efficiency and corn productivity.

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استخدام أنواع مختلفة من النقاطات في إنتاجية الذرة وتأثرها بالانتظامية

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الملخص

تم إجراء تجربة معملية بقسم الهندسة الزراعية وأخرى حقلية بمزرعة كلية الزراعة جامعة قناة السويس، بالإسماعيلية، خلال فصل الصيف ٢٠٢٣م على محصول الذرة البيضاء تحت نظام الرى بالتنقيط فى تربة رملية، وكان الهدف الرئيسي من هذه الدراسة هو دراسة تأثير انتظامية ثلاث أنواع مختلفة من النقاطات هى: النقاطات ذات السريان المضطرب turbulent flow (Em_{TF}) ونقاطات السريان الرقائقى laminar flow (Em_{LF}) والنقاطات معوضه للضغط pressure compensating (Em_{PC}) وضغوط تشغيل (٠,٢٥، ٠,٥٠، ٠,٧٥ ، ١,٠ و ١,٢٥ بار) على إنتاجية الذرة وكفاءة إستخدام المياه الحقلية مع طول الخط الرى ٥٠ م. ولقد أظهرت النتائج المتحصل عليها أن أنتظامية إنبعاث المياه (*UE*) يزداد بزيادة ضغط التشغيل. أيضاً أعطى النقاط المعوض للضغط أعلى إنتاجية للمحصول وكفاءة إستخدام المياه الحقلية وكانت نسبة زيادة انتاجية المحصول للنقاط المعوض للضغط ٨,٩٢ و ١٦,٦٨% مقارنة بالنقاط السريان المضطرب والنقاط السريان الرقائقى على التوالى، حيث كان النقاط المعوض للضغط ذو أنتظامية توزيع للمياه عالية بنسبة ٩٦,٨٧% وكفاءة إستخدام مياه ١,٤١ كجم/م^{٣} ويعمل على توفير فى كمية مياه الرى. لذلك يوصى باستخدام النقاط المعوض للضغط ذات الانتظامية العالية عند ضغط تشغيل ١,٠ بار مع طول الخط الرى ٥٠ م للحصول على أعلى معدل إنتاج وكفاءة استخدام للمياه.

الكلمات المفتاحية: النقاط، انتظامية المياه، إنتاجية الذرة.