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Full length article

Impact of modernization surface irrigation on the different efficiencies of irrigating the maize crop

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ABSTRACT

Field experiments for this research were conducted in the northern Nile Delta in Kafr El-Sheikh governorate. the impact of modernization surface irrigation and its performance in the old lands through the modernized of Marwa traditional by replacing them with one of the modernized methods (lined mesqa - buried pipes), this was done by estimating the efficiencies of water application and the rate of increase in crop productivity per unit of water for the most important summer crops (Maize) compared to the traditional irrigation system. The research also includes a hydraulic study of the systems modernized, the results can be summarized as follows average water application efficiencies were 82, 79 and 49 % for buried pipes, lining mesqa and earthen mesqa respectively. Also showed that the average values of the water distribution efficiency through buried pipe and lining mesqa with conventional irrigation methods were 78, 75 and 72 % respectively. It was found that the value of (FWUE) was 1.52,1.36 and 0.99 kg/m³ for buried pipes, lining mesqa and earthen mesqa respectively. The productivity was 3550, 3250 kg/ fed under buried pipes and lining mesqa, it was 2775 kg / fed under earthen mesqa. The result of the hydraulic evaluation of irrigation systems showed that the average values of wetted parameters through different type of mesqas were 2.62, 2.02, 1.60 and 0.6 m Also, showed that the average values of the hydraulic radius were 0.35, 0.22, 0.15 and 0.05 m for Ordinary, Roughness, Lining mesqas and Buried mesqa respectively.

1. Introduction

Under the present economic and increase in humans also because the prospective environmental challenges, Egypt is facing serious water scarcity issue. Water availability per capita rate is already one of the lowest within the world. In 2000, water withdrawal per capita was around 1000 m³. this is often alleged to halve and, hence, fall below the scarcity rate by 2025. Also, renewable water share has been declining from 853.5 m³ (2002) to 785.4 m³ (2007) and reached 722.2 m³(2012). This is often predicted to decrease of 534 m³ by 2030 (FAO, 2014).

Surface irrigation is the oldest and most common method of applying water to croplands (USDA, 2012).

Surface irrigation has evolved into an array of configurations which may broadly be classified as: basin irrigation, border irrigation, furrow irrigation and wild flooding. the excellence between the varied classifications is usually subjective. for instance, a basin or border system could also be furrowed (Ismail et al., 2014)

At got to review water management, particularly in areas with demographic changes and vulnerability to climate, to make sure sustainable and safe water supply. Implications by climate fluctuations should be

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carefully evaluated, covering a wide range of human activity. Water management should address the emerging conflicts between water users by providing primary options and alternatives in distribution and use of water resources while protecting the sustainability of water resources (Tzanakakis et al., 2020)

Water application efficiency provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. water application efficiency may be a measure of fraction the entire volume of water delivered to the farm or field thereto which is stored within the root zone to satisfy the crop evapotranspiration needs. losses from the sector occur as deep percolation (depths greater than required depth) and as field or runoff and reduce the application efficiency (Irmak et al., 2011). Used improved management practices package (land leveling, cultivation on raised beds and irrigation scheduling) are often useful in reducing applied water and soil loss (Zohry et al., 2020).

Application of wide beds under a coffee infiltration soil can produce negative effects on crops within the bed middle thanks to poor lateral infiltration; therefore, convenient management of bed furrow sizes consistent with soil and field conditions has the potential to save lots of irrigation water and increase crop yield and water productivity (Akbar et al., (2017).

Field water uses Efficiency (FWUE) has been the most widely used parameter to describe the efficiency of irrigation in terms of crop yield. Field Water use efficiency (FWUE) is the ratio between economic yield and water applied in season (Howell, 2003).

Canal lining is a method of augmenting water quantity. Lining of irrigation channels can be done in various ways viz: hard surface lining, which includes concrete, stone, ferro cement, bricks, and shotcrete (pneumatically applied mortar), exposed and buried membranes such as butyl rubber, polyvinyl chloride (PVC) and polyethylene, soil linings and soil sealants, like silt, clay, and some chemicals, can also be used for lining (Ahmed et al., 2009).

The main objective of this study was conducted to gauge the system of the On-farm Irrigation Development in Nile Delta Egypt, to develop the surface irrigation and to extend the sector water use efficiency, to maximizing the productivity, raise the efficiency of surface irrigation system.

2. Materials and methods

2.1. Laboratory experiments

A field experiment was carried out during the summer planting season 2021. in the northern Nile Delta in Kafr El-Sheikh governorate in the Dakalt region. Figs. 1, 2 and 3 shows the general layout of modernized surface irrigation and traditional surface irrigation. The study was conducted by studying the impact of modernization surface irrigation and evaluating its performance in the old lands through the development of marwa and mesqa traditional by replacing them with one of the development methods (lined mesqa - buried pipes), to increase the efficiency of using.

To study the impact of modernization surface irrigation and evaluating its performance in the old lands, three fields were irrigated by three different systems with equal areas 27 × 100. The First field which irrigated by buried pipe 280 mm diameter, the second field was irrigated by lining mesqa, 0.4 m width and 0.6 m height, the third field irrigated by earthen mesqa. Three fields were selected for crop maize (Pioneer 30K8) in summer season where maize is considered principal crop in the study area.

2.2. Soil properties

The soil texture of the experimental site according to Black and Hartage (1986) is classified as clay soil as shown in Tables 1, 2 and 3.

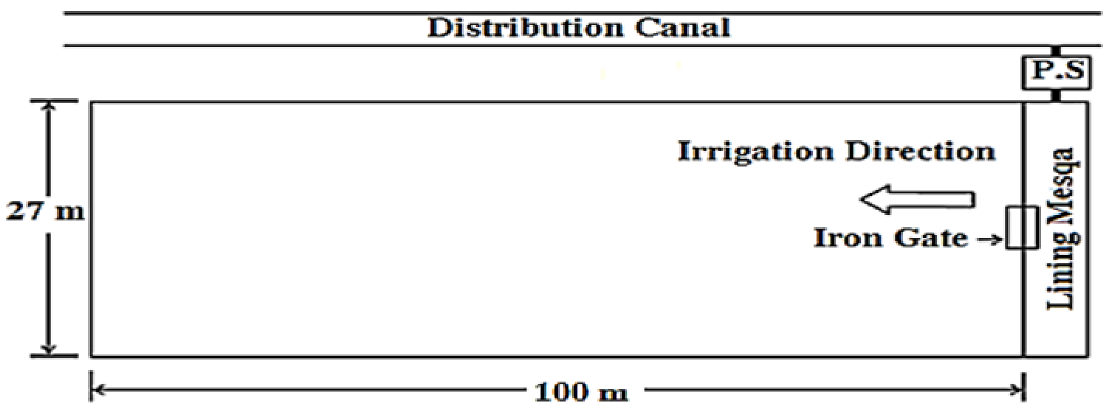

Fig.1. General layout of modernized surface irrigation (lining mesqa) for field (No.1)

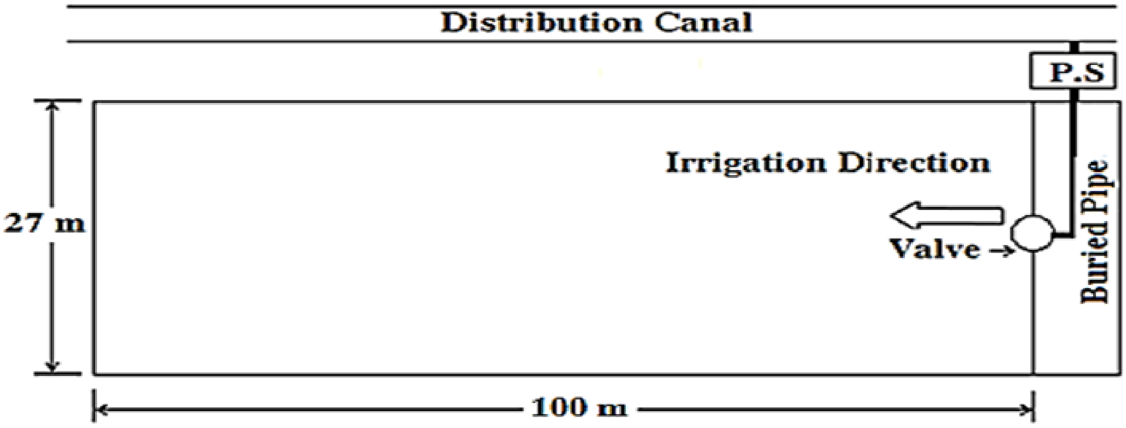

Fig. 2. General layout of modernized surface irrigation (Buried pipe) for field (No.2).

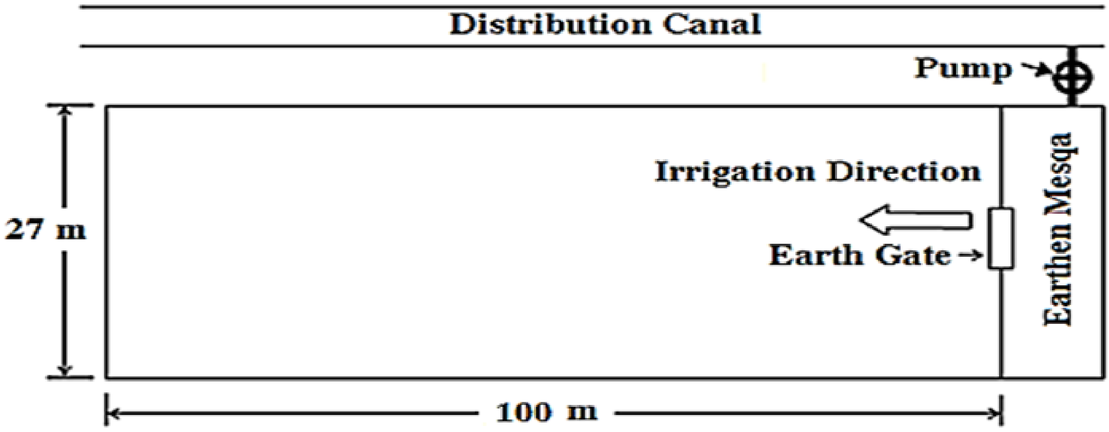

Fig. 3. General layout of earthen surface irrigation for field (No.3).

Table 1
The physical and mechanical analysis of soil, at first experimental field (buried pipes) field (No.1)

Depth (cm)	Mechanical analysis			Soil texture	Field Capacity (%)	Wilting Point (%)	Bulk density (g/cm³)
	Clay	Silt	Sand				
0 - 15	49.99	27.56	22.45	Clay	36.2	17.4	1.12
15 - 30	50.30	27.75	21.95	Clay	38.1	18.1	1.13
30 - 45	52.57	26.86	20.57	Clay	36.5	20.2	1.15
45 - 60	52.95	26.51	20.54	Clay	35.8	19.0	1.17
Mean	51.45	27.17	21.38	Clay	36.65	18.68	1.14

Table 2
The physical and mechanical analysis of soil, at second experimental (lining mesqa) field (No.2)

Depth (cm)	Mechanical analysis			Soil texture	Field Capacity (%)	Wilting Point (%)	Bulk density (g/cm³)
	Clay	Silt	Sand				
0 - 15	52.11	26.21	21.68	Clay	37.1	17.9	1.14
15 - 30	52.23	26.32	21.45	Clay	36.5	18.5	1.15
30 - 45	53.66	25.96	20.38	Clay	36.9	19.8	1.18
45 - 60	53.35	26.44	20.21	Clay	35.2	20.0	1.19
Mean	52.8٤	26.23	20.93	Clay	36.43	19.05	1.17

Table 3
The physical and mechanical analysis of soil, at second experimental (traditional surface irrigation) field (No.3)

Depth (cm)	Mechanical analysis			Soil texture	Field Capacity (%)	Wilting Point (%)	Bulk density (g/cm³)
	Clay	Silt	Sand				
0 - 15	51.81	26.65	21.54	Clay	35.3	18.1	1.18
15 - 30	51.55	26.9	21.55	Clay	37.2	19.2	1.19
30 - 45	53.72	25.75	20.53	Clay	35.6	21.1	1.20
45 - 60	53.13	26.47	20.40	Clay	34.9	22.0	1.17
Mean	52.55	26.44	21.005	Clay	35.75	20.1	1.18

2.3. Modernized surface irrigation

In modernized surface irrigation the field received water from the branch canal through electric pumping unit to the main and branch buried UPVC pipes instead of traditional Mesqa and Marwa. The main line (Mesqa) diameter ranged from 225 to 280 mm and line (Marwa) diameter was 180 mm. The UPVC pipes were connected together using faucet rubber ring jointing system. On branch line there is risers ended by 160 mm hydrant valve. Fig. 4 shows vertical section for buried pipelines.

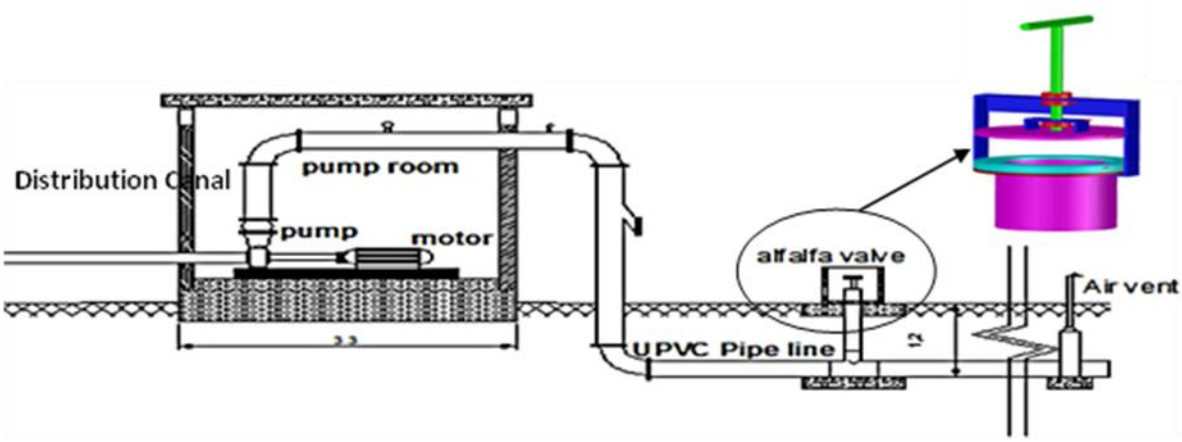

Fig. 4. Vertical section for buried pipelines.

One U-section lining Mesqas were used. It is about raised Mesqas up to the ground. Mesqas aspects and its base of bricks U-section height 40 cm and width 60 cm. The water is lifted to the Mesqas using pumps. The irrigation water come through holes located at the head of each Marwa**.**

Earthen Mesqas receive irrigated water by individual farmer's pumping units. The pump lift irrigation water from the branch canal to convey irrigation water to earthen Marwa by gravity to the field. The area served by a Mesqa is usually 20 to 100 feddan.

2.4. maize variety

principle crop in the study area so, selected for Maize (bayunir 30K8) Single Hybrid White

2.5. Water_application efficiency (WAE)

To evaluate and compare the irrigation systems the soil samples from six points along field and four depths at root zone (0-15, 15-30, 30-45 and 45-60) before and after irrigation were taken. Then the evaluations calculated by the following:

Water application efficiency was calculated from the formula [1] according to FAO (1989):

$$WAE = \left[\frac{WDZ}{WT}\right] \times 100 \quad \text{... [1]}$$

where:

WDZ = Depth of water stored in the root zone, (cm), and

WT = Gross depth of applied water, (cm).

Soil moisture distribution "SMD" was determined according to Liven and Van Rooyen (1979). The soil moisture content was determined using the gravimetric method. SMD was identified directly before irrigation and 48 hours after irrigation. Soil moisture content percentage (S.M.C.) % was determined as a dry weight according to the following formula [2]:

$$SMW = \left[\frac{(W_1 - W_2)}{W_2}\right] \times 100 \quad \text{... [2]}$$

where:
W_1 = mass of the wet soil sample, (g), and
W_2 = mass of the oven dried soil sample, (g), at 105°C for 24 hours.

Formula [3] was used to find the depth of water that entered to root zone (WDZ) during irrigation.

$$WDZ = \frac{(S.M.W_2 - S.M.W_1) \times \rho \times D}{100} \quad ... [3]$$

where:
ρ = specific mass of soil,
$S.M.W_2$ = soil moisture content in the field 48 hours after irrigation, (%),
$S.M.W_1$ = moisture content in the field before irrigation, (%), and
D = root depth, (cm).

2.6. *Water distribution efficiency, (WDE)*

The root depths of the crops were taken as the zone of distribution and were calculated using formula [4] according to Merriam and Keller (1978).

$$WDE = \frac{Zlq}{Zav} \quad ... [4]$$

where:
Zlq = the minimum infiltration depth in a quarter of the total length of the field, (cm), and
Zav = the average of the infiltrated depth, (cm).

2.7. *Field Water use efficiency (FWUE)*

After determining the amount of water applied to crop in the season. Water use efficiency was calculated according to the following formula [5] according to Howell (2003).

$$FWUE, (kg/m^3) = \frac{Yield, (kg/fed)}{Water\ applied, (m^3/fed)} \quad ... [5]$$

2.8. *The buried pipes system calibration and test procedure*

The water uniformity distribution through valves outlets along pipes along its hole length was experimentally tested under field condition through the variation of flow (q_{var}) using equation [1]. On the other hands the pressure head variation (H_{var}) could be determined by equations [2] under the same condition. It was calculated according to the following formula [6] and [7] according to Jensen (1980).

2.9. *The variation of flow through buried pipes system (q_{var})*

Can be determined by:

$$q_{var}(\%) = \frac{q_{max} - q_{min}}{q_{max}} \times 100 \quad ... [6]$$

where:
q_{max} = The maximum outlet flow along the lateral line, (l/h), and
q_{min} = The minimum outlet flow along the lateral line, (l/h).

2.10. *The pressure head variation through buried pipes system (H_{var})*

Can be determined by:

$$H_{var} = \frac{H_{max} - H_{min}}{H_{max}} \quad ... [7]$$

where:
H_{max} = maximum pressure in sub-main, (m), and
H_{min} = minimum pressure in sub-main, (m).

2.11. *Hydraulic evaluation of irrigation systems*

The value of both velocity and discharge through open mesqas were determined as the most important engineering design parameters for the Mesqa and the Marwa.

The velocity was calculated from the following formula [8] according to Khurmi (1982).

$$V = c\sqrt{m.i} \quad ... [8]$$

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{m}}} \quad ... [9]$$

$$m = \frac{A}{P} \quad ... [10]$$

The earthen and lining mesqas were trapezoidal and rectangular cross section respectively, the breadth and depth were calculated from the following formula [11] through [14].

$$A = (b + n\,y)\,y \quad ... [11]$$

$$P = b + 2\,y\sqrt{(1 + n^2)} \quad ... [12]$$

$$A = b \times y \quad ... [13]$$

$$P = b + 2\,y \quad ... [14]$$

where:
V = The velocity, (m/s),
c = The chezy's formula, dimensionless,
m = hydraulic mean depth, (m),
i = bed slope, constant,
K = Bazin constant,
A = area of flow, (m^2),
P = wetted perimeters, (m),
b = breadth of the mesqa, (m),
y = depth of the mesqa, (m), and.
n = side slope, dimensionless.

The discharge was calculated from the following formula [15] according to Khurmi (1982).

$$Q = A.c\sqrt{m.i} \quad ... [15]$$

3. Results and discussions

3.1. Water application efficiency (WAE)

Mostly, water application efficiency is one of the most important criteria used to describe field irrigation efficiency which defined as the ratio of the average depths of the irrigation water stored in the root zone to the average depths of the total irrigation water amount .The average depths of the irrigation water stored in the root zone under buried pipe and lining mesqa irrigation compared with earthen mesqa depending on soil moisture content before and after each irrigation were 36.74, 39.20 and 35.07 cm for different mesqa respectively in season.

Fig. 5 showed that the average values of water application efficiency (WAE) through Buried pipes and Lining mesqa comparing with traditional mesqa were 82, 79 and 49 % respectively during the season. Concerning the effect of mesqas type on water application efficiency (WAE), the results showed that the best water application efficiency (WAE) obtained in case of using buried pipe.

On the other hand, the results showed that increased the average values of the water application efficiency (WAE) in case of using buried pipe and lining mesqa by 33 and 30 % than irrigation traditional mesqa respectively for season.

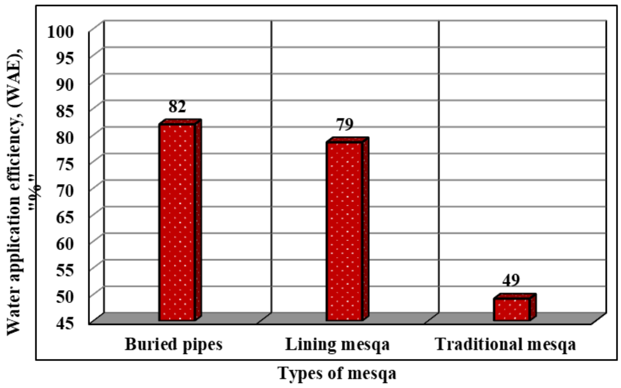

Fig. 5. Water application efficiency affected by different forms of mesqa for season.

3.2. Water distribution efficiency (WDE. %)

Water distribution efficiency indicates the extent to which water is uniformly distribution along the run.

Fig. 6 showed that the average values of the water distribution efficiency through buried pipe and lining mesqa comparing with conventional irrigation methods were 78, 75 and 72 % respectively during season.

Concerning the effect of irrigation systems on water distribution efficiency, the results showed that the best water distribution efficiency obtained in case of using buried pipe.

On the other side, the conventional irrigation methods give a minimum average value of the water distribution efficiency than buried pipe or lining mesqa due to the good uniformity of water application resulting decreased the water losses by both deep percolation and run off and also reduce the time needed to irrigation.

Mostly, as such as results show that water distribution efficiency (WDE) under Buried pipes was higher by 6.99 % and 3.62 % during season as compared to traditional surface irrigation. The differences in (WDE) between improvement and traditional surface irrigation are not great because the root depths of the crops were taken as the zone of distribution in modernized and traditional surface irrigation.

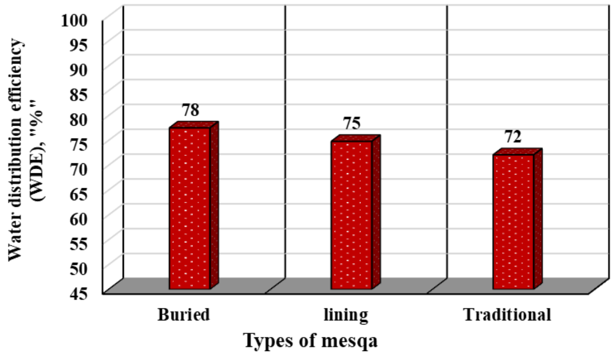

Fig. 6. Water distribution efficiency affected by different forms of mesqa for season.

3.3. Effect of modernized surface irrigation on field water use efficiency

Concerning water use efficiency (WUE) which considered as the evaluation parameter of the capability of converting irrigation water to crop productivity. The (WUE) was considered a tool for maximizing crop production per unit of water amount.

Field water use efficiency (FWUE) considered as an indicator of the capability of irrigation system to converting irrigation water to crop. The (FWUE) was considered a tool for maximizing crop production per each unit of water applied. So, values of (FWUE) for maize were calculated under developed and traditional surface irrigation.

Fig. 7 illustrates the effects of modernized and traditional surface irrigation on maize field water use efficiency. It was found that the value of (FWUE) was 0.99 kg/m^3 under traditional surface irrigation. The value of (FWUE) for crop under buried pipes was 1.52 kg/m^3. Also, it found that the value of (FWUE) in lining mesqa was 1.36 kg/m^3.

From previous results the (FWUE) under developed surface irrigation is higher than that under traditional surface irrigation because of the volume of water applied per feddan in developed surface irrigation less than the traditional surface irrigation and productivity per feddan in developed surface irrigation higher than the traditional surface irrigation so, the (FWUE) under the developed surface irrigation is higher than the traditional surface irrigation.

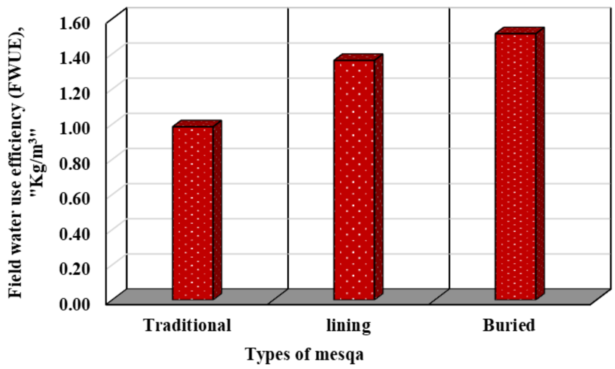

Fig. 7. Field water use efficiency affected by type mesqa for season.

The results revealed that the maximum value of water use efficiency for the irrigation with buried pipes and lining mesqas was achieved due to decrease the water irrigation amount. The minimum value of water use efficiency for irrigation with buried pipes and lining mesqas was achieved due to increase the water irrigation amount and increased the water irrigation losses by deep- percolation and run off as increased the irrigation run. Concerning the effect of using buried pipes and lining mesqas or earthen mesqa on the water use efficiency.

3.4. Crop productivity

The values of the crop productivity of season, for earthen mesqa, lining mesqa and buried pipe were determined actually on the field during as shown in Table 4. The productivity was affected by using modernized surface irrigation as it is high compared with traditional surface irrigation.

The productivity of crop was 3550, 3250 kg/ fed under buried pipes and lining mesqa, it was 2775 kg / fed under earthen mesqa.

Table 4
Effect of earthen mesqa, lining mesqa and buried pipe on crop yield, kg/ feddan.

Types of mesqas		Productivity (kg/fed)	Productivity (ardab/fed)	Percentage of increase (%)
Modernized	Buried pipes	3550	25	22
	Lining mesqa	3250	23	15
Traditional	Earthen mesqa	2775	20	---

3.5. Hydraulic estimation of irrigation systems

The value of both velocity and discharge they are controlling the engineering design of the channels in terms of the speed and volume of water passing through the channels. The results of the measurements of the average values of both velocity and discharge rates through different types of mesqas are shown graphically expressed in Fig. 8 and Fig. 9 to facilitate the discussion. Fig. 8 showed that the average values of the velocity through of mesqas were 0.20, 0.11, 0.36 and 0.22 m/s for Ordinary, Roughness, Lining mesqas and Buried mesqa respectively. Also, showed that the average values of the discharge through of mesqas were 0.18, 0.05, 0.09 and 0.01 m^3/s for Ordinary, Roughness, Lining mesqas and Buried mesqa respectively. Fig. 9 showed that the average values of the watted parimeters through of mesqas were 2.62, 2.02, 1.60 and 0.6 m for Ordinary, Roughness, Lining mesqas and Buried mesqa respectively. Also, showed that the average values of the hydraulic radius through different type of mesqas were 0.35, 0.22, 0.15 and 0.05 m for Ordinary, Roughness, Lining mesqas and Buried mesqa respectively.

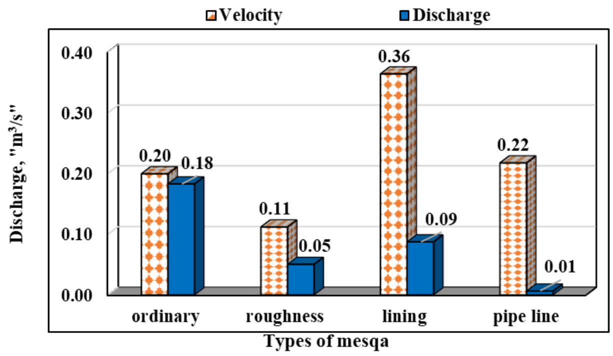

Fig. 8. Effect of modernized surface irrigation system on velocity and discharge.

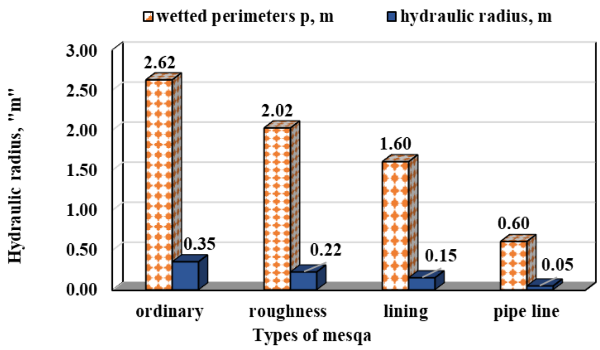

Fig. 9. Effect of modernized surface irrigation system on hydraulic radius and wetted perimeters.

4. Conclusions

- Using modernized systems for irrigating led to increase water application efficiency, without observed reduction in productivity. In addition to the above, from a health point of view, eliminating pathogens, including mosquitoes and snails.
- It is preferable to use the modernized irrigation system instead of traditional irrigation. As the use of traditional irrigation is exposed to environmental pollution as a result of direct between farms and water, and then the use of this developed system provides water that can be directed and used to cultivate alternative spaces. In addition to the above, productivity increases compared to conventional irrigation systems.

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تأثير تطوير الري السطحي على الكفاءات المختلفة لري محصول الذرة الشامية

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الملخص العربي

أجريت التجارب الحقلية لهذا البحث في شمال دلتا النيل بمحافظة كفر الشيخ بمنطقة دقلت، خلال موسم الزراعة الصيفي ٢٠٢١، وذلك بدراسة تأثير تطوير الري السطحي وتقييم أدائه في الأراضي القديمة من خلال تطوير المراوي والمساقي التقليدية واستبدالها بإحدى طرق التطوير (المساقي المبطنة – الأنابيب المدفونة)، وذلك من أجل زيادة كفاءة استخدام المياه وتعظيم الإنتاجية وترشيد استخدام مياه الري وتحقيق التنمية المستدامة للزراعة وتم ذلك بتقدير كفاءة إضافة المياه، وكفاءة استخدام المياه للري، ومعدل الزيادة في إنتاجية المحصول لكل وحدة من المياه لأهم المحاصيل الصيفية (الذرة) مقارنة بالنظام التقليدي للري، كما يشتمل البحث علي إجراء دراسة هيدروليكية للنظم المطورة. **وكانت النتائج على النحو الآتي:**

متوسط كفاءة إضافة المياه كانت ٨٢ و ٧٩ و ٤٩٪ للأنابيب المدفونة والمساقي المبطنة والمساقي الترابية على التوالي. كما بينت ان متوسط قيم كفاءة توزيع المياه من خلال الأنابيب المدفونة والمساقي المبطنة مقارنة بطرق الري التقليدية كانت ٧٨ و ٧٥ و ٧٢٪ على التوالي خلال الموسم. ووجد ان قيمة كفاءة استخدام المياه الحقلية كانت ١,٥٢و١,٣٦ و ٠,٩٩ كجم/م^3 للمواسير المدفونة والمساقي المبطنة والمساقي الترابية على التوالي. كما بلغت إنتاجية المحصول ٣٥٥٠ ، ٣٢٥٠ كجم/فدان تحت الأنابيب المدفونة والمساقي المبطنة ، وبلغت ٢٧٧٥ كجم/فدان تحت المساقي الترابية. أظهرت نتيجة التقييم الهيدروليكي لأنظمة الري أن متوسط قيم قياس المحيط المبتل من خلال أنواع مختلفة من المساقي كانت ٢,٦٢ و ٢,٠٢ و ١,٦٠ و ٠,٦ متر، كما بينت أن متوسط قيم نصف القطر الهيدروليكي كانت ٠,٣٥ و ٠,٢٢ و ٠,١٥ و ٠,٠٥ م للمساقي العادية والخشنة والمبطنة والأنابيب المدفونة على التوالي.