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Optimized Design on Hydrant under Surface Irrigation Systems

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ABSTRACT

The research aimed to modify the traditional hydrant to suit connect with the newly irrigation systems. Through evaluate the performance of the traditional "HT" and modified "HD" hydrants of the surface irrigation system applied in clay soil at KafrAldoar- El-Beheira Governorate. In summer season 2019 by cultivated the corn variety of S.C 2031. Then, the results concluded that the "HD" is shallow less than the "HT" in Zf and Es but great reduction in cv and α. While it is little increase in pd, UC, DU and Ea. The "HD" can saved advance and recession time about39.02 and 29.46%, respectively, compared with "HT" in 80 m furrow length. As it was observed, the water depth reached the recommended depth for corn plants in both hydrants for most of the length of the line, but the depth when using the modified hydrant was slightly less than the traditional hydrant. The yield and WUS increased by using "HD" about 9.07 and 28.61 % than the "HT". But it decreases the water applied about 15.16 %.The recommendation on this research is the modified hydrant can safe to use and can be generalized in the irrigation net under the surface and newly irrigation systems.

keywords: hydrant, water infiltration depth, advance and recession time, distribution uniformity, storage efficiencies, water use efficiency

INTRODUCTION

In light of exposure to water poverty that is trending in the Arab Republic of Egypt, as well as the trend towards increasing agricultural area, and the spread of the surface flood irrigation system, this necessitated the development of irrigation methods. Where can develop the surface irrigation to: (1) basin irrigation; (2) border irrigation; (3) furrow irrigation; and (4) uncontrolled flooding. Also, there are two features that distinguish a surface irrigation system: (a) the flow on a free surface responding to the gravitational gradient; and (b) the on-field means of conveyance and distribution on field surface (Walker, 1989). El-Tantawy *et al.* (2000) signed developed surface irrigation means that using perforated and gated pipe system and precision land leveling.

On the other hands, it must hard work to save irrigation water and raise the water use efficiency. This made it necessary for those working in the field of designing and implementing irrigation networks to use the raw materials and components of the network parts that have the advantages of efficiency in performance adding that increasing the life span and lowering the initial price. They also make continuous efforts that do not stop in order to provide the best raw materials to save irrigation water and the efficiency of its distribution. In this regard, many studies have been carried out, especially in Egypt, for example, through the Surface Irrigation Development Project and international actors such as the World Bank and the French Development Agency have coordinated with the Go E, which was based from its inception on saving water by lining canals and drains through many stages that reached the development and design of many network components, including valves (Ismail (1998); Abo soliman *et al.* (2005), Hassan, *et al.* (2013); Awwad *et al.* (2016) and Said El din *et al.* (2016)).

The conveyance losses in land marwas sited on selected mesqas in Kafr El Shiekh governorate was ranged from 14.47 to 21.36% while in El Bahera governorate these losses were ranged from 13.43 to 21.88%. Concerning the adopting of the marwa lining, the project lined 205.39km length of earth marwa as with farmers' participation in eleven governorate from 1998 to 2005. The data showed that by using the lined marwas the area saved was about 0.6% of total area (Abo soliman *et al.*, 2005). Kotb and Boissevain (2012) said that improved irrigation methods can be used to overcome water shortages at the end and inside the canal. In this way it work to improve water and land productivity. Assist management to the association system-wide water users to take over. Awwad *et al.* (2016) evaluated the effect of modified surface irrigation in old land through improving mesqas (buried pipeline) and marwas of irrigation systems developer which were chosen. They found that the agricultural land which was saved through using buried pipes instead of traditional mesqa ranged from about 2.1 % to 3.7 % with developed surface irrigation systems for mesqa and marwa respectively. Average conveyance efficiency were obtained as ranged from about 91% and more 98% with developed surface irrigation systems for mesqa and marwa respectively compared with 83% through traditional surface irrigation. While the average application efficiencies for irrigation developed systems for mesqa and marwa were ranged from about 61.5 % to 77 % and ranged from about 53 % to 66.4 % during traditional surface irrigation.

The hydrant as a valve is the last part of the components of the developed irrigation network. It is the

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part that appears on the ground surface and is not buried like pipes. Phocaides (2007). FAO (2002) explain that the hydrants were developed to can control in amount and direction of irrigation water. Water can also be diverted into furrows through gated pipes or hoses connected to a hydrant fitted on buried pipes. Conejero *et al.* (2020) and Fernández *et al.* (2016) cleared that in networks, the operating conditions must be considered in the design of such networks. This ensures hydrant service conditions are adequate for the proper of on-field irrigation systems, applying the expected water depth and avoiding inadequate irrigation schedules that lead to inecient use of water. González *et al.* (2014) and Salvatierra *et al.* (2018) said that the hydraulic features of the on-farm irrigation system must also be considered to establish the irrigation programming. These features depend on the type of system (surface, sprinkler, or trickle) and its design (layout) and hydrant operation (sectoring)

Meanwhile, Mohammed (2008) studied the effect of using gated piping system to supply water into furrow, control the inlet discharge, and apply fertilizers with irrigation water. The gate was designed from a gate valve (3.45 cm D.) installed on the pipe orifice using rubber and external flexible hose mounted in front of the valve to control the direction of water. Water uniformity for the furrow irrigation profile was determined using infiltrated water along the systematical furrow lengths. Uniformity coefficient as well as distribution uniformity evaluate the design of irrigation systems. He also, explained that application and storage efficiencies evaluate the design of the system synchronizing with the irrigation scheduling. Application efficiency "Ea" seasonally achieved a value of 92.8, 89.5 and 90.5% by applying 6.0, 4.5 and 3.6 m^3/h inlet discharge, respectively. Osman (2002) reported that, using gated pipes, can saved water about 29.64%, 29.9%, 14.5%, and 19.7% in cotton, wheat, corn and rice respectively compared with traditional (flooding) system.

The main objective of this research is modified design of the hydrant for the surface irrigation systems.

MATERIALS AND METHODS

To realize the research aim, the traditional and modified hydrants were manufacture at 2019 in special workshop (Figs. 1 through 4). The specific dimensions and components of the traditional (Figs. 1 and 2) and modified (Figs. 3 and 4) manufactured to suit local conditions. The both hydrants were designed and manufactured from locally materials that available at Egypt iron material.

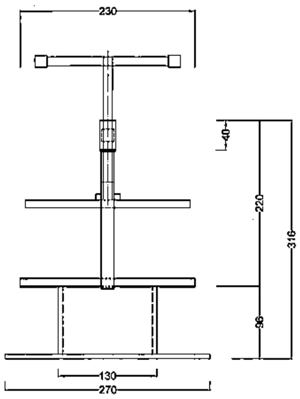

Fig. 1. Schematic diaphragm of a locally traditional hydrant.

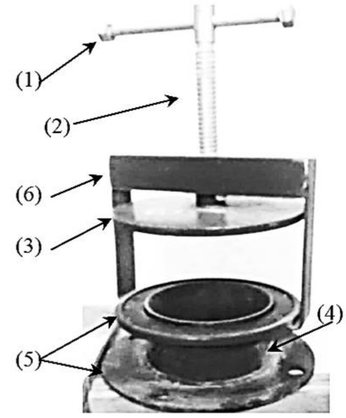

Fig. 2. Plate of a locally traditional hydrant

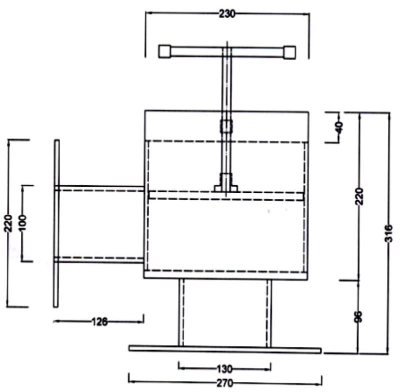

Fig. 3. Schematic diaphragm of the modified hydrant

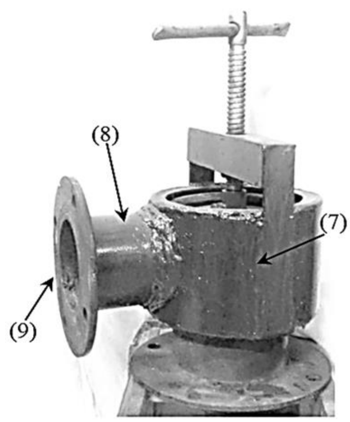

Fig. 4. Plate of the modified hydrant

The main dimensions of the both are; 230 and 316 mm respectively for diameter and body length. They consist of hand "1" connect with screw arm "2" which, supported as a "T" shape. The screw arm carries a floor "3" with a diameter of 220mm and thickness of 20 mm. Two flanges "4" with a diameter of 250 mm were welded upper and lower cylinder "5" has 96 and 130 mm length and diameter respectively. The upper flange carried with the frame "6"shaped like ∩. This hydrant advantage of the transportation efficiency is not less than 98%. This means that it is better than dirt and lined mesqa. But it is inability to connect with a gated pipes irrigation system and to a fertilizer tank. For this the modified hydrant (Figs. 3 and 4) constructed by adding a horizontal pipe (8) welded with chamber (7) (surrounding to the cylinder (4) in Fig. (2) in the traditional hydrant). This horizontal pipe has a length of 120 mm and diameter of 100mm.At the free end of the horizontal pipe the flange (9) was welded to able the different system can use. Some technical operation of the both hydrant were tabulated in table (1) the main dimensions of the both are; 230 and 316 mm respectively for diameter and body length. They consist of hand "1" and screw arm "2" which supported as a "T" shape. The screw arm carries a floor "3" with a diameter of 220mm and thickness of 20mm. Two flanges "4" with a diameter of 250 mm were welded upper and lower cylinder "5" has 96 and 130 mm length and diameter respectively. The upper flange carried with the frame "6"shaped like ꓵ. This hydrant advantage of the transportation efficiency is not less than 98%. This means that it is better than dirt and lined mesqa. But it is inability to connect with a gated pipes irrigation system and to a fertilizer tank. For this the modified hydrant (Figs. 3 and 4) constructed by adding a horizontal pipe (8) welded with chamber (7) (surrounding to the cylinder (4) in Fig. (2) in the traditional hydrant).

This horizontal pipe has a length of 120 mm and diameter of 100mm.At the free end of the horizontal pipe the flange (9) was welded to able the different system can use. Some technical operation of the both hydrant were tabulated in table (1).

Table 1. Some technical operation of the both hydrant

Symbol	Traditional hydrant (mm)	Modifying Hydrant (mm)
Chamber	-	210
Horizontal pipe	-	120
Flange	-	220
Mass (kg)	10.250	16.750
Discharge (m^3/h)	20	20

Experimental procedure

The laboratory experiment was done, at National Laboratory for testing the components of irrigation networks, Agricultural Engineering Research Institute, Egypt (2019), to test and determine the hydraulic characteristics of a modified hydrant. Then the field experiments include the net constructed, water management, corn crop and soil properties.

The field irrigation net constructed as shown in Fig. (5) for 46 feddan, through farm irrigation development project (OFIDO), that follows the Ministry of Agriculture at Kafr Aldoar- El-Beheira Governorate. The constructed net include centrifugal pump, 8/10'' with electrical engine, engine speed of 1500 rpm, engine power of 11.03 kW (15 hp), pump max. discharge of 40 L/s, and max. operating pressure of 15 bar. Table (2) indicated the quantity of main and sub main pipe of UPVC, Number of valves and hydrant. A rectangular shapes crested weir to measure the water advance and recession times. The randomized selected strips test area of 24 × 80 m in three replicates that included for each of modified hydrant under gated-pipe irrigation method and traditional hydrant under free surface irrigation method were identified.

The amount of irrigation water for each treatment was measured by 6 inches flow meter mounted on the pumping unit. The stream of irrigation was cut-off at 90 % of the irrigation run. After that all the agricultural processes for all treatments were the same in quantity.

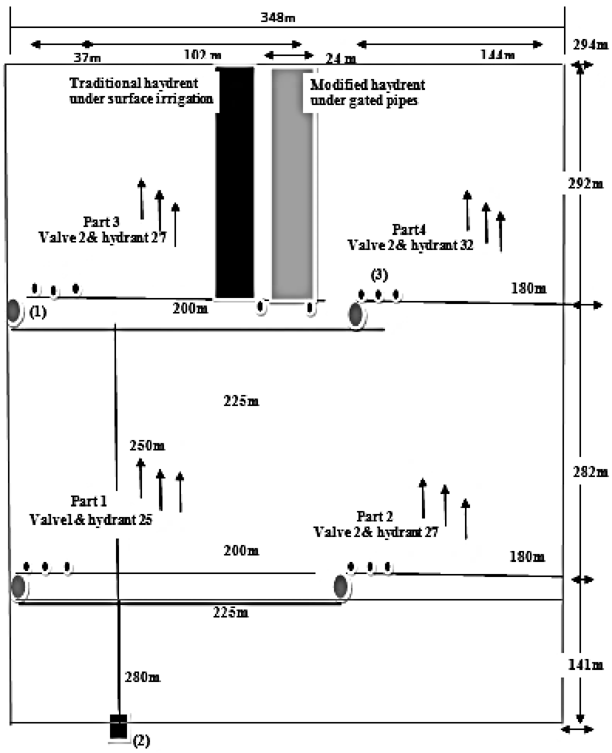

Fig. 5. Layout of the irrigation net
(1) Main valve (2) Pump (3) Hydrant

Table 2. The quantities of main and sub main pipe UPVC, number of valves and hydrant

Part Name	Area served Fed.	Marwa valve dia. (mm)	Diameters of marwas installed (m) 200 mm	180 mm	Total (m)	No. of Hydrants (farmers served) per block	Diameters mesqa installed (m) 280 mm	250 mm	225 mm
1	10.8	150	134	-	134	25	141	282	282
2	11.7	150	11	144	155	27			
3	11.2	150	137	-	137	27			
4	12.3	150	9	148	157	32			
Totals	46		291	292	583	111	705		

Table 3. mechanical analysis for soil located in the experimental site

Depth, cm	Fine sand, %	Silt, %	Clay, %	Texture grade	Bulk density, gm/cm^3	Field capacity, %	Permanent wilting point, %
0 : 30	12.34	32.94	54.72	clay	1.22	42.15	20.37
30 : 60	12.96	33.20	53.84	clay	1.32	41.61	20.02
60 : 90	13.74	31.41	54.85	clay	1.45	39.95	19.89

These areas were cultivated by corn variety of S.C 2031 which produced by Hi-Tech Co. The operations of soil-bed preparation, planting, fertilizing and amount of irrigated water were applied as the recommended.

The field experiments done in clay soil. The soil properties tabulated in table (3) according to Jackson (1967) and (Ali and Mohammed, 2015).

The performance of the two hydrants can determine by the following guides:

Water infiltration: The "Z_f" was measured in the upper of 30 cm above soil surface using double ring infiltrate-meter at beginning of experiment at the site location according to Micheal (1978). The disappeared irrigation depth was recorded with interval time (t). Water infiltration was estimated according to Eq. (1).

$$Z_f = 9.31\, t^{0.46} \text{ , cm} \qquad \text{....(1)}$$

Coefficient of variation: The distribution uniformity was measured at each station (20 m) per furrow length of 80 m. The distribution uniformity can determine by calculating the coefficient of variation (cv, %) as Eq. (2):

$$cv = \frac{s}{Z_f} * 100, \% \qquad \text{....(2)}$$

Where s, refer to standard deviation

Schedule parameter (α): The "α" specifies the deviation of any schedule irrigation depth (d) to average of water infiltration in soil depth (Z_f) in terms of cv and can be calculated approved by Amer (2007) as formulated at Eq. (3).

$$\propto = \frac{1}{cv} * \left(\frac{d}{Z_f} - 1\right) \qquad \text{...(3)}$$

Where: α : range from ±1.725 at optimum irrigation, α ≥ 1.725 in deficit irrigation, and α ≥ −1.725 in excess irrigation (Amer and Amer, 2010),

d: refer to water depth expressing the plant water requirement calculated from ET.

Deficit percentage (PD): The "PD" can be formulated using a linear distribution of water applied by the irrigation system according to Amer and Amer (2010) using Eq. (4).

$$PD = \frac{(1.725 + \propto)^2 * cv}{6.9(1 + \propto * cv)}, \% \qquad \text{.....(4)}$$

Uniformity coefficient (UC): The "UC" can be expressed in power distribution for water infiltrated depth which determined from Eq. (5) as stated by Amer and Amer (2010)

$$UC = 1 - 0.8cv \qquad \text{....(5)}$$

Distribution uniformity (DU): The "DU" determined from Eq. (6) according to Amer *et al.* (2010) as follows:

$$DU = 1 - 1.3cv \qquad \text{.... (6)}$$

Storage efficiency (Es): The "Es" can calculated from Eq. (7)

$$Es = \left(\frac{Vs}{(VFc - Va)}\right) * 100 \text{ , } \% \qquad \text{..... (7)}$$

Where: Vs = volume of water stored in the soil root zone from an irrigation event (acre-inch)

VFc = volume capacity at field capacity in the crop root zone (acre-inch)

Va = volume of water in the soil root zone prior to an irrigation event (acre-inch)

Application efficiency (Ea): The "Ea" was determined from Eq. (8).

$$Ea = 100(1 - Ps) \qquad \text{... (8)}$$

Where Ps, refer to deep seepage percent

$$\text{at "}\alpha = -1.725 \text{ to } 1.725, \; Ps = \frac{(1.725 - \propto)^2 * cv}{6.9}$$

$$\text{"}\alpha\text{"} \leq -1.725, \; Ps = -\propto * cv$$

Water use efficiency (WUE): The "WUE" values were calculated according to Mohammed (2008) as follows:

$$WUE = \frac{yield(kg/fed)}{Applied\ irrigation\ water(m^3/fed)} \text{ , kg/m}^3 \qquad \text{....(9)}$$

Finally, the corn crop yield and the water applied were measured to determine the differences between the performances of used two hydrants.

RESULTS AND DISCUSSION

Some irrigation performance

Table (3) shows the effect of used traditional hydrant "H_T" and the modified hydrant "H_D" on irrigation performance under each of (Z_f), (cv, %), (α), (PD), (UC), (DU), (Es) and (Ea). Through comparing the average of data for most parameters at using the "H_D" is less percentage than "H_T" as Z_f of 12.30%, cv of 63.89%, α of 127.10% and Es of 1.44%. On the other side, some parameters clear the using the "H_D" is more than the "H_T" as a percentage of PD of 22.23%, UC of 6.47%, DU of 11.22% and Ea of 9.67%. These results due to use gated pipe during modified hyant.

Table 4. The performance parameters for the traditional and modified hydrants

Type of hydrant	Z_f	cv	α	PD
Traditional	-63.6228	0.188297	-0.46935	0.047197
Modified	-56.6547	0.114892	0.20667	0.06069
	UC	DU	Es	Ea
Traditional	0.849362	0.755214	95.28	86.8597
Modified	0.908087	0.850641	93.93	96.1614

Advance time

The advance time at using the traditional and modified hydrants are shown in Fig. (6). The relationship between advance time and furrow length under the traditional and modified hydrants had a direct relationship. Generally, the advance time decrease by using the modified hydrant than the traditional per furrow length. For example, the figure clear that at 10 m from the beginning furrow the advance times were 6.0 and 2.5 min for the traditional and modified hydrants respectively. While at 80 m from the beginning furrow the advance times were 82 and 50 min for the traditional and modified hydrants respectively. These mean that about 39.02 % saved in advance time at 80 m from the beginning furrow for the modified hydrant. These results due to increase the distribution efficiency and advance the irrigation water to the end furrow.

The regression analysis declares that the coefficient of termination was (R^2 = 0.923). Also the factors affected the advance time arranged as the analysis of variance as follow: furrow length "L" (p-value = 2.96E-9) < hydrant types "T" (p-value = 0.00016).

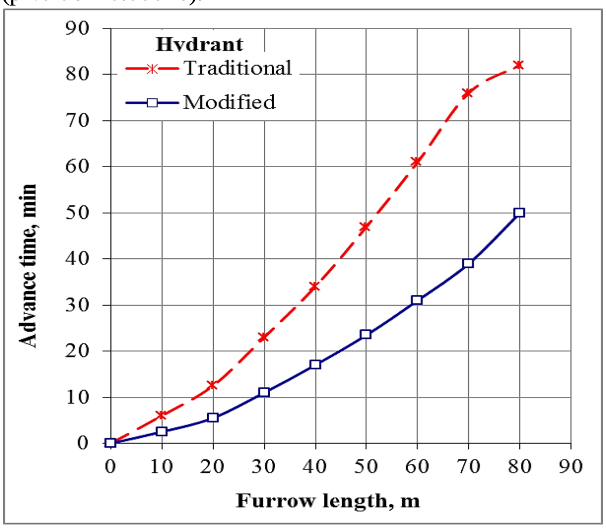

Fig 6. Effect of hydrant types on advance time

Recession time

The recession time as using the traditional and modified hydrants are shown in Fig. (7). The relationship between recession time and furrow length by using the traditional and modified hydrants had linear relationship. The figure clear that increasing the recession time from 90 to 112 min and from 61 to 79 min by increases the furrow length from 0 to 80 m respectively. These mean that about 29.46 % reduction in recession time at using the modified hydrant. These results due to increase the distribution efficiency and advance the irrigation water to the end furrow.

The regression analysis declares that the coefficient of termination was (R^2 = 0.9977). Also the factors affected the recession time arranged as the analysis of variance as follow: hydrant types "T" (p-value = 1.08E-20) < furrow length "L" (= 6.10E-15).

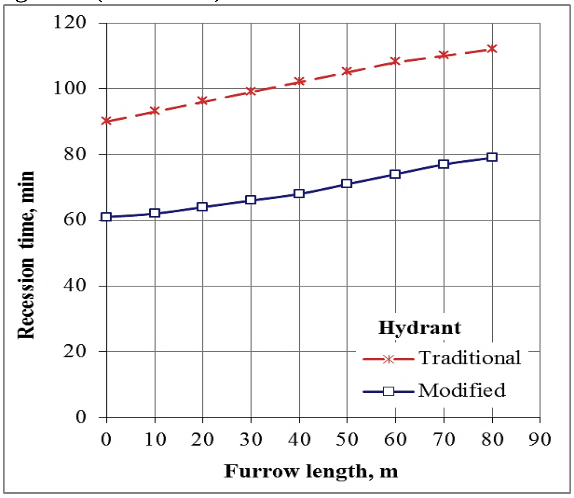

Fig. 7. Effect of hydrant types on recession time

Infiltration depth

The infiltration depth at using the H_T and H_D hydrants are shown in Fig. (8). The relationship between infiltration depth and furrow length using the traditional and modified hydrants had inversely relationship. The figure clears that, decreasing the infiltration depth from -79.56 to -47.68 cm and from -66.37 to -46.94 cm by increasing the furrow length from 0 to 80 m respectively. The recommended infiltration depth for corn crop is -58 cm. These mean that the most of furrow length must be conducted surrounding these recommendations. The data at using the traditional and modified hydrants deviated from -21.56 to 10.32 and from -8.37 to 11.06 respectively. These mean that the modified hydrant can spare suitable recommended infiltration depth which can save each of irrigated water and operating time.

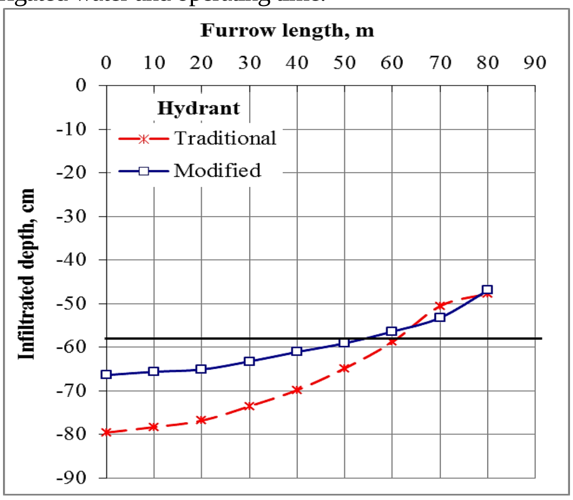

Fig. 8. Effect of hydrant types on infiltration depth

The regression analysis declares that the coefficient of termination was (R^2 = 0.8792). Also the factors affected the advance time may be arranged as the following ascending on relative to analysis of variance as follow: furrow length "L" (the p-value from analysis as P x_2 = 7.93E-8) <hydrant types "T" (the p-value from analysis as P x_1 = 0.0012).

Yield, water applied and WUE

The data in table (5) clear that the comparing values of using the traditional and modified hydrants on yield, water applied and WUS. The data shows that the yield and WUS increased by using the modified hydrant about 9.07 and 28.61 % than the traditional hydrant. But it decrease the water applied about 15.16 %. These results mean that the modified hydrant gave a high uniformity of water distribution, save irrigated water and gave improve of crop yield and WUE.

Table 5. Yield, water applied and WUE for corn crop.

Type of hydrant	Yield kg/fed	Water applied m^3/fed	WUE kg/m^3
Traditional "H_T"	2150	2540	0.846
Modified "H_D"	2345	2155	1.088

CONCLUSION

The research concluded that the modified hydrant "HD" is less shallow than the traditional hydrant "H_T" in Z_f and Es but great reduction in cv and α. While it is little increase in pd, UC, DU and Ea. The "HD" can saved advance and recession time about 39.02 and 29.46%, respectively, compared with "HT" in 80 m furrow length. Then the infiltration depth for the both hydrants around the corn recommended. The yield and WUS increased by using "HD" about 9.07 and 28.61 % than the "HT". But it decreases the water applied about 15.16 %.The recommendation on this research is the modified hydrant can safe to use and can be generalized in the irrigation net under the surface and newly irrigation systems.

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تصميم معدّل لمحبس تحت نظام الرى السطحى

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معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية - دقي - جيزة – مصر

يهدف البحث إلى تعديل محبس (صمام) المياه التقليدي ليتواصل مع أنظمة الري الحديثة. لتقييم أداء الصمام التقليدي "HT" و "HD" المعدل لنظام الري السطحي المطبق في التربة الطينية بكفرالدوار - محافظة البحيرة. في موسم الصيف 2019 تم زراعة صنف الذرة فردي هاي تك 2031. وقد تم خلال التجربة قياس وتقدير كلٍ من عمق تسرب المياه، معامل الإختلاف، معامل الجدولة، نسبة العجز، معامل الانتظامية،انتظامية التوزيع، كفاءة التخزين، كفاءة إستخدام المياه، إنتاجية المحصول، كمية المياه المضافةوكفاءة استخدام المياه لتقييم أداء الصمامين تحت الإختبار. خلصت النتائج إلى أن إستخدام الصمام المعدل "HD" يخفض بدرجة طفيفة قيم Z_f، Es ويخفض بدرجة كبيرة قيم cv، α. في حين يزيد زيادة طفيفة في قيم PD، UC، DU، Ea. كما أمكن التوصل إلى أن إستخدام الصمام المعدل يوفر في وقت التقدم والانحسار للمياه حوالي 39.02، 29.46٪ على التوالي، مقارنة بالصمام التقليدى عند طول خط 80 مترًا. كما لوحظ أن عمق الماء وصل إلى العمق الموصى به لنبات الذرة في كلا الصمامين في معظم طول الخط إلا أن العمق عند إستخدام الصمام المعدل أقل من التقليدى بدرجة طفيفة. أظهرت النتائج أيضاً زيادة كلٍ من المحصول وكفاءة إستخدام المياه بنسبة 9.07، 28.61٪ عند إستخدام الصمام المطور مقارنة بالصمام التقليدىفى حين تنخفض كمية المياه المضافة بنحو 15.16٪. لذا يمكن التوصية بإمكانية إستخدام الصمام المعدل بشكل آمن كما يمكن تعميم إستخدامه في شبكات الرى السطحى وأنظمة الري الحديثة.