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DESIGN AND MANAGEMENT OF MODIFIED PIVOT IRRIGATION SYSTEM

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ABSTRACT

The main objectives of this study are to modify pivot irrigation system to be more suitable to irrigate trees, and other crops under special conditions, to evaluate the modification system and to reduce the investment costs of the modified system. Center pivot modification depends on replacing the sprinkler heads (sprayers) by polyethylene hoses ending by nozzles. Field experiments were conducted at the Experimental Farm of Faculty of Agriculture, Ain Shams University, to modify sprinkler pivot to work as a moving surface irrigation system. Two different nozzle shapes were selected (trapezoid and triangle) with two different hoses length (25 and 200 cm). Pilot area was divided into two halves; the first was straight furrows, while the second was round furrows as well as concentrated with track of pivot wheels. Maize crop was planted under pivot system. Results showed that the modified pivot system was operated at low pressure head (1.95 bar), irrigation water was decreased by (16.8%) compared to sprinkler pivot system, the uniformity coefficient for triangle form was 91.6%, pulled hoses (200 cm) were better than the short hoses. On the other hand, water use efficiency with modified pivot system was (2.5 kg/m^3), while it was (1.84 kg/m^3) with sprinkler pivot system and the modified pivot system reduced the hazard of chemigation. The investment cost of the modified system was reduced compared with sprinkler pivot system with little energy required for the modified pivot system. There's no significant difference between the two methods of furrow on grain yield of maize.

Keywords: Sprinkler irrigation, Water requirements, Maize, Energy and costs

INTRODUCTION

Egypt is mainly an agricultural country in which irrigation technologies play an important role in supporting national economy. Irrigation water consumes about 85-88% of the country's water budget for cultivating approximately 8 million feddans with an annual crop area of about 15 million feddans.

Developed irrigation systems are very important for sustainable agriculture,

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sprinkler irrigation system is one of the most important modern irrigation systems especially in new reclaimed areas, but in special cases, this system needs to be modified to be more suitable for this region. **Helweg, (1989)** suggested modifications to decrease instantaneous application rates are only suitable for row crops. The traveling trickle system designed for grain crops showed promise of being more efficient. On the other hand, **Wilmes *et al* (1993)** reported that, center pivot systems can be one of the most efficient and uniform method of applying irrigation water if the system is properly good designed and managed, also **Broner, (2002)** reported that, high-pressure to low-pressure conversion, a change from high-pressure to low-pressure systems, if done properly reduces pumping costs. However, low-pressure systems require sprinkler heads (water-emitting devices) that usually have a smaller radius of throw that results in higher instant application rates. Higher application rates for lower pressures is the main trade-off between high- and low-pressure systems. However, there are several other factors to consider if you change from high to low-pressure systems or to LEPA systems.

MATERIAL AND METHODS

Modification of pivot system

The basic modification of pivot system depended on replacing the sprinkler heads by polyethylene hoses which can be operated at low pressure (1.5-2.0 bars). A technique characters of simple pivot at the Experimental Farm, Faculty of Agriculture, Ain Shams University (clay loam soil), for a single tower center pivot irrigation system (48 m radius, 127 mm outer diameter of lateral line, 3mm thickness of pipe and 75cm space between sprinklers) according to handbook of pivot technique characters.

For that, it's clear that pressure head reduces along lateral line of pivot causes of friction losses. According to dynamic equal, we can see the reserve relationship between velocity of water flow and section area of water exits (nozzles). For modification of sprinkler pivot system, it was carried at the following steps:

1. Determination hose diameters

From continuing equation:

$$Q = C^* A^* V \text{ ------------- -- } (1)$$

$$\because A = (Q / C^* V) \quad \text{and} \quad A = \pi D^2 / 4$$
$$\therefore \pi D^2 / 4 = (Q / C^* V)$$

$$D = (4Q / \pi C^* V)^{0.5} \quad \text{---- --- } (2)$$

Where: "Q" is Water flow thruogh hoses (m^3/sec.), "A" is section area of hoses (m^2), "C" is discharge coefficient and equal 0.7, "V" is velocity of water flow (m /sec) and "D" is inside diameter of outlets (mm).

From dynamic energy of water equals:

$$V = (2gh)^{0.5} \text{ ---------------- } (3)$$

Where: "g" is gravity acceleration (9.81 m/sec^2) and "h" is outlet pressure head (m).

From equation (2) and equation (3) can be determined the diameter of outlets as follows:

$$D = (4Q / \pi C (2gh)^{0.5})^{0.5} \text{ ---(4) or}$$

$$D = 536.3 [Q^{0.5} / h^{0.25}] \text{ ------ } (5)$$

This equation uses under boundary conditions ($Q > 0$ and $h > 0$).

2. Determination pressure head and friction losses

It's important to mention that wanted discharge is assumed in this study is 0.5 l/s, while the pressure head was measured at each delivery. And friction losses were calculated using **Darcy–Weisbach** equation at $2000 < Re < 10^5$ because Reynolds number (Re) in this study equals:

$$\because Re = \rho \, v \, D / \mu \quad \text{--------} \; (6)$$

$$Re = (1000 \times 10.4 \times 0.025) / (60 \times 0.001) = 4.354 \times 10^3$$

$$\therefore hf = k \, (Q^{1.75} D^{-4.75}) \, L \quad \text{-------} \; (7)$$

Where: "hf" is friction head losses (cm), "**D**" is inside diameter (mm) for pipe less than 128 mm diameter, "**K**" is 7.89 x 105 for SI units and for water temperature at 20 °C, "**Q**" is flow within pipeline (l/s) and "**L**" is length of pipeline (m).

Theoretical calculations using equation (5) to calculate the diameter of outlets showed that change of the inside diameter of hose is very small (0.02, 0.03, 0.04 and 0.05mm). The calculated diameters have very small changes which are not available at the markets. Therefore, to design the modified pivot outfitting using the available materials at local markets, must make the following two steps:

1. Reducing the diameter to be suitable for calculated diameters.
2. Obtaining small change of calculated diameters.

The experimental calculations begun by selecting five categories of hoses have inside diameters (10.5, 11, 11.5, 12 and 12.5mm) or cross section area of 86.5, 95, 103.8, 113and 122.6mm^2. From the calculated diameters to be carried out the following:

a- Outfit design of modified pivot

Outfit which design contrasts inside hoses which also constructed at lateral line of pivot at sprinkler places by using barbed. The modified pivot outfits construct from excavated cylinder of wood to allow to water inflow pass at limited area which calculated,

b- Basic components of modified pivot outfits

1. Polyethylene hose (20 mm outer diameter),
2. Hose connection (barbed: 3/4"/ 20 mm diameter).
3. Cylinder of wood stick (19 mm outer diameter).

c- Form and cross-section area of hole outlets

Two forms of cross-section area of hole outlets were selected in this study. Outlets are excavated along the stream of wood stick cylinder according to designed areas. These forms are shown in Fig. (1).

1. Trapezoid plus segment of a circle

From experimental calculations, this form is produced depends on excavated linear tunnel at cylinder of wood to give the wanted section area by changing of trapezoid rise (L=4, 5, 6, 7 and 8mm) and down base of trapezoid. Calculation the gradually area of trapezoid plus segment of a circle as follows:

$$A_T = A_t + A_C \quad \text{-----------} (8)$$

$$A_C = 2/3(a\ b \times e\ f) \quad \text{---------} (9)$$

$$A_t = ((a\ b + c\ d)/2)\ L \quad \text{--- --} (10)$$

Where: "A_T" is total area of the water outlet (mm^2), "A_t" is cross section area of trapezoid (mm^2), "A_C" is cross section area of segment of circle (mm^2), "a b" is string of circle of stick wood section (base of trapezoid), (mm), "c d" is the down base of trapezoid (mm) and "L" is altitude of trapezoid (mm).

2. Triangle plus segment of a circle

The experiments appear that suitable change for previous gradually diameters were obtained also by changing of central angle. Where, the changeable area can be obtained from relationship between central angle changing and area changing. The rate of central angle change was 10 degrees, beginning with (100, 110, 120, 130, and 140 degree). Calculation the gradually area of triangle plus segment circle as follows:

$$A_1/\theta_1 = A_2/\theta_2 \quad \text{-------- ----} (11)$$

$$A_{cn} = (\theta_n/360) \times A_t \quad \text{---- -- ---} (12)$$

Where: "A_{cn}" is cross section area of triangle plus segment circle (mm^2), "θ_n" is central angle (degree) and "A_t" is cross section area of outlet (mm^2).

3. Diameter category distribution at pivot lateral line

Five categories of outlets section area were used in this study (86.5, 95, 103.8, 113 and 122.6 mm^2) and distributed along the pivot lateral. So, outlets have the first category (86.5mm^2) were constructed at beginning of pivot lateral, then the next category of arrangement of outlets appears according to friction losses and water outlet position at pivot lateral as driven in the following equations:

$$H_i = H_a + h_{fr} + \Delta Z + h_r + h_{cv} \quad \text{---} (13)$$

$$H_d = H_i - (hf + \Delta Z + hr) \quad \text{----} (14)$$

$$A_d = A_i \ (H_i / H_d)^{0.5} \quad \text{------ ---} (15)$$

Where: "H_i" is pressure head at lateral beginning (m), "H_a" is rise of pivot tower above the soil surface (m), "H_d" is pressure head of lateral at the next outlet (m), "h_{fr}" is head losses at lateral (m), "ΔZ" is difference of lateral elevation (m), "h_r" is rise of outlet (m), "h_{cv}" is total of secondary losses of connection parts (m), "A_i" is area of the first outlet (mm^2), and "A_d" is area of the next outlet (mm^2).

4. Hose lengths

For two nozzle shapes, there's two lengths of hose were fixed; the first length is 25 cm and suspended at 75 cm from soil surface, while the second length is 200 cm and pulled at soil surface as shown in Fig. (2)

5. Uniformity coefficient evaluation of modified center pivot

22 from 45 outlets along the pivot lateral were selected for determination water distribution uniformity of modified center pivot. Samples were taken by received water application at gradual container during period from the time according to (**Keller and Karmeli, 1975**).

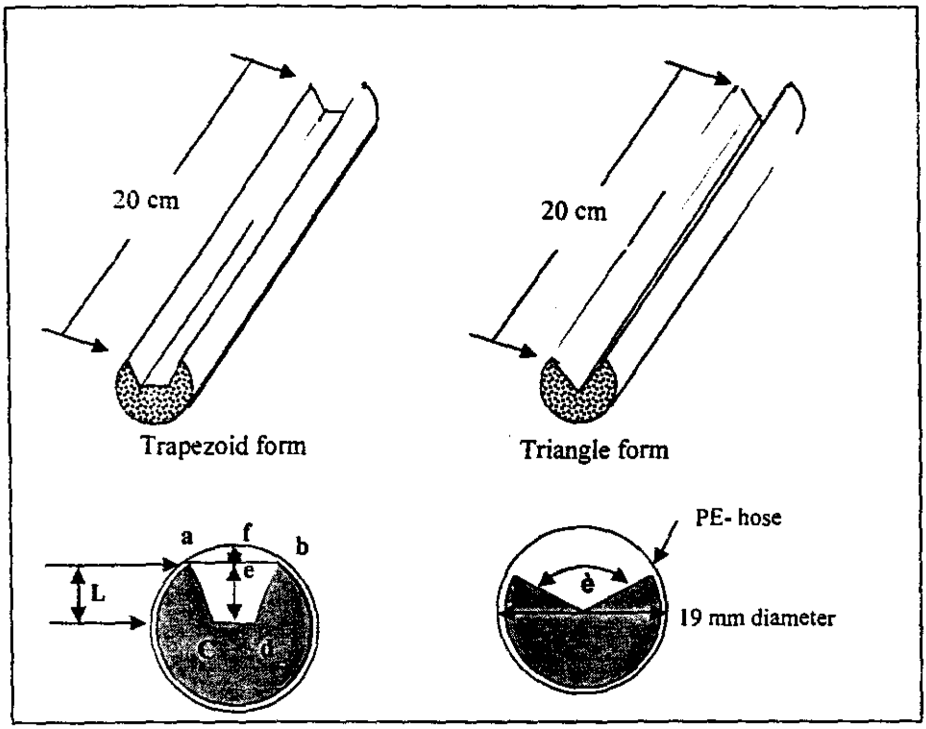

Fig. 1. Two forms of the outfits

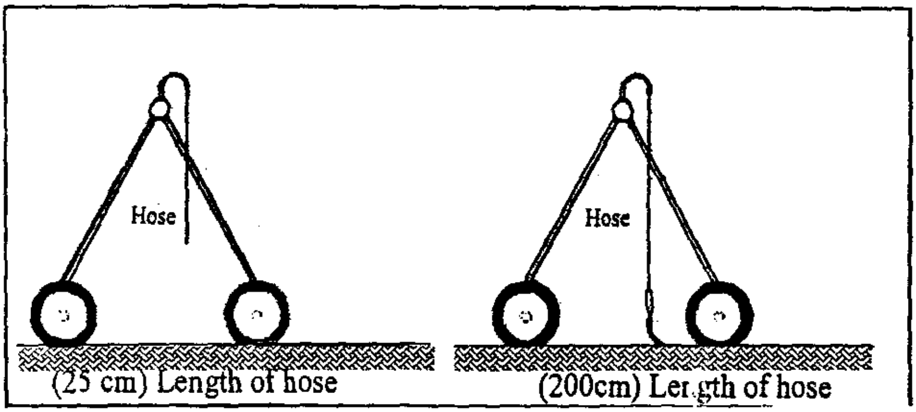

Fig. 2. Two lengths of hoses

For reducing experimental error, discharge was measured four times. Uniformity coefficient was calculated according to (**Bralts *et al* 1987**).

$$Uf\ \% = 100[1-(\Sigma\ Q_d\ /N\ Q_x)\ ] \text{ ----- } (16)$$

Where: "Uf" is uniformity coefficient (%), "Q_d" is absolute deviation of each sample from the mean discharge (l/s), "Q_x" is the mean of outlets discharge (l/s), and "N" is number of measurements.

6. Field Experiment

1. Experimental site

Zea maize (single cross No.10) was planted under modified pivot system using triangle plus segment of circle with hoses length of 200cm at the Experimental Farm of Agriculture Faculty, Ain Shams University (clay loam soil). Some properties of soil and irrigation water are presented in Tables (1 and 2). The last crop is clover. The furrow space was 70 cm and the plant space along furrow was 25 cm.

2. Soil preparation

Soil was ploughed twice and ridged by two methods; first one is traditional method (straight furrows) and second method is round furrows with track of pivot wheels as shown in Fig. (3).

3. Irrigation requirements

Irrigation water requirement for maize was applied weekly and calculated using the weather data at El-Kanater Weather Station as follows:

a- Crop consumptive use was calculated according to **Doorenbos and Pruitt, (1977)**

$$Et_c = Et_0 \times K_c \text{ ----------------- } (17)$$

Where: "Et_c" is crop consumptive use (mm/day), "Et_0" is reference evapotranspiration (mm/day) and "K_c" is crop coefficient (dimensionless) for maize was used according to **FAO, (1984)**

b- Irrigation requirement was calculated according to **Vermeiren and Jobling, (1980)**

$$IR = (Et_C\ (1+LR) \times 4.2/E_a) \times I \text{ ----- } (18)$$

Where: "IR" is irrigation requirement (m^3/fed/ Irrigation), "LR" is leaching requirement (%) and equal $EC_i/2EC_d$, "EC_i" is salinity of irrigation water (dS/m), "EC_d" is salinity of drainage water (dS/m), "Ea" is application efficiency (%) and "I" is irrigation intervals (days).

4. Irrigation management

Irrigation scheduling under pivot irrigation system depended on velocity percentage of towers moving, amount of applied water, modified pivot discharge and irrigated area, therefore, irrigation scheduling for pivot was calculated by using the following relationships:

$$Ti = \frac{AW}{Q} \text{ ------ ---- } (19)$$

$$vi = \frac{\pi\ D}{Ti} \text{ --------- } (20)$$

$$v\% = \frac{vi}{vmax} \text{ ------ } (21)$$

Table 1. Some physical properties of soil

Soil depth, (cm)	Partial size distribution, %				Texture class	F C (%)	PWP (%)	Bulk density (g/cm^3)	WHC (m/m)	Hydraulic Conduct. (m/s)
	Course sand	Fine sand	Silt	Clay						
0 – 30	3.3	35.2	21.2	40.3	C. L.	29	17	1.26	151	$4.1x10^{-6}$
30-60	2.4	22.8	22.8	41.9	C. L	30	19	1.40	154	$5.3x10^{-6}$
60-100	4.0	30.5	26.0	39.5	C. L	28	18	1.45	145	$4.7x10^{-6}$

F C: Field capacity, PWP: Permanent wilting point, WHC: Water holding capacity and C.L: Clay loam. Field capacity and permanent wilting point were calculated based on weight.

Table 2. Some chemical properties of irrigation water

pH	EC dS/m	SAR	Soluble cations, meq/l				Soluble Anions, meq/l			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	$CO_3^=$	$SO_4^=$	Cl^-
8.0	1.1	4.21	1.72	0.85	4.78	0.85	2.18	-	0.14	5.88

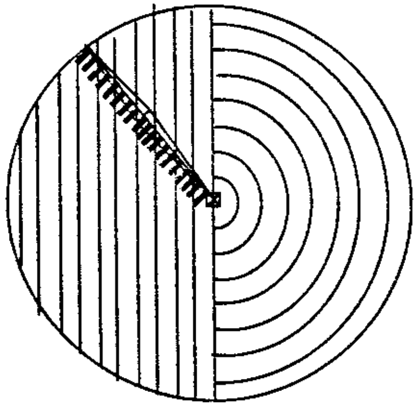

Fig. 3. Traditional furrow and round furrow

Where: "**Ti**" is irrigation time (h), "**AW**" is amount of water applied, "**Q**" is pivot discharge (m^3/h), "**D**" is diameter of pivot lateral (m), "**vi**" is pivot velocity (m/h), "**vmax**" is maximum velocity for center pivot (m/h) and "**v %**" is velocity percentage for center pivot (%).

5. Fertilization program

Phosphorus fertilizers were added by traditional method during the soil preparation with rate of 250kg/fed of super phosphate (15.5% P_2O_5) according to the recommendation of Field Crop Department, ARC, Ministry of Agricultural and Land Reclamation for maize, nitrogen fertilizers were 300kg/fed of Ammonium Nitrate (33% N) which divided into six doses each of about 50 kg/fed of Ammonium Nitrate and 100 kg/fed. of potassium sulphate (48% K_2O) were divided into two doses. Nitrogen and potassium fertilizers were injected through pivot system.

6. Measurements and calculations

1. Crop yield

Crop samples were taken by selecting three areas (0.5m x 1.4m) for each treatment, the distance of area samples is 16 m starting at the one third center of pivot lateral and finishing at the lateral end of pivot. Each sample contained 9 plants and three samples were taken at traditional and round furrow. Total grain yield (Mgram/ha.) and water use efficiency (kg grain/m^3 water) were determined after 110 days from planting when the mean moisture of kernel was 16.4%.

2. Energy requirement

Energy requirement and energy applied efficiency (**EAE**) were determined for modified pivot according to **Batty *et al*** **(1975)** using the following formula:

a- Power consumption use for pumping water (B_p) was calculated as follows:

$$Bp = \frac{Q * TDH * Yw}{E i * Ep * 1000} \text{ ------- } (22)$$

Where: "**Bp**" is power consumption, (kW), "**Q**" is total system flow rate,m^3/h, "**TDH**" is total dynamic head, (m), "E_i" is total system efficiency ,(%), "E_p" is pump efficiency, (%), and "Y_w" is water specific weight (taken as 9810 N/m^3).

b- Pumping energy requirements (E_r) (**kW.h/ha**) was calculated as follows:

$$E_r = B_p * H \text{ ---------------- } (23)$$

Where: "**H**" is irrigation time per hectare throghout the growing season (h/ha).

c- Energy applied efficiency was calculated as follows:

$$EAE = Y / E_r \text{ ---------------- } (24)$$

Where: "**EAE**" is energy applied efficiency (kg/kW.h), "**Y**" is total grain yield (Kg/ha), and "**Er**" is energy requirements (kW.h/ha).

3. Cost analysis

Cost analysis to evaluate the modified pivot system and it was computed according to **Worth and Xin (1983)**. Total irrigation costs are calculated according to market price levels of 2004 for equipment and operating irrigation process and on based the pivot irrigated 63 hectares.

RESULTS AND DISCUSSION

Modification of sprinkler pivot system to be more suitable to irrigate different crops is required to redesign some parts, specially the water outlets (nozzles) to improve irrigation efficiency after modification.

1. Evaluation uniformity of modified pivot

Data are presented in Table (3) showed that mean results for total discharge of pivot, outlets discharge, pressure head at outlets, and uniformity coefficient of applied water application.

a- Trapezoid form (hoses length 25 cm and 200 cm)

Data illustrated in Table (3) and Fig. (4) showed that, water distribution of outlets is nearly constant and uniformity coefficient is high. It was 92.5% and 87.8% for hoses length of 25cm and 200cm respectively, which is considered excellent and good according to **Merriam and Keller, (1978)**. Also, results showed that the mean total discharge for hoses length (25 cm) of modified pivot was 48.6 m^3/h, and the mean discharge of outlets was constant 0.3 l/s, while the mean total discharge of modified pivot had hoses length (200 cm) was 40.5m^3/h, and the mean discharge of outlets 0.25 l/s. On the other hand, the deviation of pressure head from the mean ranged between (0.1- 0.4m) for hoses length of 25cm and (0.2-0.6m) for hoses length of 200 cm as shown in Fig. (5).

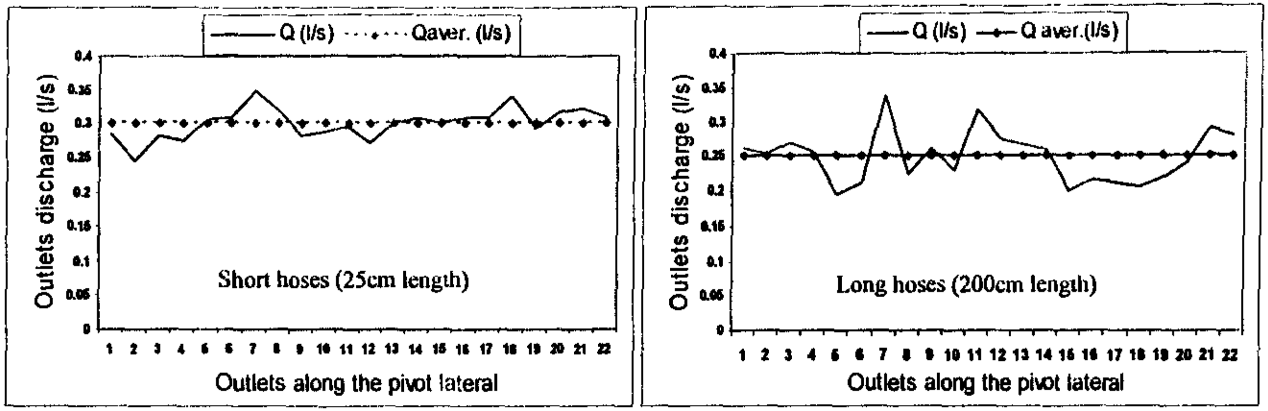

Fig. 4. Deviation of outlets discharge (Q) from the mean discharge (Q_{aver}) at trapezoid form

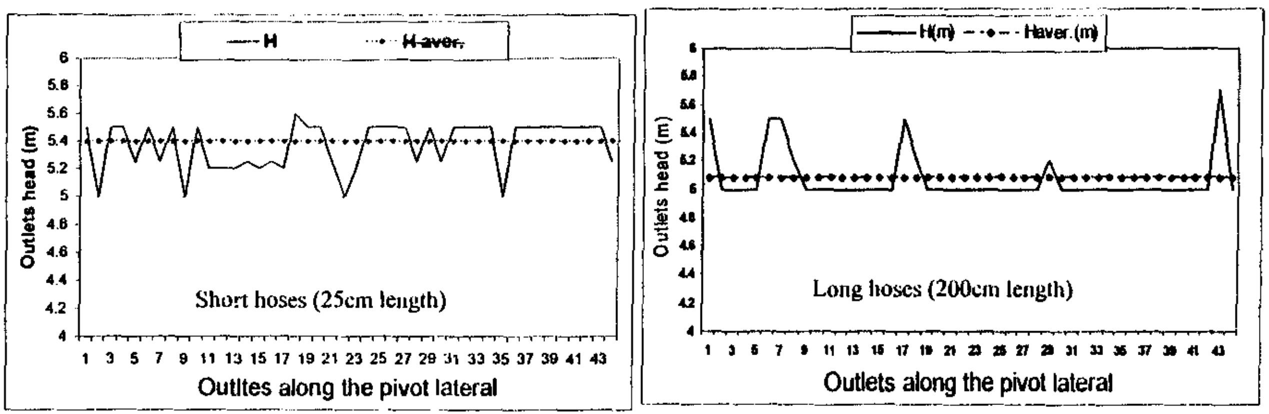

Fig. 5. Deviation of outlets pressure head (´H) about the mean pressure head (H_{aver}) at trapezoid form

b- Triangle (hoses length of 25 cm and 200 cm)

Data illustrated in Table (3) and Fig. (6) showed that, water distribution of outlets is nearly constant. Uniformity coefficient is higher than that under trapezoid form, it was 93 % and 90.7 % for hoses length of 25 cm and 200 cm respectively. This uniformity is excellent according to **(Merriam and Keller, 1978)** for both hoses length.

Regarding the mean total discharge for hoses length of 25cm. Data indicated that, mean total discharge of modified pivot was 52.3 m^3/h and the mean discharge of outlets was 0.33 l/s, while the mean total discharge for modified pivot had hoses length of 200 cm was 48.6 m^3/h, and the mean discharge of outlets was 0.3 l/s. The difference between mean nozzle discharges for all of simple pivot due to experimental error which result to difference of discharge measurements for both of them. On the other hand, results showed that the deviation of pressure head from the mean ranged between (0.3 - 0.5m) and (0.3 - 0.7m) for hoses length of 25 and 200 cm respectively as shown in Fig. (7).

Generally, results indicated that the deviation of outlets discharge from the mean discharge along pivot lateral may be due to experimental error. Also average pressure head of water outlets is equal to 5m and it's nearly constant along pivot, where the deviates ranged between 0.25 to 0.5 meter. Beside, the deference between the two lengths of hose does not affect on uniformity or pressure head along the lateral. The hoses which have 200 cm length are better compared with others (25cm length), because the short hose is a basic reason of soil erosion beside it's not favorite to apply water for plant causes some fungi diseases.

On the other hand, high uniformity coefficient of modified pivot due to the outfits design, which present the graduated diameters according to changeable pressure head for outlets and also, high water application under modified center pivot due to big size of outfits diameter and consequently high outlet discharge (0.295l/s) comparing with size of sprinkler hole for sprinkler pivot system (0.107l/s). Also, irrigation process is operated at low pressure head (19.5m) under modified pivot comparing with the high pressure for sprinkler pivot (35m) as shown in Table (4).

2- Irrigation requirement of maize under modified center pivot

Water distribution under modified pivot is very important indicator for water application efficiency and system efficiency which was 90.7%, beside the amount of applied irrigation water throughout the growing season was 4744 m^3/ha as presented in Table (5), while it was 5702 m^3/ha under pivot sprinkler pivot systems according to **(El-Gindy *et al* 2003)**.

Average applied water under modified pivot was lower by 16.8% of applied water under sprinkler pivot. This is due to the ratios of water stored in the root zone to the water delivered to the field resulted in low evaporation losses from water flowing on the soil surface or in the air draft from sprinkler nozzles.

3. Crop yield and water use efficiency

Table (5) showed that maize grain yield under modified system was 11.57 Mgram /ha for round furrows, while it

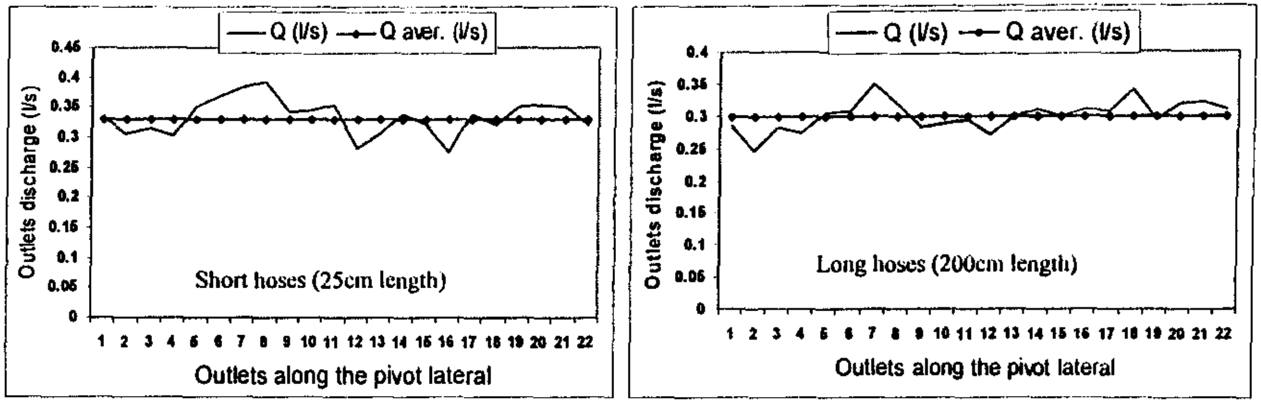

Fig. 6. Deviation of outlets discharge (Q) from the mean discharge (Q_{aver}) at triangle form

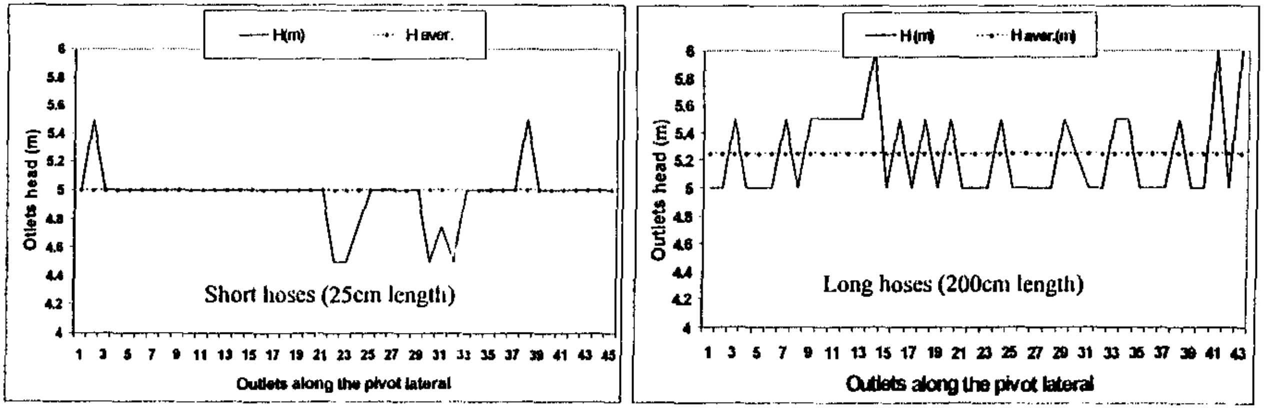

Fig. 7. Deviation of outlets pressure head (H) about the mean pressure head (H_{aver}) at triangle form

Table 3. Total discharge, outlets discharge, pressure head of outlets, and uniformity coefficient

Type of outlets	Hoses length	Mean discharge of outlets, (l/s)	Total discharge of pivot, (m^3/h)	Mean pressure head at outlets (m)	Uniformity coefficient (%)
Trapezoid	25cm	0.30	48.6	5.4	92.5
	200cm	0.25	40.5	5.2	87.45
Triangle	25cm	0.33	52.3	5.0	92.5
	200cm	0.30	48.6	5.25	90.75

Table 4. Some characteristics for modified and sprinkler pivot systems

Irrigation system	Mean discharge of water outlet (l/s)	Total discharge (m^3/h)	Pressure head at outlets (m)	Total dynamic head (m)	Uniformity coefficient, (%)
Modified pivot	0.295	47.79	5.25	19.5	90.7
Sprinkler pivot	0.107	17.33	20	35.0	90

Table 5. Grain yield and water use efficiency under modified pivot

Planning method	Grain yield, Mgram /ha.	Applied water, m^3/ha.	WUE, kg/m^3
Straight furrows	12.37	4744	2.61
Round furrows	11.57	4744	2.44
Mean	11.97	4744	2.53

was 12.37Mgram/ha for traditional furrows. Difference between the used traditional furrow and round furrow is insignificant. The difference in the yield may be due to history prepare land. It's important to mention that both maize grain yield under two furrow treatments was good according to (**El-Gindy *et al* 2003**).

On the other hand, water use efficiency for maize under modified pivot system was 2.61 and 2.44kg/m^3 for both round and traditional furrows respectively, compared to (1.84 kg/m^3)for sprinkler pivot according to (**El-Gindy *et al* 2003**).

4. Energy requirements

Data are presented in Table (6) indicated that the power consumptive use for pumping water through modified pivot system (2.96kW) was lower than that for sprinkler pivot system (4.0 kW) by 26%, while the energy requirements for water pumping throughout the growing season was (164.15 kW. h) under modified pivot system compared to (833kW.h) under sprinkler pivot system with an increase of 80%. This is due to decrease both irrigation time and the power consumptive use under modified pivot compared to sprinkler center pivot system.

On the other hand, the highest energy application efficiency was (10.34 Kg/kW. h) when using modified pivot system compared to sprinkler pivot system (26.4Kg/kW.h) by an increase of 60.8%. It's clear because the energy requirement for modified pivot system is lower than that under sprinkler pivot system, while the yield was approximately equal under the two irrigation systems.

5. Cost analysis

By calculating both annual fixed and operating costs for both modified and sprinkler pivot systems, it becomes crystal clear that modified pivot was more economical compared with sprinkler pivot system as shown in Table (7). This difference is due to static package sprinklers compared with modified pivot fittings, repairs and maintenance costs of hours per season beside, to the reduced of energy costs.

Data in Table (7) appears that, total cost for modified pivot was lower than sprinkler pivot by 19.56%, while cost of production unit of maize under modified pivot system was lower than that under sprinkler pivot system by 23 %.

CONCLUSIONS

1- Felexbility of derived relationship to calculate the suitable diameters of outlets for many pivot towers.This relationship is:

$$D = 536.3 \, [Q^{0.5} / h^{0.25}]$$

Where: "D" is inside diameter of outlets (mm), "Q" is discharge of outlets (m^3/s) and "h" is outlet pressure head (m).

2- Modified pivot had advantages both pivot irrigation and modified surface irrigation.

3- Traingle form of nozzles was more suitable than trapzioed form due to facility and flexbility design.

4- Uniformity coffiecent for two forms of nozzles (outlets) and two hose lengths was high .

5- Total dynamic head was reduced from (3.5bar) under sprinkler pivot irrigation system to (1.95bar) under modified pivot system and consequently, saving the energy and irrigation costs.

Table 6. Pumping power, energy requirement, and energy application efficiency for modified and sprinkler pivot systems

Items	Sprinkler pivot	Modified pivot
Power consumptive use (kW)	4.0	2.96
Energy requirements (kW.h)	833	164.15
Energy application efficiency (kg / kW.h)	10.34	26.4

Table 7. Cost analysis for modified and sprinkler pivot systems

Item	Sprinkler pivot	Modified pivot
- Control head included pump + pivot lateral cost , LE/ha	5873	5873
- Nozzles cost , LE/ha	139.7	26.0
1. Capital cost ,LE/ha	**6012.7**	**5899**
2. Annual fixed cost, LE/year		
- Deprecation	270.6	265.4
- Interest	330.7	324.4
- Taxes and Insurance	120.3	118.0
Subtotal	721.6	707.8
3. Annual operating costs, LE/ha		
- Labor	70	70
- Energy	120	22.5
- Repairs and maintenance	120.3	59.0
Subtotal	310.3	151.5
Total annual costs, LE/ha/year	1031.9	859.3
Total annual costs, LE/ha/season	**515.9**	**429.7**
Cost of production unit (LE / Kg)	**0.039**	**0.030**

6- Amount of applied irrigation water by using modified pivot system was lower by16.8 % compared with sprinkler pivot system.
7- Pulled hoses (200cm length) were more suitable for crops irrigating than short hoses (25cm length).
8- Using chemigation tehniques with modified pivot was more safe compared to sprinkler pivot system.
9- There was not significantly difference in the grain yield under both modified and sprinkler pivot irrigation systems.
10- Water use efficiency was increased as a result in reduces water losses by wind or evaporation.
11- There's no optical difference between traditional furrow (straight furrows) and concerting furrow (round furrows).
12- Total cost for modified pivot was lower than sprinkler pivot by 19.56%, while cost of production unit for modified pivot was lower than sprinkler pivot by 23 %.

Flexibility of modified pivot to irrigate shrubs, small trees, and plants which are sensitive to water without any fungal diseases or flowers falling.

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تصميم وإدارة نظام رى محورى مطور

[٢٨]

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نظام الرى بالرش المحورى من نظم الرى الحديثة الشائعة الاستخدام فى بلدان العالم ، ولكن فى بعض الحالات يعتبر هذا النظام غير ملائم خاصة عندما تكون نوعية مياه الرى منخفضة الجودة أو تكون المحاصيل المنزرعة حساسة لتساقط المياه والأسمدة على أوراق النبات. لذلك كان من الضروري إجراء بعض التعديلات على هذا النظام ليكون أكثر ملائمة لهذه الظروف، وأيضا ليصبح ملائ م لرى الأشجار أو الشجيرات ذات الارتفاع المنخفض ويؤدى نفس الأداء لنظام الرى بالرش المحورى فى رى مساحات كبيرة. ولتحقيق هذه الأهداف أجريت تجربة حقلية فى محطة التجارب والبحوث الزراعية التابعة لكلية الزراعة- جامعة عين شمس مع عمل بعض التعديلات على نظام الرى بالرش المحورى ليعمل كنظام رى سطحى متحرك ، وذلك عن طريق تركيب خراطيم مصنوعة من مادة البولى إيثيلين ذات قطر خارجى ٢٠مم بطول ٢٥ ، ٢٠٠سم بدلا من الرشاشات وفى نهاية هذه الخراطيم تم تركيب نوعين من المخارج (النوع الأول على شكل شبة منحرف والآخر على شكل مثلثى). وعن طريق تغيير مساحة مقطع هذه المخارج على طول الجهاز يمكن الحصول على التصرف المطلوب. وتم تقسيم المساحة المنزرعة تحت جهار الرى المحورى إلى قسمين (القسم الأول تم تخطيطه على هيئة خطوط طولية فى حين تم تخطيط القسم الثانى دائريا ليتلائم مع حركة جهاز الرى بالرش المحورى بعد تطويره).

أوضحت النتائج التى تم الحصول عليها الآتى

١- نظام الرى بالرش المحورى بعد تطويره يعمل على الضغوط المنخفضة (١,٩٥بار) مقارنة بنظام الرى بالرش المحورى قبل التطوير والذى يعمل على ضغط ٣,٥ بار.

٢- انخفضت كمية مياه الرى لمحصول الذرة الشامية بنسبة ١٦,٨% بالمقارنة بنظام الرى بالرش المحورى قبل تطويره.

٣- ارتفاع معامل انتظامية توزيع المياه لكل من مخارج المياه مثلثية الشكل والمخارج ذات الشكل شبة المنحرف.

٤- استخدام الوصلات المجرورة على الأرض ذات الطول ٢٠٠سم أفضل من الوصلات القصيرة ذات الطول ٢٥سم لأن الوصلات القصيرة تسبب نحر للتربة.

٥- كانت كفاءة استخدام المياه تحت نظام الرى بالرش المحورى المطور ٢,٥ كجم/م٣ مقارنة بـ ١,٨٤ كجم/م٣ لنظام الرى بالرش المحورى قبل التطوير.

٦- انعدام حدوث أى أضرار للنباتات النامية نتيجة لإضافة الأسمدة أو الكيماويات الزراعية مع مياه الرى عند استخدام نظام الرى بالرش المحورى بعد تطويره .

٧- لا يوجد اختلاف معنوي فى الإنتاجية لمحصول الذرة الشامية فى حالة استخدام كل من نظام الرى المحورى قبل وبعد التطوير.

٨- لا يوجد تأثير معنوى لطريقة تخطيط الأرض على إنتاجية محصول الذرة الشامية.

٩- انخفاض احتياجات الطاقة تحت نظام الرى المحورى المطور بنسبة ٨٠% مقارنة بنظام الرى بالرش المحورى قبل التطوير.

١٠- انخفاض تكاليف التشغيل لرى مساحة قدرها هكتار واحد منزرع بالذرة الشامية بنسبة ١٩,٥٦%، وكذلك انخفاض تكلفة إنتاج الطن من الذرة الشامية بنسبة ٢٣% باستخدام نظام الرى المحورى المطور مقارنة بنظام الرى بالرش المحورى قبل التطوير.

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