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Economic Return for Maize Crop under Surface Irrigation System

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ABSTRACT

The field experiment was conducted at Sidi Salem city, KafrElshekh governorate, Egypt. Located at latitude 31^0 27' N, longitude 30^0 78' E and 6,1m Altitude during season 2023 to determine the performance of alternate furrow irrigation and effect of water deficit by reducing the water applied. The treatments were two alternative irrigations first, irrigated one furrow and non-irrigated one furrow second, irrigated two furrows and non-irrigated one furrow. Two Surface irrigation systems, developed irrigation and traditional irrigation. Three levels of irrigation water applied (100% ETc, 85% ETc and 70% ETc). The results showed that the yield and water use efficiency increased by 15.40% and 32.43% respectively, as the application of water (m^3/fed.) decreased by 19.49% compared with those in the plot that irrigated with traditional irrigation. The cost of irrigation (LE/fed.) in the developing plot was decreased by 82.11 % compared with traditional irrigation. The net return (LE/fed.) increased by 18.17% compared with traditional irrigation. The yield of the developed surface irrigation for two furrows irrigated and one furrow non-irrigated increased by 9.09, 1.30 and 9.47 % compared with developed surface irrigation using one furrow irrigated and one furrow non-irrigated, developed surface irrigation using two furrows irrigated and one furrow non-irrigated and traditional irrigation surface irrigation using one furrow irrigated and one furrow non-irrigated respectively. Application efficiency (Ea) decreased by 5.95 and 16.09 % when the ETc decreased from 100 % to 85% and from 100% to 70%, respectively.

Keywords: developed and surface irrigation, water applied, economic return.

INTRODUCTION

The agricultural sector is considered one of the most important economic sectors in Egypt economy depends on several factors, the most important factors are land, water and labor. El-Beltagy and Abo-Hadeed (2008) reported that the agricultural sector consumes about 84% of the water resources, while USDA 2011 reported that maize is one of the major seed crops in Egypt. It is the most important crops after wheat, which save the daily bread for the population of rural areas. Egypt is number fourteen as the largest producer of maize in the world, producing about 5682 thousand metric tons per year. Maize is grown in a wide range of climates is and one of the most important seed crops in Egypt (after wheat and rice). Moreover, it is used as pharmaceutical and industrial materials besides human food and animal feed. Maize is the most widely grown grain crop; also grain corn represents 55% of the area. Recently, because of high yields and high prices received by farmers, corn became a very profitable crop to grow.

Swelam and Atta (2011) said that surface irrigation (traditional irrigation method) represents about 80% of irrigated areas in Egypt despite lower water application efficiency (45–50%) compared with other methods because of water losses due to deep percolation. Farmers are commonly seen to Excessive irrigation of their fields, which leads to more losses leading to profile drainage, which in turn increases water storage that cannot be taken up by plants. So, irrigation application, throughout the growing season, is important for increasing water use efficiency without more costs.

The agriculture sector is one of the largest water consuming sectors and more than 95% of agricultural output is achieved through irrigated agricultural land. Therefore, water resources are considered the scarcest agricultural productive elements and therefore are considered to be the most important determinants of horizontal expansion.

Maize crop, under bed planting compared to flat basin irrigation, reached 68% greater water productivity, 29% lower irrigation depths with 42% greater grain yield (Shafiq *et al*., 2003). The research aims to decrease the losses in the economic resources of land and water. Used in the production of corn field crops during the agricultural season 2022/2023. In order to achieve this objective, the research examined the loss of economic resources for the crop under study, the agricultural returns of the studied crop and the agricultural returns of the agricultural cycles in the sample of the study in kafrElshekh Governorate during the agricultural season 2022/2023 and study the economic value of irrigation water used in the production of each of the most important field crops and the most important agricultural cycles in the sample of kafrElshekh Governorate during the same season.

Hassan (1998) reported that surface irrigation has low irrigation efficiency to a maximum of 50%, because of more water amount loss through deep percolation, seepage, and evaporation waste canal. In addition, the farmer does not apply to the field but leaves water flowing through a field until reaching the drain at the tail of the field. Also, in many cases, yields actually decrease when excessive water is

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applied. Generally, a surface irrigation system entails one or more of the following shortcomings very low water use efficiency, low net land and very high labor requirement. Karrou et. al., (2012) said that flood irrigation caused the loss of large quantities of water in evaporation and free agricultural drainage. So, about 45 % or more of the water applied is lost in surface runoff and deep percolation. Abd-El-Halim (2013) found that alternate furrow irrigation (AFI) is considered the most effective method to decrease the quantity of water applied under this technique, produce higher productivity, one of the most effective methods to save irrigation water, improve application efficiencies as compared to traditional furrow irrigation method. Rafiee and Shakarami, (2010) reported there was no difference between both alternative and fixed furrow irrigation, as irrigation performance compared with traditional furrow irrigation decreased application of irrigated water rates by 26.2 % and 23.0 %, respectively.

Uniformity coefficient (Uc) and distribution uniformity (Du) increased when inlet discharge increased but acceptable values were achieved for all discharge treatments although the Du (93.10%) and Uc (95.70%) were the highest for 6 m^3/ h inlet flow. Due to the increasing water deficit in root zone, the application efficiency achieved a value of 92.80% for 6 m^3/h discharge, but due to decreasing dried soil content in the root zone, the storage efficiency achieved a value of 94 % for 4.50 m^3/h (Mohammed, 2008). Abdel-Aal (2012) concluded that trickle irrigation, water applied of 100% of ET actual and lateral line spacing 1.4m is recommended for achieving water saving, highest maize crop yield, yield components, water use efficiency and highest net profit.

The objective of the research is determining the performance of alternate furrow irrigation and effect of water deficit by reducing the water applied and developed surface irrigation on the maize productivity and economic return for maize crop.

MATERIALS AND METHODS

The field experiment was conducted in, Sidi Salem city (Mesqa 56 Right Side - Jadallah al-Haddadi's Canal), KafrElshekh governorate Egypt. Located at latitude 31.27^0N, longitude 30.78^0E and 6,1m Altitude during season 2023 to determine the performance of alternate furrow irrigation system and the effect of water deficit by reducing the water applied and developed surface irrigation on seeds yield of maize crop and economic return for maize. Maize was planted on 27 May, with the same agricultural practices as usual in the area planted maize was received for all the treatments Before beginning the experiment, the soil samples were taken from three locations, at the tail, the middle, and the field head, to calculate the soil's physical properties. During the execution of the experimental work, soil samples were collected after irrigations from each furrow, for the calculation of soil moisture content and distribution pattern. The samples were taken at four depths: (0-15 cm), (15-30 cm), (30-45 cm) and (45-60 cm) every 5 meters for each area. Table (1) shows the chemical, mechanical analysis and the bulk density of different depths in the experimental area.

Table 1. Mechanical, chemical analysis and the bulk density of different layers in the experimental area

Depth, cm	Coarse sand, %	Fine sand, %	Silt %	Clay %	Texture	Organic matter, %	CaCo3	Bulk density, gm/cm3
(0-15)	4.67	15.96	17.53	61.84	clay	6.00	3.50	1.11
(15-30)	4.50	14.00	17.50	64.50	clay	5.00	4.00	1.09
(30-45)	4.40	14.50	17.60	63.50	clay	2.00	3.90	1.14
(45-60)	3.00	16.00	16.00	65.00	clay	2.00	3.50	1.14

Experimental design

The treatments were conducted randomly with three replications in a split area design. The developed irrigation system took the main plots, the sub-plots for the alternate furrows treatment, and the sub-subplots for the irrigation quantities treatments. An area was divided into 54 plots each plot contains 6 furrows each 0.60 m wide and 50 m length. The experiment was divided to: -

1- D: Treatments of irrigation system,

D_1: developed surface irrigation (Figure 1).

D_2: traditional irrigation method (Figure 2).

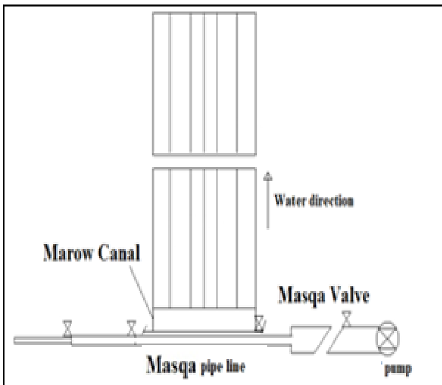

Fig. (1): Layout of the traditional irrigation system

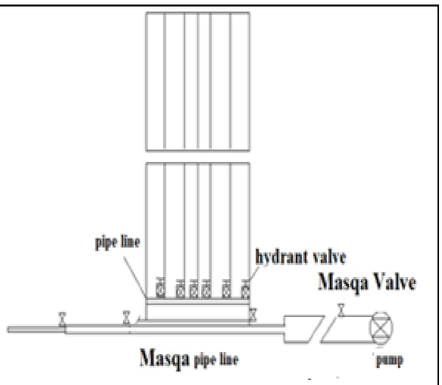

Fig. (2): Layout of the developer irrigation system

2- F: Treatments of Furrows (Figs. 3, 4 and 5).

F_1: irrigated one furrow and left one furrow.

F_2: irrigated two furrow and left one furrow.

F_3: irrigated all furrows (Control).

3- Q: Treatments of applied irrigation water (m^3/fed),

Q_1: 100% ETc. Q_2: 85% ETc. Q_3: 70 % ETc.

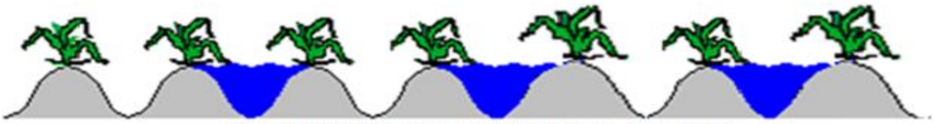

Fig. (3): irrigated one furrow and left one furrow (F_1).

Fig. (4): irrigated two furrows and left one furrow (F2).

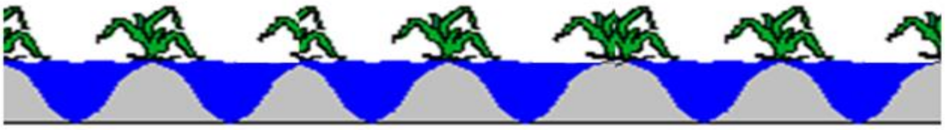

Fig. (5): irrigated all furrows in land (F3).

Infiltration depth

Guirguis (1988) said that infiltration depth is the basic main to evaluate the application efficiency and distribution uniformity. so it is the indicator for selecting the best surface irrigation regime. The basic infiltration rate was calculated by using a double ring.

At the harvest, the productivity of maize (ton/fed) and economic return (EL/fed) were measured and calculated. Every furrow was measured for each treatment, application efficiency of water (Ea), distribution efficiency of water (Ed) and water use efficiency (WUE) were calculated. During the experiment, soil samples were collected two days after irrigation from each furrow to determine soil moisture content and distribution patterns. Also, soil samples were taken just before irrigation to determine soil moisture distribution pattern. The performance of the maize irrigation methods under the variables treatments can be determined using the following confirmed.

The water application efficiency (Ea).

$$Ea = (Stw/Aw) * 100 \quad \text{.....................(1)}$$

Where: -

Ea: Application efficiency of water %.
Stw: Water stored in the root zone.
Aw: Water applied.

Distribution uniformity (DU)

The following equation calculated distribution uniformity according to (Merrian and Keller, 1978)

$$DU = \frac{\text{Average low quarter depth of water}}{\text{Average depth of water}} * 100 \quad \text{.......(2)}$$

Distribution efficiency (Ed)

$$Ed = 1.0 - \frac{\sum |y - d|}{N \times d} \times 100 \quad \text{.........(3)}$$

Where:-

Ed : Distribution efficiency, %.
d : Average depth of stored water.
│y -d│: Average absolute numerical deviation from d.
N : Number of reading.

Applied of water:

Discharge rate of pumping unit was 90 m^3/h measured by 6 inches' flowmeter and measuring gate outflow by measuring the time to fill a certain volume of a tin for all treatments. –

Water use efficiency (WUE)

Awady *et al.* (1976) using the following equation to calculate the water use efficiency:

$$\text{Water use efficiency } (kg/m^3) = \frac{\text{production yield } (kg/fed)}{\text{WaterApplied } (m^3/fed)} \quad \text{.......(4)}$$

Calculation the economic return

The economic variables was expressed in terms of Net return, Return on water unit were calculated using the following equations according to https:// agri .aljeel alm oshreq.com.

$$\text{Net return (LE/fed)} = \text{Total revenue (LE/fed)} - \text{Total cost (LE/fed)} \quad \text{......(5)}$$

$$\text{Return on water unit (LE/m3)} = \frac{\text{Total revenue (LE/fed)}}{\text{Water applied (m3/fed)}} \quad \text{......(6)}$$

$$\text{Rate of return on variable costs (\%)} = \frac{\text{Total revenue (LE/fed)}}{\text{Total variable costs (LE/fed)}} \times 100 \quad \text{.......(7)}$$

RESULTS AND DISCUSSION

Water applied, Yield and Water use efficiency under Control treatments (D1) and (D2)

Effects of the irrigation development (with 100% Etc.Q_1 and irrigated all furrows F_3) on yield and water use efficiency are presented in Table 2. Results indicated that the yield was increased with D_1 treatment, these results may be due to using development decreased moisture content existed at the root depth and then water stresses which will inhibit the root growth. In the plot that used irrigation development, roots grew in suitable moisture data indicated that the yield increased by a ratio of 15.40, and 32.43 % for yield and water use efficiency, respectively, while the application of water m^3/fed decreased by a ratio of 19.49% compared with those in the plot which irrigated with D_2.

Table 2. Effect of irrigation development on water applied, yield and water use efficiency

Treatments of irrigation systems	Applied water (m^3/fed.)	Yield (Ton/fed.)	WUE (Kg/m^3)
D_1	2850	3.175	1.11
D_2	3540	2.686	0.759

Cost of irrigated, Total cost and Net return under Control treatments (D_1) and (D_2)

Effect of the irrigation development (with 100% Etc.Q_1 and irrigated all furrows F_3) on cost of irrigated (LE/fed), Total cost (LE/fed) and Net return (LE/fed) are shown in Table (3). Data indicated that the cost of irrigated (LE/fed.) in the developed plot (D_1) was decreased by 82.11 % compared with treatment (D_2) this may be as a results of reduce applied water m^3/fed. and reduce the energy consumption, while yield income (LE/fed.) increased by 15.32% compared with treatment (D_2) and the net return (LE/fed.) increased by 18.17% compared with treatment (D_2) this may be as results of reduce the cost of irrigation.

Table 3. Effect of irrigation development on the costs and economic return (LE/fed.).

Treatments of irrigation systems	Cost of irrigated (LE/fed.)	Cultivated cost (LE/fed.)	Total cost (LE/fed.)	Yield income (LE/fed.)	Net return (LE/fed.)
D_1	142.50	4890	5032.50	55068.75	50036.25
D_2	796.50	4890	5686.50	46633.50	40947

Effect of treatments D and F on water applied, yield, and water use efficiency for Q1

Data in Table (4) indicated clearly that the applied of water m^3/fed., yield and water use efficiency kg/m^3 were affected by developed surface irrigation (D_1) and using partial root zone drying irrigation technique. It's clear that the yield and water use efficiency were increased with (D_1 F_2), also, data indicated that the yield in the treatment (D_1 F_2) increased by 1.3%, 8.5% and 8.28% compared with treatments (D_1 F_1), treatments (D_2 F_1) and treatments (D_2 F_2) respectively.

Table 4. Effect of irrigation development and alternate furrows irrigation on water applied, yield and water use efficiency

Treatments of irrigation systems	Treatments of cultivated method	Applied water m^3/fed.	Yield ton /fed.	WUE Kg /m^3
D_1	F_1	3095	3.075	0.993
	F_2	3010	3.115	1.034
D_2	F_1	3250	2.850	0.877
	F_2	3130	2.857	0.913

Also, the water use efficiency (kg/m^3) followed the same trend for the treatment (D_1 F_2) increased by 15.18%, 11.7% and 4% compared with treatments (D_2 F_1), treatments (D_2 F_2) and treatments (D_1 F_1) respectively, this may be due to the treatment two furrow were irrigated and one furrow non-irrigated increased the distribution uniformity and application efficiency.

Effect of irrigation of D and F treatments on the economic return per Q1

Data in Table (5) indicated clearly that irrigation development and alternate furrows irrigation on the economic return (LE/fed.) like, irrigated cost (LE/fed.) and total cost (LE/fed.), the data indicated that the irrigated cost in the treatments (D_1 F_2) decreased by 2.82% and 78.63% compared with treatments (D_1 F_1) and treatments (D_2 F_2) respectively. On the other hand, the data indicated that the net return (LE/fed.) in the treatments (D_1 F_2) increased by 1.44% and 10.21% compared with treatments (D_1 F_1) and treatments (D_2 F_2) respectively.

Table 5. effect of irrigation development and alternate furrows irrigation on the economic return LE/fed.

Treatments of irrigation systems	Treatments of cultivated method	Cultivated cost (LE/fed.)	Irrigated cost LE/fed.	Total cost (LE/fed.).	Yield income (LE/fed.)	Net return (LE/fed.)
D_1	F_1	4890	154.75	5044.25	53343.75	48299.50
	F_2	4890	150.50	5040.50	54033.75	48993.25
D_2	F_1	4890	731.25	5621.25	49463.50	43842.25
	F_2	4890	704.25	5594.25	49583.25	43989.00

Evaluation of furrow irrigation efficiencies as affected by the all different treatments.

Application efficiency (Ea) and distribution efficiency (Ed) are shown in Table (6) and fig (6). It is clear that the application efficiency (Ea), and distribution efficiency (Ed) were increased by increasing the discharge rate. Water application efficiency decreased by 5.95% and 16.09% when the 100% ETc decreased to 85% ETc and 70% ETc respectively. Water application efficiency (Ea) and distribution efficiency (Ed) were affected by the interactive furrows irrigation, surface irrigation development and water quantities, the water application efficiency and the distribution efficiency with treatment (F_2) were increased by 18.71% and 9.05% compared with the application efficiency and distribution efficiency with treatment (F_1) respectively.

Table 6. Effect of the surface irrigation development, water quantities and alternative furrows irrigation on average depth infiltration, distribution uniformity, and application efficiency.

Indicators of efficiency and uniformity	Treatments of irrigation systems		Treatments of water applied			Treatments of cultivated method	
	D_1	D_2	Q_1	Q_2	Q_3	F_1	F_2
Average depth of water applied (mm)	70.20	70.20	70.20	59.69	49.16	29.40	46.30
Average depth of water infiltrated (mm)	51.00	56.00	59.00	37.00	26.00	23.00	43.00
Distribution uniformity (%)	82.94	89.33	91.65	86.50	78.95	81.90	93.50
Application efficiency (%)	72.65	79.77	84.05	61.98	52.89	78.23	92.87

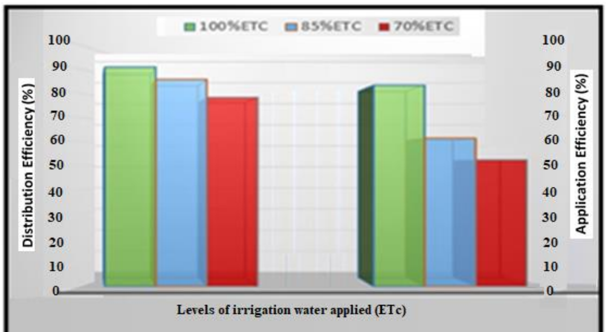

Fig. 6. Effect of levels irrigation water applied (ETc) on distribution and application efficiency

The interaction effect of all treatments (the irrigation systems, partial furrow irrigation and irrigation water quantities) on yield, applied of water and water use efficiency.

Also, the distribution efficiency with treatment (F_2) was increased by 14.16% and 5.85% compared with the water application efficiency with treatment (F_1), respectively. Also, the application efficiency and distribution efficiency were affected by the development of surface irrigation (D_1) whereas, the distribution uniformity and the water application efficiency increased by 7.70% and 9.80% compared with the water distribution uniformity and the water application efficiency in the traditional irrigation (D_2) respectively.

The interaction effect of the irrigation systems, partial furrow irrigation and irrigation water quantities on yield, applied of water and water use efficiency of Maize crop were obtained in Table (7).

Table 7. The interaction effect of the irrigation systems, partial furrow irrigation and irrigation water quantities on yield, water applied and water use efficiency of maize crop.

All Treatments			Water applied (m^3/fed.)	Yield (Ton/fed.)	Water use efficiency kg/m3
D_1	F_1	Q_1	2800	3.195	1.41
		Q_2	2240	3.298	1.47
		Q_3	1960	2.830	1.44
	F_2	Q_1	2690	3.315	1.12
		Q_2	2152	3.458	1.61
		Q_3	1883	2.818	1.50
D_2	F_1	Q_1	3250	2.850	0,88
		Q_2	2600	2.971	1.14
		Q_3	2275	2,776	1.22
	F_2	Q_1	3247	2,857	0,88
		Q_2	2598	2.960	1.14
		Q_3	2273	2.725	1.20
Control	$D_2Q_1F_3$		3540	2.686	0.76

The yield, applied of water and water use efficiency of maize crop were affected by the interaction of the three main variables. The interaction data in Table (7) showed that the highest yield was obtained under treatments (D_1 F_2) with 85% ETc. Maximum value of water use efficiency (WUE) was obtained under treatments (D_1 F_2) with 85% ETc which has the same trend it gave 1.61 kg/m^3. While, the lowest value in water use efficiency under treatments (D_1 F_2) and 100% ETc by value 1.12 kg/m^3. On the other hand, the highest and lowest values of water use efficiency were 0.88 and 1.22 kg/m^3 were obtained under treatments (D_2 F_2) with 100% ETc and (D_2 F_1) with 70% ETc respectively.

The interaction effect of all treatments (the irrigation systems, partial furrow irrigation and irrigation water quantities) on the economic return (LE /fed) of maize crop.

The interaction effect of the irrigation systems, partial furrow irrigation and irrigation water quantities irrigation on the economic return (LE/fed) of maize crops is in Table (8). From Table (8) it is clear that the economic return (LE/fed) of maize crop was affected by the method of irrigation, costs of irrigation were reduced by using developed surface irrigation**,** partial furrow irrigation and irrigation water quantities irrigation it is clear that when using treatments (D_1 F_2) with 85% ETc the costs reduced by 14% compared with control treatment. Also, the net return (LE/fed.) when using treatments (D_1 F_2) with 85% ETc increased by 25.5% compared with control treatment. This may be due to development of irrigation and alternative furrow irrigation reduced the quantity of irrigation water (m^3/fed.) and irrigation cost (LE/fed.).

Table 8. The interaction effect of the surface irrigation development, partial furrow irrigation and irrigation water quantities irrigation on the economic return L.E/fed. of maize crop.

All Treatments			Cultivated cost (LE/fed.)	Irrigated cost (LE/fed.)	Total cost (LE/fed.)	Yield income (LE/fed.)	Net return (LE/fed.)
D1	F1	Q_1	4890	140.00	5030	55413.75	50383.75
		Q_2	4890	112.75	5002.75	57190.50	52187.75
		Q_3	4890	98.00	4988	49117.50	44129.50
	F2	Q_1	4890	134.5	5024.5	57483.75	52459.25
		Q_2	4890	107.6	4997.6	59950.50	54952.90
		Q_3	4890	94.15	4884.15	48910.50	43926.35
D2	F1	Q_1	4890	731.25	5621.25	49600.50	43979.25
		Q_2	4890	585.0	4575	51549.75	46074.75
		Q_3	4890	511.88	5401.8	48186	42784.20
	F2	Q_1	4890	730.58	5620.58	49583.25	43962.67
		Q_2	4890	584.55	5474.55	51360	45885.45
		Q_3	4890	511.43	5401.43	47306.25	41904.82
Control	$D_2Q_1F_3$		4890	796.5	5686.5	46633.50	40947

CONCLUSION

The developed irrigation system using two furrows irrigated and one furrow non-irrigated and 85% ETc achieved high results of net return and then followed by developed irrigation using two furrows irrigated and one furrow non-irrigated with 100% ETc and then followed by developed irrigation using one furrow irrigated and one furrow non-irrigated with 85%.

RECOMMENDATION

The use of developed irrigation instead of traditional irrigation because of its advantage effects on productivity and net income. In addition, the use of developed irrigation with irrigation applied (85%) of total water irrigation with two furrows irrigated and one furrow non-irrigated to irrigate the corn crop.

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العائد الاقتصادى لمحصول الذرة تحت نظام الرى السطحي

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الملخص

أجريت التجربة الحقلية في مدينة سيدي سالم، محافظة كفر الشيخ، مصر، على خط العرض N' $31^0 27'$، وخط الطول E '' $30^0 78''$ و على ارتفاع ٦,١ م خلال موسم ٢٠٢٣ لتقدير أداء نظام الري البديل بالخطوط وتأثير العجز المائي وتطوير الري السطحي على إنتاجية الذرة الصفراء والعائد الاقتصادي للذرة. كانت المعاملات عبارة عن طريقتين للري البديل (خط واحد مروي وخط غير مروي وايضا خطان مرويان وخط غير مروي) مع نظامان للري السطحي (نظام الري المطور ونظام الري التقليدي، مع اضافة ثلاثة مستويات من مياه الري (١٠٠% ، ٨٥%، ٧٠%). أظهرت النتائج أن انتاجية المحصول و كفاءة الاستخدام المائي زادت بنسبة ١٥,٤٠% و ٣٢,٤٣% على التوالي، تحت الري المطور بينما انخفضت كمية المياه المستخدمة (م٣/فدان) بنسبة ١٩,٤٩% مقارنة بتلك الموجودة في الأراضي المروية بالري التقليدي. انخفضت تكلفة الري (جنيه/ للفدان) في الأراضي التي تروي بنظام الري المطوربنسبة ٨٢,١١% مقارنة بالري التقليدي. وارتفع صافي العائد (جنيه/ للفدان) بنسبة ١٨,١٧% مقارنة بالري التقليدي. كما ارتفع انتاجية المحصول في ظل الري السطحي المطور باستخدام خطان مرويان وخط غير مروي بنسبة ٩,٠٩ و ١,٣٠ و ٩,٤٧% مقارنة مع (الري السطحي المطور باستخدام خط واحد مروي وخط غير مروي) ، (الري السطحي المطور مع خطان مرويان وخط غير مروي) و(الري التقليدي باستخدام خط واحد مروي وخط غير مروي) على التوالي. كما سلكت كفاءة استخدام المياه (كجم/م٣) نفس السلوك. كما أدى تطوير الري السطحي المرتبط بالري البديل بالخطوط (اثنان مرويان وواحد غير مروي) ومستوي مياه الري المضافة بنسبة ٨٥% إلى أعلى إنتاجية. كما ان العائد الصافي (جنيه/للفدان) عند استخدام الري السطحي المطور مع باستخدام خطان مرويان وخط غير مروي ومياه الري مضافة ETc ٨٥% زاد بنسبة ٢٥,٤٩% مقارنة بالمعاملة المقارنة.

الكلمات الدالة: الري السطحي، المياه المضافة، العائد الاقتصادي للذرة، الري السطحي المطور .