EVALUATION OF PARTIAL ROOT ZONE DRYING IRRIGATION UNDER GATED PIPES SYSTEM FOR CORN CROP

Gomaa, A.H [1]; A.A. Samak [1]; S. l. ELKhatib [2]; and H. M. Sharaf[2]

ABSTRACT

In recent time, Egypt is suffering from the scarcity of fresh water. In addition, Egypt is one of the event states under the water poverty line, who is identified as less than 1000 m^3 per capita per year due to the existence of dry climatic conditions in most parts of the country and limited available water resources, therefore optimization and saving of water consumption have vital importance. The main goal of this research is to study the effect of Partial Root zone Drying (PRD) on corn yield, water distribution efficiency and water use efficiency compared with conventional irrigation (CI).Field experiment was conducted during summer season of 2017 in the Agricultural research station, Etay El-Baroud, El-Behera Governorate (Etay-El-Baroud region is 6m above sea level, 30˚ 88 / N and 30˚ 66 / E).Corn plants were planted under different irrigation regimes which were Alternate Partial Root zone Drying (APRD),Fixed Partial Root zone Drying (FPRD),and Conventional Irrigation (CI) comparing with control irrigation. The irrigation regimes were carried out under two levels of land leveling (0.05% - 0.1%), and three levels of water cutting times. The experimental treatments were irrigated by 152mm diameter of PVC gated pipes system. The results indicated that, the APRD treatment achieved the highest value of corn production (7.85Mg ha^{-1}) when the applied water was reached to the end of furrow plus 5 minutes storage (Q_3) under furrow slope of 0.1% and improving water use efficiency (WUE) when applied water was reached 5m before the end of furrow length (Q_2) by 1.73 kg m^{-3} under furrow slope of 0.1%. Also, the APRD regime saved 37.16% of applied water under Q_2 and furrow slope of 0.1%.

Key words: *Gated Pipes System - Conventional Irrigation - Partial Root zone Drying– Corn Crop - Water Use Efficiency.*

[1] Agricultural Engineering Department, Faculty of Agri., Menoufia University
[2] Agricultural Engineering Institute, Agricultural Research Center (ARC).

1. INTRODUCTION

Egypt has reached a state where the quantity of water available is imposing limits on its national economic development. Water shortage is the most important factor constraining agriculture production all over the world. In Egypt, agriculture consumes the largest amount of the available water with its share exceeding 85% of the total demand for water. So, the study is an attempt to find ways to solve the water scarcity problem. According to the Ministry of Water Resources and Irrigation, Egypt already uses 127% of its water resources meaning that Egypt imports 27% of its water used through imported food and other products and by 2020 Egypt could be using 147% according to **Waseem, (2017**).Partial Root Zone Drying (PRD) is modified form of Deficit Irrigation (DI) that half of the root system is subject to drying soil and the other half is growing in irrigated soil in each irrigation event. Partial root zone drying is one of the deficit irrigation strategies designed to keep half of the root system in a drying state, while the other half of the root zone is irrigated. Then, the treatment is reversed, allowing the previously well-irrigated side of the root system to dry down addition to fully irrigating the previously dry side. **Wang et al., (2012)** indicated that, alternate partial root zone irrigation (APRD) is water saving irrigation techniques being intensively studied in many regions of the world on a wide range of crops. Partial root zone drying and regulated deficit irrigation techniques have proven the efficiency in improving the irrigation water use efficiency and fruit quality and dry fruit yield as compared with control irrigation **(Mahmoud et al., 2019)**. Fixed Partial Root zone Drying (FPRD) is an irrigation technique where water is applied only from one side of the root system while the other part is exposed to continuous dry conditions. FPRD was used as a water saving irrigation strategy compared to Alternate Partial Root zone Drying (APRD) and conventional irrigation **(Lekakis et al., (2011)**. Surface irrigation has a lower efficiency than other methods and it is the oldest most widely used irrigation method in Egypt and the world over. Irrigation water generally infiltrates into the root zone during conveyance and recession of water at the soil surface **(Amer and Amer, 2010)**. Gated irrigation pipes system is an important tool for improving surface irrigation, its development depends on replacing the gates by designed self-compensating nozzle (**Abdel-Rahman, 2010)**.Using of gated pipes system in surface irrigation helps to reduce water losses commonly associated with the use of the traditional furrows **(El-Shafie, et al., 2017)**.In Egypt, Corn crop (*Zea mays L.*) is one of the most important cereal crops grown principally during the summer season. Great attention has been paid to increase total corn production**(Osama and Ahmed, 2015)**.The main goal of this research is to study the effect of Partial Root zone Drying (PRD) on corn yield, water distribution efficiency and water use efficiency compared with conventional irrigation (CI).

2. MATERIALS AND METHODS

Field experiment was carried out during summer season of 2017 growing in the Agricultural research station, Etay El-Baroud, El-Behera Governorate. Soil located at an arid site in northern Egypt (Etay El-Baroud region is 6m above sea level, 30˚ 88 /N and 30˚ 66/ E). Two levels of field leveling were selected as plots design which were 0.05% leveling as the first plot and 0.1% leveling as the second plot. Each furrow had 0.75m wide and 45m long. Some physical and mechanical analysis of the soil was determined according to **Black et al., (1965).**The soil samples were collected upto 60cm soil depth to determine soil mechanical analysis, field capacity, permanent wilting point, density and organic matter for each soil depth and the results presented in Table (1).

Table (1): Soil mechanical analysis of the experimental site

Soil depth(cm)	Particle size distribution, %				Soil texture class	Field Capacity (%)	Wilting Point (%)	Bulk density (g, cm^{-3})
	Sand Coarse	Sand Fine	Silt	Clay				
0 – 15	4.67	15.96	17.53	61.84	Clay	37.8	18.6	1.11
15 – 30	4.50	14.00	17.50	64.50		34.2	16.2	1.09
30 – 45	4.40	14.50	17.60	63.50		33.1	15.5	1.24
45 – 60	3.00	16.00	16.00	65.00		30.6	14.7	1.34

Soil moisture content (M_c) was calculated by using the following equation according to **Casillas, (1978)**:

$$M_c = \frac{M_w - M_d}{M_d} \times 100 \quad \text{.................................(1)}$$

Where: M_c is the soil moisture content (dry weight basis) %, M_w is the wet weight of soil (gm), and M_d is the dry weight of soil (gm).

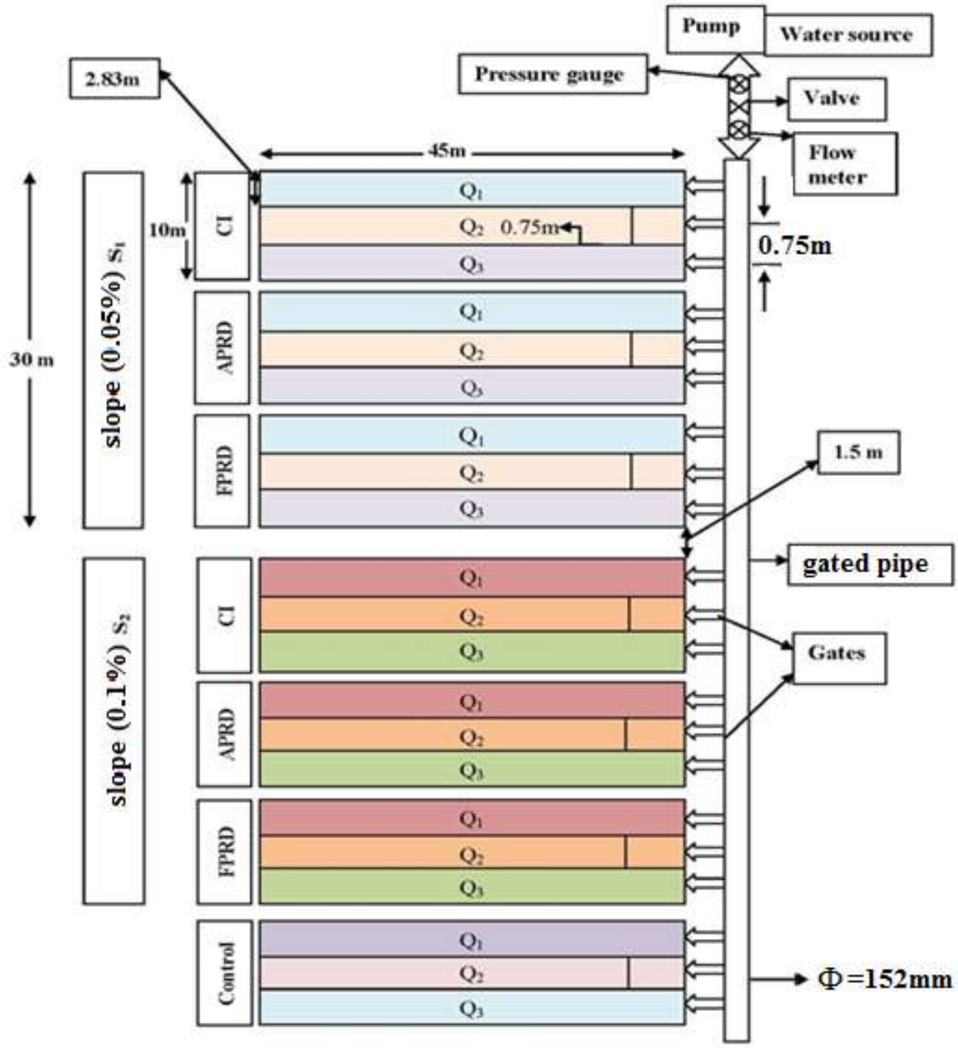

Fig. (1): schematic diagram of the experimental set up and arrangements of treatments.

CI = Conventional irrigation	**APRD** = Alternate partial root zone drying irrigation
FPRD = Fixed partial root zone drying irrigation	**S** = Laser leveling (S_1= 0.05% and S_2 = 0.10%)
Q_1 = Apply water to the end of furrow	Q_2 = Apply water 5 m before the end of furrow
Q_3 = Apply water to the end of furrow with 5 min storage	

Field experiment was concerned with three factors which can be described as follows: Two levels of soil leveling were used which were 0.05% and 0.1%, three levels of water cutting time which were (Q_1) water cutting when reached to the end of furrow, (Q_2) water cutting when reached to 5 m before the end of furrow, and (Q_3) water cutting when reached to the end of furrow with 5 minutes storage. Also, the tested irrigation regimes were conventional irrigation (CI), alternate partial root zone drying irrigation (APRD), and fixed partial root zone drying irrigation (FPRD). Two levels of field leveling were selected as plots design 0.05% leveling as the first plot and 0.1% leveling as the second plot. In every experimental plot there were three subplots, every subplot with 10 m width and 45 m length, included 9 furrows; each three furrows were considered as one specified treatment. Each furrow had 0.75 m wide and 45 m long. The site description of the experimental field is as shown in Fig. (1).

Water distribution efficiency (DU) was calculated according to **James (1988)** as follows:

$$DU = \frac{Y}{(1-dr)} \times 100 \text{ ....(2)}$$

Where: DU is distribution uniformity (%), d_r is the average depth of soil water stored along the run during the irrigation (cm), and Y is the average standard deviation from d_r (cm).

Water application efficiency (E_a) was estimated using the following equation of **Brouwer et al., (1985)**

$$E_a = \frac{w_{av}}{w_a} * 100 \text{.................................... (3)}$$

Where: E_a is water application efficiency, %, W_{av} is volume of water stored per hectar in root zone during the irrigation, $m^3\ ha^{-1}$, and W_a is volume of water delivered to the farm per hectar, $m^3\ ha^{-1}$.

The water use efficiency (WUE) as a measure to clarify variation in yield due to irrigation water was calculated according to **Michael (1978)** as following:

$$WUE\ (kg\ m^{-3}) = \frac{Y_i}{W_a} \text{............................ (4)}$$

Where: WUE is water use efficiency, (kg m^{-3}), Y_i is yield, (Mg ha^{-1}) and W_a is the seasonal total applied water, ($m^3\ ha^{-1}$).

The obtained data were analyzed using the Statistical Analysis System Software (Costat, V6.4). Two ways analysis of variance was used.

3.RESULTS AND DISCUSSION

3.1. Water advance, water recession time, and infiltrated depth

The results showed that, water advance time, water recession time and infiltrated depth were affected by furrow slope as shown in Fig. (2). It was obvious that, increasing slope from 0.05% to 0.1%, water advance time decreased, recession times about water infiltrated depth was increased. The reported results are in agreement with results found by **Eltantawy et al. (2006).**

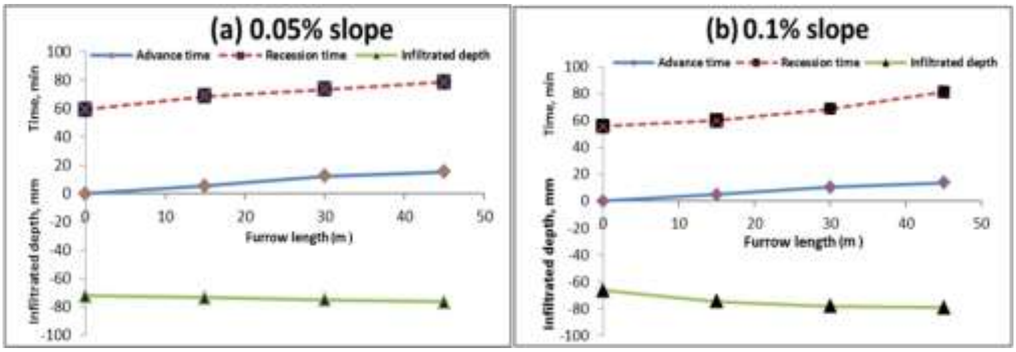

Fig. (2): Water advance time, water recession time and infiltrated depth of APRD treatment under Q_1 of water application for (a) 0.05% and (b) 0.1% of furrow slope.

Fig. (2). illustrated the results of APRD at water application of Q_1 treatments, the total water advance times were 15.4 min and 13.6 min at furrow slopes of 0.05% and 0.1%, respectively (decreased by 11.69%). On the other hand, total recession time were 78.6 min and 81.4 min at furrow slopes of 0.05% and 0.1%, respectively (increased by 3.56%). The maximum infiltrated depths were 76.5 mm and 79.3 mm at furrow slopes of 0.05% and 0.1%, respectively (increased by 3.66%) under Q_1 treatment where the water cutting was occurred when the water reached to the end of furrow length.

The results showed that, the total water advance times were 16.5 min and 12.2 min at furrow slopes of 0.05% and 0.1%, respectively (decreased by 26.1%). Meanwhile, the total recession time were 82 min and 83.2 min at furrow slopes of 0.05% and 0.1%, respectively (increased by 1.46%). The maximum water infiltrated depths were 74.4 mm and 76.9 mm at furrow slopes of 0.05% and 0.1%, respectively (increased by 3.36%). These results are in agreement with the results reported by **Abd El-Rahman (1985)**.

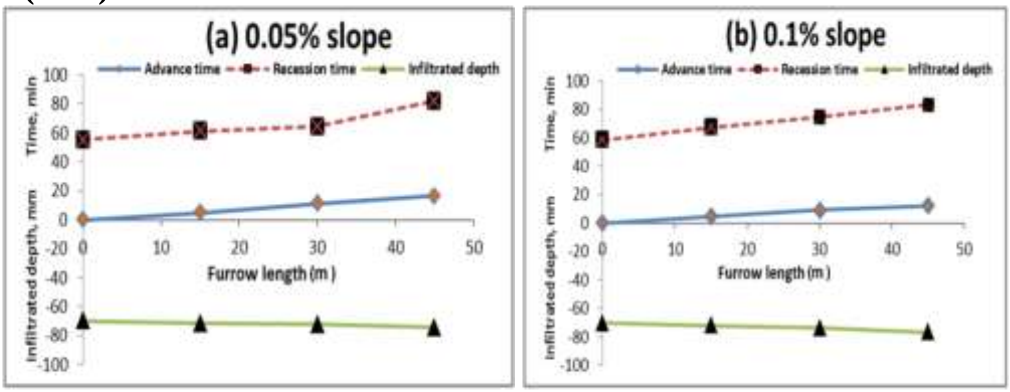

Fig.(3): Water advance time, water recession time and infiltrated depth of CI treatment at Q_1 of water application for (a) 0.05% and (b) 0.1% of furrow slope.

3.2. Corn yield parameters

The relationship between the effect of water amount and irrigation regime under furrow slope of 0.05% and 0.1% on corn yield under different three water application treatments (Q_1, Q_2 and Q_3) are shown in Table (2). It showed that, under all of water amount there were high significant differences between treatments, where there were significant differences between APRD, FPRD and CI in Q_1 at furrow slope of 0.05%, while at furrow slope of 0.1% there were high significant differences between APRD, FPRD and CI in Q_1. Also, there were significant differences between APRD, FPRD and CI in Q_2 at furrow slope of 0.05% and 0.1%; also, there were high significant differences between APRD, FPRD and CI in Q_3. For corn yield, it was noticed that, there were significant differences between treatments, where there were significant differences between APRD, FPRD and CI in Q_1 at furrow slope of 0.05%, while at furrow slope of 0.1% there were high significant differences between APRD, FPRD and CI in Q_1. In addition, there were significant differences between APRD, FPRD and CI in Q_2 andQ_3at furrow slope of 0.05% and 0.1%. Moreover, it can be noticed that, the corn yield under APRD treatment was the highest (7.85 Mg ha $^{-1}$) under the water application of

Q_3 comparing with the other treatments of Q_1 and Q_2. It increased by about 9.68% and 18.5%, respectively under furrow slope of 0.1%. The same results were reported by **Consoli et al., (2017)**.

Table (2): Seasonal water applied and corn yield under the different irrigation treatments

Slope of furrow	Irrigation regime	Seasonal water applied ($m^3 ha^{-1}$)			Corn yield ($Mg ha^{-1}$)		
		Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
	Control	7735.0[a]	7358.9[a]	8032.5[a]	5.59[d]	3.76[d]	6.06[d]
0.05 %	APRD	5698.2[c]	5155.1[d]	5873.8[d]	6.97[a]	6.62[a]	7.71[a]
	FPRD	5597.8[d]	5331.2[c]	6016.6[c]	6.18[c]	5.41[c]	6.31[c]
	CI	5895.3[b]	5597.8[b]	6176.1[b]	6.83[b]	6.26[b]	7.35[b]
LSD=0.05		51.07	48.342	40.150	0.036	0.027	0.052
0.1 %	APRD	5031.3[d]	4629.1[d]	5416.8[d]	7.09[a]	6.40[a]	7.85[a]
	FPRD	5176.5[c]	4867.1[c]	5585.9[c]	6.14[c]	4.71[c]	5.47[c]
	CI	5383.6[b]	5207.4[b]	5659.6[b]	6.90[b]	6.33[b]	7.40[b]
LSD=0.05		50.155	38.821	41.190	0.074	0.114	0.114

Table (3) showed, the effect of total seasonal water applied and irrigation regime on physical characteristics of corn crop (weight of 100 grains (g) - number of grains per row and plant height (cm). It was noticed that, weight of 100 grains (g) under control treatment had a high value inQ_2 (33.6 g) and low value in Q_3 (31.5 g).

Table (3): Physical characteristics for all the studied experimental treatments

Slope of furrow	Irrigation regime	Weight of 100 grain (g)			Number of grains per row			Plant height (cm)		
		Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
	Control	32.7[c]	33.6[c]	31.5[d]	37.5[c]	34.6[d]	39.2[d]	327.2[a]	321.5[a]	335.4[a]
0.05 %	APRD	35.9[a]	38.6[a]	33.9[a]	42[b]	46.1[a]	45[b]	314.7[d]	306.5[d]	320.8[c]
	FPRD	34.9[b]	36.3[b]	32.8[c]	46[a]	43[b]	46.5[a]	322.6[b]	307.1[c]	312.5[d]
	CI	30.8[d]	31.5[d]	33.8[b]	38[d]	41.2[c]	42.5[c]	318.5[c]	316.8[b]	326.4[b]
	LSD=0.05	0.142	0.071	0.116	0.074	0.167	0.026	0.379	0.741	0.590
0.1 %	APRD	34.8[b]	36.7[a]	37.2[a]	43.4[b]	44.7[a]	44.8[b]	305.1[d]	302.3[c]	318.6[c]
	FPRD	35.9[a]	36.1[b]	29.5[c]	47[a]	42[c]	48[a]	308.5[c]	302[d]	316.3[d]
	CI	35.9[a]	33.5[d]	36.2[b]	42[d]	43[b]	44.5[c]	312.5[b]	308.6[b]	319.4[b]
	LSD=0.05	0.084	0.131	0.239	0.119	0.127	0.089	0.150	0.464	0.129

Under furrow slope of 0.05%, the APRD and FPRD achieved the highest values in weight of 100 grains (g) under Q_2 treatment; it was recorded about (38.6 g) and (35.9 g), respectively. Meanwhile, the CI treatment achieved the highest value of 100-grains weight (g) under Q_3 treatment, which was recorded(33.8 g).Under furrow slope of 0.1%, the APRD resulted in highest value in Q_3 (37.2 g).Also, in FPRD the Q_2achieved high value (36.1g). Meanwhile, under CI treatment, the Q_3 achieved high value (36.2 g). On the other hand, there were significant differences between treatments, where there were significant differences between APRD, FPRD and CI in Q_1under furrow slope of 0.05%, while under furrow slope of 0.1% there were high significant differences between APRD, FPRD and CI in Q_1. Also, there were significant differences between APRD, FPRD and CI in Q_2 and Q_3 under furrow slope of 0.05% and 0.1% for 100-grainsweight. The results showed also that, the number of grains per row under the control treatment recorded high value with Q_3 (39 grains per row); while with APRD irrigation regime, Q_2 treatment result in a high value (46 grains per row). At FPRD treatment the Q_3 achieved the highest value (about 46). Also, under CI treatment, the Q_3 resulted in high value (42 grains per row). Meanwhile under furrow slope of 0.1%, the APRD resulted a high value in Q_3 (44 grains per row). At FPRD treatment the Q_3 achieved high value (48 grains per row). Also, at CI treatment the Q_3 resulted high value (44 grains per row). It was noticed that, there were significant differences between treatments Q_1, Q_2 and Q_3under furrow slope of 0.05% and 0.1% for number of grains per row. However, there were high significant differences between irrigation regimes (APRD, FPRD and CI) in Q_1, Q_2 and Q_3under furrow slope of 0.05% and 0.1% for plant height. The same results were reported by **Han and Kang (2002)**.

3.3. Water distribution efficiency, water application efficiency, and water use efficiency

Results in Table (4) showed that, the value of water application efficiency was the greatest value with FPRD (Q_1) 75.9%under furrow slope of 0.05% compared with APRD and CI. While under furrow slope of 0.1%, the APRD resulted in the highest value compared with FPRD and CI treatments where it was 85.2 %. However, under applied water of (Q_2), the control treatment resulted in the lowest value for water application efficiency (51.8%) compared with other treatments. Under furrow slope of 0.05%, the FPRD achieved the highest value (80.1%) compared with APRD and CI. While under furrow slope of 0.1%, the CI recorded the highest value (85.8%) compared with APRD and FPRD treatments.

Table (4): Water distribution efficiency, water application efficiency, water use efficiency and water saving percent

Furrow slope	Irrigation regime	Water distribution efficiency, (%)			Water application efficiency, (%)			Water use efficiency, (kg m^{-3})			Water saving, (%)		
		Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
	Control	85.5	84.8	81.3	48.5	51.8	49.5	0.87	0.91	0.82	-	-	-
0.05%	APRD	89.1	89.1	89.8	74.9	79.1	73.0	1.32	1.53	1.29	27.1	30.0	26.9
	FPRD	89.4	89.7	88.4	75.9	80.1	73.9	1.35	1.41	1.22	27.6	27.6	24.1
	CI	80.6	82.6	84.6	73.2	71.3	70.1	1.12	1.19	1.16	23.8	24.0	23.1
0.1%	APRD	89.7	90.2	89.3	85.2	84.9	79.9	1.51	1.73	1.41	34.9	37.2	32.6
	FPRD	87.7	82.8	84.9	83.0	85.5	81.9	1.38	1.57	1.28	33.1	33.9	30.5
	CI	86.1	87.0	83.3	77.4	85.8	76.9	1.32	1.41	1.29	30.4	29.3	29.5

On the other hand, under applied water amount of (Q_3), the control treatment recorded the lowest value of water application efficiency (49.5%) compared with other treatments. Meanwhile under furrow slope of 0.05%, the FPRD achieved the highest value (73.9%) compared with APRD and CI treatments. While, under furrow slope of 0.1%, the FPRD resulted the highest value (81.9%) compared with APRD and CI treatments. For water distribution efficiency, under applied water amount of Q_1, the FPRD treatment recorded the highest value under furrow slope of 0.05% 89.4%, while under furrow slope of 0.1% APRD achieved highest value 89.7%, also with applied water amount of Q_2, the FPRD treatment recorded the highest value under furrow slope of 0.05% were 89.7%, while under furrow slope of 0.1%, the APRD treatment achieved the highest value 90.4%. Meanwhile with applied water amount of Q_3, the APRD treatment recorded the highest value under slopes of 0.05% and 0.1% were 89.8% and 89.3%, respectively. The value of water use efficiency was the greatest value under the APRD treatment (1.53 kg m^{-3} and 1.73 kg m^{-3}) compared with FPRD, CI and control irrigation. The results indicated that, the APRD treatment achieved the highest value of water saving in case of water cutting was occurred when irrigation water reached 5 m before the end of furrow length (Q_2), where the highest value under furrow slopes of 0.05% and 0.1% were 30.02% and 37.16%, respectively.

4. CONCOLUSION

Water advance time was decreased by increasing furrow slope, but water recession time and irrigation depth were increased by increasing furrow slope. The highest value of corn yield was occurred under the PRD treatment where water cutting was occurred when irrigation water reached to the end of furrow length (Q_1), the APRD treatment achieved high value of corn yield (6.97 Mg ha^{-1}) under furrow slope of 0.05%, and (7.09 Mg ha^{-1}) under furrow slope of 0.1% compared with CI and control irrigation. Meanwhile, when the water cutting was occurred when irrigation water reached to the end of furrow with 5minutes storage (Q_3), the APRD treatment recorded the highest value of corn yield under furrow slope of 0.05%, and under furrow slope of 0.1% (7.71 and 7.85 mg ha^{-1}, respectively).The value of water use efficiency was the greatest under the APRD treatment (1.53 kg m^{-3} and 1.73 kg m^{-3}) compared with FPRD, CI and control irrigation treatments. The results indicated that the APRD treatment achieved the highest value of water saving in case of water cutting was occurred when irrigation water reached 5 m before the end of furrow length (Q_2), where the highest value under furrow slopes of 0.05% and 0.1% were 30.02% and 37.16%, respectively.

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الملخص العربي

تقييم الري الجزئي للجذور تحت نظام الأنابيب المبوبة لمحصول الذرة

أحمد حسن السيد جمعة[١] ، **عبد اللطيف عبد الوهاب سمك**[١]،
صلاح الدين إسماعيل الخطيب[٢] و **هند محمود حلمى شرف**[٢]

أصبحت مصر تعاني من مشكلة نقص المياه، حيث إن الزراعة تستهلك أكبر كمية ماء فى مصر حيث إن ماء الرى الزراعي يمثل حوالي ٨٥ % من الماء المتاح، لذا وجب التفكيرفى تطوير أنظمة الرى وإيجاد أساليب حديثة لتوفير كمية الماء المستخدم فى الزراعة. يعتبر الرى الجزئي اسلوب حديث ومطور يستخدم لتوفير كمية الماء وفيه يتم الرى بالتناوب بين الجانبين حيث يروى جانب والجانب الأخر يترك جاف فيكون هناك تناوب خلال فترة من ١٠ إلى ١٤ يوما. تم إجراء التجربة بمحطة البحوث الزراعية بايتاي البارود بمحافظة البحيرة، حيث تم زراعة محصول الذرة (هجين ثلاثي -٣١٠) خلال موسم الزراعة ٢٠١٧. وكانت المسافة بين الخطوط ٠,٧٥ متر، كما استخدمت الأنابيب المبوبة المصنعة من البولي فينيل كلوريد (PVC) لري التجربة. حيث كانت معاملات الدراسة في التجربة كالاتي:

- تسوية سطح التربة بالليزر باستخدام ميلين مختلفين لسطح التربة وهما ٠,٠٥ % و٠,١٠ %.
- أنظمة الرى وهي الرى الجزئي (التبادلي والثابت) والري التقليدي بالميول ومقارنة هذه الأنظمة بالري التقليدي بدون ميول والمستخدم مع معظم المزارعين.
- استخدام ثلاث طرق لإضافة الماء وهي إضافة الماء حتى يصل لنهاية الخط (Q_1)– إضافة الماء حتى يصل قبل نهاية الخط بـ ٥ متر (Q_2)، إضافة الماء حتى يصل لنهاية الخط مع إضافة ٥ دقائق تخزين (Q_3).

[١] **قسم الهندسة الزراعية - كلية الزراعة - جامعة المنوفية**
[٢] **معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية - مصر**

وكانت النتائج المتحصل عليهاالاتي:

١. حقق الرى الجزئي التبادلي باستخدام التسوية بالليزر تحت نظام الأنابيب المبوبة أفضل انتاجية وبالتالى أعلى كفاءة ري مقارنة بالري التقليدي.
٢. اظهرت النتائج ان اعلي كفاءة لإضافة المياه تحت ميل الأرض ٠,١٠ % وكانت النتائج ٨٣ %، ٨٦ % و ٨٢ % على الترتيب أيضا.
٣. اعلي قيم لكفاءة توزيع مياه الري تحت نظم إضافة المياه Q_1 و Q_2 كانت ٨٩ % وذلك تحت نظام الري الجزئي الثابت، اما تحت نظام إضافة المياه Q_3 فكانت اعلي قيمة لكفاءة توزيع مياه الري ٩٠ % وذلك تحت نظام الري الجزئي التبادلي عند ميل سطح التربة مقداره ٠.٠٥ %.
٤. تحت ميل سطح التربة يعادل ٠,١٠ % كانت كفاءة توزيع مياه الري الأعلى تحت نظام الري الجزئي التبادلي وذلك تحت جميع نظم إضافة مياه الري الثلاث Q_1، Q_2 و Q_3 وكانت ٩٠ %.
٥. تحققت أعلي قيمة لكفاءة استخدام مياه الري في حالة معاملة الري الجزئي التبادلي مقارنة بالري التقليدي والري الجزئي الثابت وذلك تحت ميلي ٠,٠٥ %، ٠,١٠ % وكانت قيمتها حوالي ١,٥٣ كجم / متر مكعب و ١,٧١ كجم / متر مكعب من مياه الري على الترتيب.
٦. استخدام نظام الري الجزئي التبادلي حقق اعلي نسبة توفير لمياه الري تحت نظام إضافة مياه الري Q_2 حيث يتم إضافة المياه حتى تصل قبل نهاية الخط ب ٥ متر وذلك تحت جميع المعاملات المستخدمة. وكانت اعلي قيم لنسب توفير المياه لهذه المعاملة تحت ميلي ٠,٠٥ % و ٠,١٠ % لسطح التربة هي ٣٠ % و ٣٧ % على الترتيب.