MODIFY POP-UP SPRINKLER TO GIVE A WETTING SQUARE SHAPE

Hashad* A. A; A. M. El Metwally; A. A. Derbala***; E. E. wasif**** and T. Z. Fouda *****

ABSTRACT

In order to be able to irrigate all of square area, a preliminary experiment was carried out to study the effect of changing the area cross-section of the water outlet of pop-up sprinkler on pressure and wetted radius. The pre- experiment results were used in the design and manufacture of two models, each of them consists of two parts from artilon materials, which were added to the pop-up sprinkler. A final experiment was carried out to evaluate the performance of the modified pop-up sprinkler (MPS) after adding the two parts to the sprinkler in comparison of the normal pop-up sprinkler (NPS) at the same wetted radius. The parameters under study were two designs of the fixed part {the first design with dimensions of nozzles (2×d) mm where d= (1.2:8.1) mm, the second design with dimensions of nozzles (3×d) mm where d= (4.1:11.8) mm}. The positions of pressure reduce valve were closed and open. The internal nozzles dimensions of the rotor part were {(3×8), (2×8), (1×8)} mm for first design and {(4×11.8), (3×11.8), (2×11.8)} mm for second design. The results showed that, the collected water from MPS by first and second design was found to be greater than which collected from NPS at a distance of 2 and 4 m from the sprinkler. On the contrary, the amount of fallen water from NPS was found to be greater than which collected form MPS at a distance of 6 to 8 m from the sprinkler. The amount of collected water when the valve was closed was larger than one when the valve was opened. In case of the first design, the amount of fallen water near the sprinkler was increased then decreased by increasing the distance from sprinkler. Also, the amount of water fell at the angle of Ɵ= (45, 135, 225, 315) was greater than the amount of fallen water at the angle of Ɵ = (0, 90, 180, 270).

*Graduate student, Agric. Eng. Dep., Faculty of Agric., Tanta Univ.,

**Asso. Prof. of Agric. Eng., Agric. Eng. Dep., Faculty of Agric., Tanta Univ.,

***Prof. of Agric. Eng., Agric. Eng. Dep., Faculty of Agric., Tanta Univ.,

****Head of Res. Agric., Eng., Res. Inst., Agric., Res. Center., Dokki, Giza.

In case of the second design, the amount of fallen water was increased by increasing the distance from sprinkler to reach maximum value at 4 m, then the amount of fallen water was decreased. Also, the amount of fallen water at the angle of ϴ = (0, 90, 180, 270) was greater than one which fell at the angle of ϴ = (45, 135, 225, 315). MPS in the first design obtained Christiansen 's uniformity coefficient smaller than that obtained by NPS. On the contrary, MPS in the second design obtained Christiansen 's uniformity coefficient greater than which obtained by NPS. MPS in the first and the second design obtained distribution uniformity (DU) smaller than which obtained by NPS. MPS with the first design gave application efficiency of low quarter smaller than which obtained by NPS. MPS with the second design gave application efficiency of low quarter greater than which obtained by NPS at the same wetted radius. The smallest results of coefficient of variation for square shape ($C.V_S$) recorded 15.3% by MPS with the second design and internal nozzle dimension was (4×11.8) mm using closed valve position.

Key words*: pop-up sprinkler, pressure, nozzle cross-section area, wetted area.*

INTRODUCTION

When operation NPS inside a square area, the water is pushed in a diagonal direction. The formation of wetting is circle and its center is the position of the sprinkler. Overlapping must be done between the wetted circles to avoid non-irrigated area of 22%, which represents the corners of the square. **Hegazi, *et al.* (2007)** tested the effect of pressure (100 to 350 kPa) and the trajectory angles range of 6o to 30^o (6- positions deflector) with overlapping range from 40 to 120% in square and triangular layouts. They found that, the application rate increased by increasing the water pressure. **El-Berry, *et al*. (2009)** studied the effect of nozzle pressure (137 kPa, 172.5 kPa, 207 kPa and 241.5 kPa) and nozzle shape (square, rectangle, triangle and circle) on water distribution. They found that, by increasing pressure the coefficient of uniformity increased for all nozzle shapes. Also, they reported that the noncircular nozzles have acceptable coefficient of uniformity for all pressures. Meanwhile the circular nozzles have unacceptable coefficient of uniformity at 138, 172.5kPa and gives acceptable at 207kPa and higher. **Sancheza, *et al.* (2011)** evaluated the agricultural impact sprinklers under different combinations of pressure, nozzle diameter and meteorological conditions. They founded that, the discharge of the evaluated sprinkler increased with nozzle diameter. **Amer, *et al*. (2012)** tested a rotating sprinkler (K- Rain 75 pop-up) under 100 to 300 kPa, nozzle #8 with 25^o trajectory angle and #3 with 11^o and 25^o trajectory angle, square and rectangular layouts at 100% and 80% overlapping. They indicated that, the throw was increased by exceeding pressure regarding to creating high jet velocity by pressure. The aim of present study was to design, manufacture and evaluate the performance of NPS with a wetting square shape.

MATERIALS AND METHODS

The experimental work was carried out to design, manufacture and evaluate the performance of pop-up sprinkler with a wetting square shape. The experiments were done at the village of Kafr Hashad, Kafr El-Zayyat, Gharbia Governorate, during summer 2017. The experiment area was about (24*24) m and situated at 31˚ 07΄ longitude and 30˚ 79΄ latitude. It has an elevation of about 20 m above mean sea level. The characteristics of the field climate during the experiment were 17 km/h of wind speed at direction of northwest. A sprinkler irrigation line was carried out as shown in Fig. 1 to carry out the experiments. It consists of a main line with a pipe made of aluminum material with internal diameter of one inch, non-return valve, centrifugal pump with a power of 0.5 hp Italian manufacturing, non- return valve, the control valve, pressure gauge, pressure reduce valve and the control unit connected to the lateral line. The lateral line consists of 0.75 inch polyurethane of 11 meters in length with a composite T-link with a pressure gauge and a 0.75 inch sprinkler. A preliminary experiment was carried out to study the effect of change of the cross- section area of nozzles on the pressure, the wetted diameter, the discharge at a constant rotation rate of the pump during the period of the experiment. The numbers of nozzles used in the experiment were increased from 8 to 13 nozzles with an increase of 5 nozzles by manually expanded. Nozzles cross- section areas were measured by using digital caliber. The pressure was measured by using a pressure gages with an accuracy of 0.2 bar. Wetted diameter was measured using long steel measuring tape as tall as 20 m with an accuracy of 2 mm. The discharge from the sprinkler was measured by using a tank with capacity of 18 L to collect the water within 30 s using a stopwatch and then calibrate the volume of water collected by the tank using a 500 ml graduated cylinder with an accuracy of 5 ml. The distribution uniformity (DU), Christiansen's uniformity coefficient (CU) and application efficiency of low quarter (AELQ) were calculated using 48 catch cans. The catch cans were 0.12 m internal diameter, and it placed at a distance of 2 m using a rope inserted every 2 m in 4 diagonal lines. The volume of water falling in the catch cans was measured by using a 100 ml graduated cylinder with an accuracy of 5 ml. To find out the optimum treatment for MPS, coefficient of variation values for square shapes ($C.V_S$) were calculated by digital planimeter. The distribution of water for the optimum treatment for MPS was measured using 79 catch cans. The catch cans were placed at a distance of 2 m in 19 diagonal lines for quarter of the square, where one line for 5 angles.

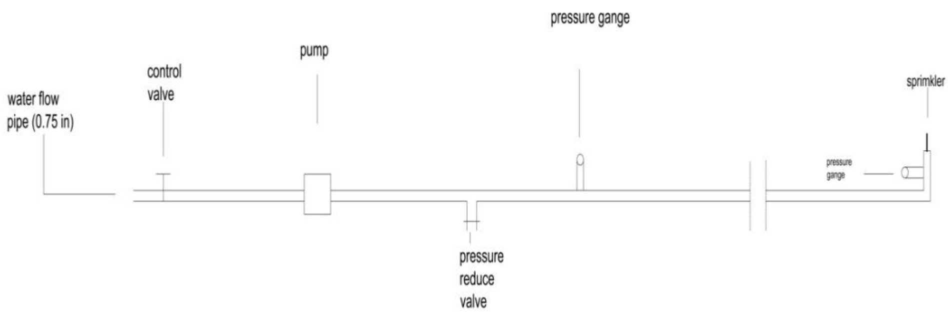

Fig. 1: Schematic diagram of sprinkler irrigation line

The applied water under sprinkler irrigation

Flow rate of sprinkler was measured at operating pressure by collecting a known volume of water in a container over a specified period (one min), and was calculated using the following Equation (**Melvyn, 1983):**

$$Q = \frac{V}{T} \text{ -------------------------------------- } [1]$$

Where:

Q = Flow rate of sprinkler in $m^3 h^{-1}$,

V = Collecting water volume in m^3 and

T = Time of collecting water in h.

Irrigation water efficiencies

The distribution uniformity, Christiansen's uniformity coefficient and application efficiency of low quarter were calculated for individual sprinkler. The test duration time was one and one and half hours. The collected water in catch cans was measured as a volume and divides its on cross area of catch cans to record in depth.

Distribution uniformity

The distribution uniformity (DU) was calculated by the following Equation **(Heermann *et al.*, 1990):**

$$DU = \left[\frac{Z_{lq}}{Z_{av}} \right] \times 100 \text{ -------------------------- [2]}$$

Where:

DU = Distribution uniformity in %,

Z_{lq} = Average of catch cans depth in the low quarter in mm and

Z_{av} = Average of catch cans depth in mm.

Application efficiency of low quarter

The application efficiency of low quarter (AELQ) was calculated by the following Equation **(Merriam and Keller, 1978):**

$$AELQ = \left[\frac{Z_{lq}}{D} \right] \times 100 \text{ ----------------------- [3]}$$

Where:

$AELQ$ = Application efficiency of low quarter in %,

Z_{lq} = Average of catch cans depth in the low `quarter in mm and

D = Average depth of applied water in mm.

Christiansen's uniformity coefficient

The Christiansen's uniformity coefficient (CU) was calculated according to the Equation of **Christiansen, 1942** as follows:

$$CU = \left[1 - \frac{\sum_{i=1}^{N} \left| X_i - \overline{X} \right|}{N \, \overline{X}} \right] \times 100 \text{ --------------- [4]}$$

Where:

CU = Christiansen's uniformity coefficient in %,

X_i = Water depth collected by catch cans in mm,

$\bar{X}$ = Mean water depth in all catch cans in mm and

N = Total number of catch cans.

Coefficient of variation for square shape

Coefficient of variation for square shape equation was devised from Coefficient of variation equation. Where, coefficient of variation (C V) was defined as the ratio of standard deviation of the applied water depth and the average of water depth. Coefficient of variation for square shape ($C.V_S$) was calculated using the following Equation:

$$C.V_S = \left[\frac{A_{out} + A_{in}}{A}\right] \times 100 \text{ --------------------- [5]}$$

Where:

$C.\ V_S$ = Coefficient of variation for square shape in %,

A_{out} = the excess wetted area outside square shape in cm^2,

A_{in} = The area not wet inside square shape in cm^2 and

A = Square area in cm^2.

Theoretical approach

At the beginning of the experiment, the pressure before running the pump was recorded 2 bar. After running the pump and using the nozzle number one with the section area of 2.25 mm^2, the pressure was recorded 5.8 bar, the wetted radius was 9.5 m at discharge of 3.6 L /min. When change the nozzle number one and installed the nozzle number 2 which a larger section area of 3.61 mm^2 and operated the pump at the same speed of the previous rotation, the pressure decreased to recorded 5.6 bar, the wetted radius was increased to recorded 10 m and the discharge was increased to recorded 4.4 L/min. Repeat the experiment at the same speed of the pump with change cross-section area of water outlet by changing the nozzles numbers. The effect of the change in the nozzles cross-section areas on the pressure, the wetted radius and the discharge at a constant speed of the pump are listed in Table 1. The data obtained from the pre-experiment were entered between the cross- section area of the nozzles (A) and the throw (L) in a straight line relationship and linked to the relationship between the triangle base (R), the flux (throw) (L) and the angle between them (Ɵ). Then, the conclusion of a relationship between the cross- section area of the nozzles (A) and the angle (Ɵ) up to 45°. Two parts were manufactured from artilon material for two designs as shown in Figs. 2 and 3. The first part was installed in the rotor part of the sprinkler. This part contains one hole (internal nozzle) which gets out of water to the second part. The second part was installed in the fixed part of the body sprinkler. This part contains 9 holes with varying variable cross- section areas according to the equation was obtained between the cross- section area of the nozzles (A) and the angle (Ɵ) up to 45°. This section of second part which contains 9 holes was repeated 8 times during 360° to obtain 72 holes during the whole cycle of sprinkler. This means that every 5° correspond to a hole with a different cross- section area in order to obtain a square shaped pattern.

Table 1: **The effect of the change in the nozzle cross-section area on the pressure, the wetted radius and the discharge at a constant of pump speed**

Nozzle number	Cross-section area, mm^2	Pressure, bar	Wetted radius, m	Discharge, L/min
1	2.25	5.8	9.5	3.6
2	3.61	5.6	10.0	4.4
3	4.84	5.4	10.5	5.6
4	6.00	5.2	11.0	7.6
5	7.04	5.0	11.8	9.0
6	9.75	4.3	11.8	11.2
7	12.71	3.8	12.2	13.5
8	16.32	3.2	12.1	15.0
9	18.60	2.8	11.4	16.8
10	22.40	2.2	10.8	18.0
11	24.80	1.8	10.3	20.1
12	30.24	1.6	9.5	21
13	34.31	1.4	9.2	22.5

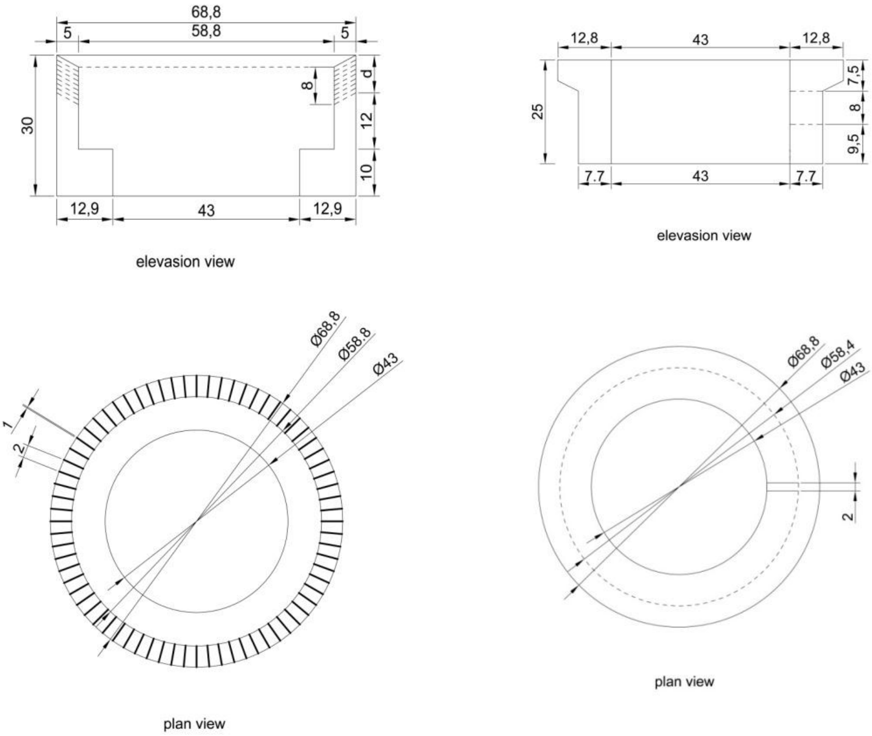

Fig. 2: Engineering drawing of first design (Dim. in mm)

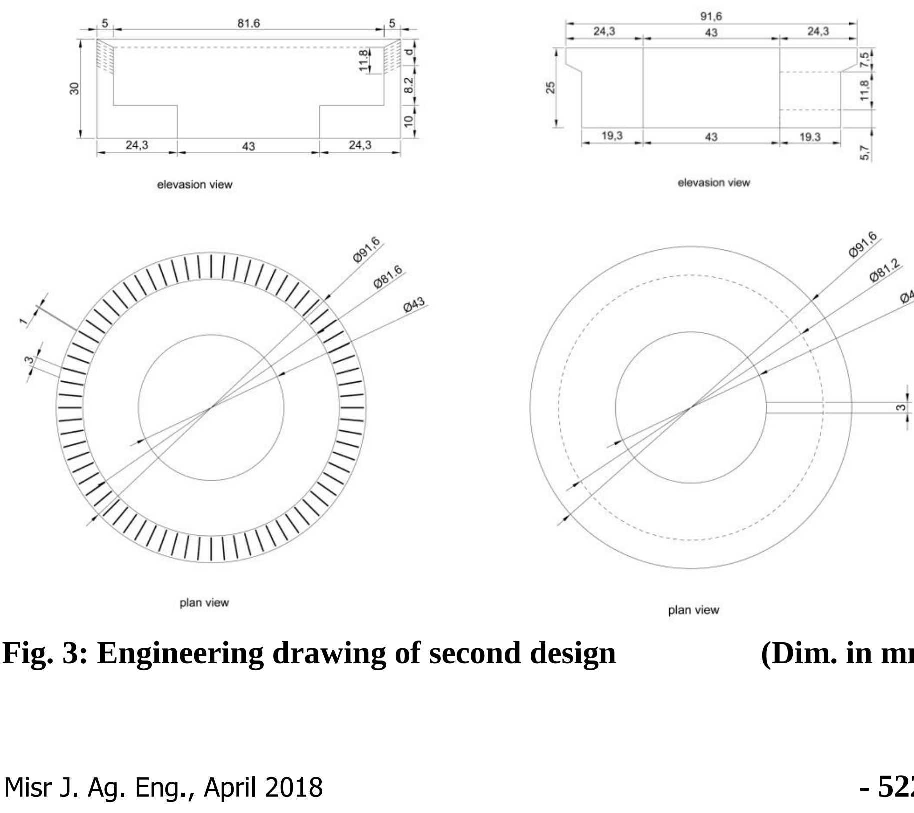

Fig. 3: Engineering drawing of second design (Dim. in mm)

RESULTS AND DISCUSSION.

MPS with 2 positions of valve and its effect on wetted radius

Fig. 4 shows the effect of **first design** sprinkler with open and closed valve on wetted radius. Wetted radius increased by about 13% from 7.5 m with open valve to 8.5 m with closed valve under the internal nozzle dimensions (3×8) mm. Meanwhile wetted radius increased by about 10% from 8.0 m with open valve to 8.8 m with closed valve under the internal nozzle dimensions (2×8) mm. The wetted radius decreased by about 7% from 7.0 m with open valve to 6.5 m with closed valve under the internal nozzle dimensions (1×8) mm. The results in Fig. 5 show the effects of **second design** sprinkler with open and closed valve on wetted radius. Wetted radius increased by about 17% from 6.0 m with open valve to 7.0 m with closed valve under the internal nozzle dimensions (4×11.8) mm. Also, the wetted radius increased by about 15% from 6.5 m with open valve to 7.5 m with closed valve under the internal nozzle dimensions (3×11.8) mm. Meanwhile, it increased by about 14% from 7.0 m with open valve to 8.0 m with closed valve under the internal nozzle dimensions (2×11.8) mm. From the previous results it is clear that, wetted radius recorded larger values at operated sprinkler with closed valve in comparison with operated sprinkler with open valve under all internal nozzle dimensions. Wetted radius also, increased by decreasing the internal nozzle dimensions. This is due to decrease the internal nozzle dimensions and closed the valve leads to increase the pressure and therefore increased wetted radius.

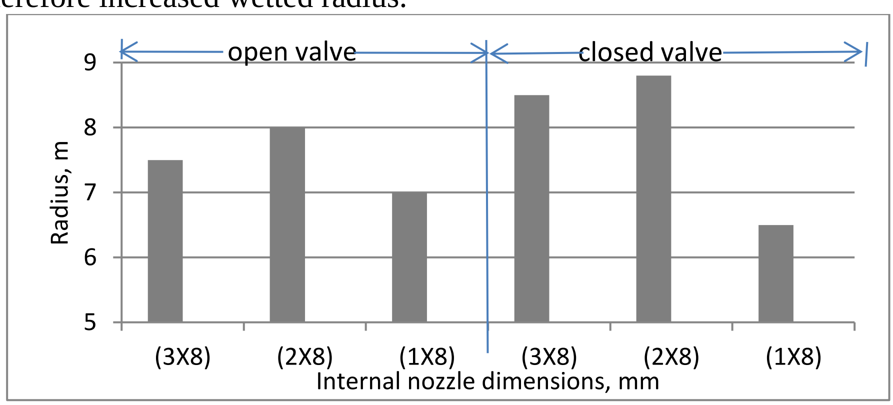

Fig. 4: Effects of the first design sprinkler on wetted radius

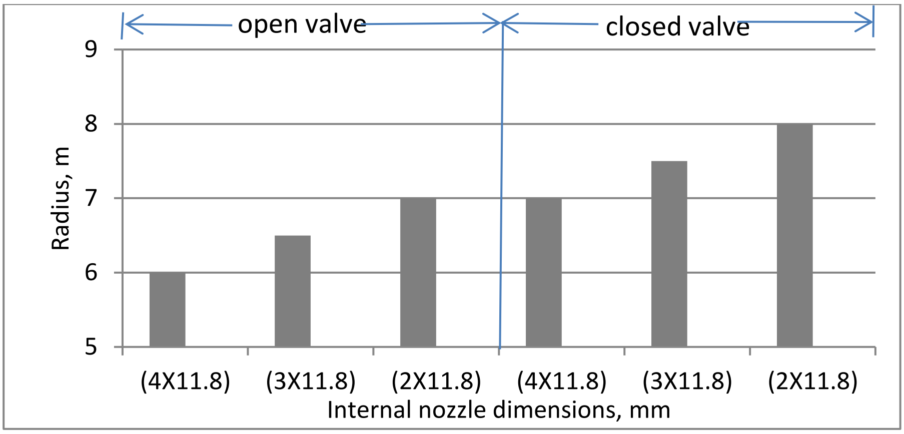

Fig. 5: Effects of the second design sprinkler on wetted radius

MPS with two positions of valve and its effect on operating pressure

Table 2 illustrates the effect of the **first design** sprinkler with open and closed valve on operating pressure in comparison with NPS by nozzle number of (6) at the same wetted radius. Pressure increased (under 7.5 m wetted radius) from 0.8 bar by NPS to (2.6:1.6) bar by MPS with internal nozzle dimensions (3×8) mm and open valve. Pressure increased (under 8.5 m wetted radius) from 1.0 bar by NPS to (3.0:2.0) bar by MPS with internal nozzle dimensions (3×8) mm and closed valve. Pressure increased (under 8.0 m wetted radius) from 0.9 bar by NPS to (3.6:2.6) bar by MPS with internal nozzle dimensions (2×8) mm and open valve. Pressure increased (under 8.8 m wetted radius) from 1.2 bar by NPS to (4.0:3.0) bar by MPS with internal nozzle dimensions (2×8) mm and closed valve. Pressure increased (under 7.0 m wetted radius) from 0.7 bar by NPS to (4.0:3.4) bar by MPS with internal nozzle dimensions (1×8) mm and open valve. Pressure increased (under 6.5 m wetted radius) from 0.6 bar by NPS to (4.4:3.6) bar by MPS with internal nozzle dimensions (1×8) mm and closed valve. Data presented in Table 3 illustrate the effect of operated the **second design** sprinkler with open and closed valve on operating pressure in comparison with NPS by nozzle number of (9) at the same wetted radius. Pressure increased (under 6.0 m wetted radius) from 0.5 bar by NPS to (0.8:1.6) bar by MPS with internal nozzle dimensions (4×11.8) mm and open valve. Pressure increased (under 7.0 m wetted radius) from 0.8 bar by NPS to (1.2:2.0) bar by MPS with internal nozzle dimension was (4×11.8) mm and closed valve. Pressure increased (under 6.5 m wetted radius) from 0.7 bar by NPS to (1.2:2.2) bar by MPS with internal nozzle dimensions (3×11.8) mm and open valve. Pressure increased (under 7.5 m wetted radius) from 0.9 bar by NPS to (1.6:2.8) bar by MPS with internal nozzle dimensions (3×11.8) mm and closed valve. Pressure increased (under 7.0 m wetted radius) from 0.8 bar by NPS to (1.8:2.4) bar by MPS with internal nozzle dimensions (2×11.8) mm and open valve. Pressure increased (under 8.0 m wetted radius) from 1.0 bar by NPS to (2.2:2.8) bar by MPS with internal nozzle dimensions (2×11.8) mm and closed valve. In general, operating pressure recorded larger values at the first design in comparison with the second design. Operating pressure recorded larger values when operated sprinkler with closed valve in comparison with operated sprinkler with open valve under all internal nozzles dimensions. Operating pressure increased by decreasing the internal nozzles dimensions. The operating pressure in case of MPS was greater than one in case of NPS at the same wetted radius.

Operated MPS with open, closed valve and its effect on discharge

Fig. 6 shows the effect of the **first design** sprinkler with open and closed valve on discharge in comparison with NPS by nozzle number of (6) at the same wetted radius. Discharge increased (under 7.5 m wetted radius) from 5.7 L/min by NPS to 15.0 L/min by MPS with internal nozzle dimensions (3×8) mm and open valve. Discharge increased (under 8.5 m wetted radius) from 6.3 L/min by NPS to 18.0 L/min by MPS with internal nozzle dimensions (3×8) mm and closed valve. Discharge increased (under 8.0 m wetted radius) from 6.0 L/min by NPS to 11.4 L/min by MPS with internal nozzle dimensions (2×8) mm and open valve. Discharge increased (under 8.8 m wetted radius) from 7.2 L/min by NPS to 13.8 L/min by MPS with internal nozzle dimensions (2×8) mm and closed valve. Discharge increased (under 7.0 m wetted radius) from 5.4 L/min by NPS to 9.0 L/min by MPS with internal nozzle dimensions (1×8) mm and open valve. Discharge increased (under 6.5 m wetted radius) from 5.1 L/min by NPS to 9.6 L/min by MPS with internal nozzle dimensions (1×8) mm and closed valve.

Table 2: Effect of the **first design** sprinkler on operating pressure

Wetted Radius, m	Modify pop-up sprinkler (MPS)			Normal pop-up sprinkler (NPS)	
	Position of valve	Internal nozzle dimension, mm	Pressure, bar	Nozzle number	Pressure, bar
7.5	Open valve	(3×8)	2.6 : 1.6	6	0.8
8.0		(2×8)	3.6 : 2.6	6	0.9
7.0		(1×8)	4.0 : 3.4	6	0.7
8.5	Closed valve	(3×8)	3.0 : 2.0	6	1.0
8.8		(2×8)	4.0 : 3.0	6	1.2
6.5		(1×8)	4.4 : 3.6	6	0.6

Table 3: Effect of the **second design** sprinkler on operating pressure

Wetted Radius, m	Modify pop-up sprinkler (MPS)			Normal pop-up sprinkler (NPS)	
	Position of valve	Internal nozzle dimension, mm	Pressure, bar	Nozzle number	Pressure, bar
6.0	Open valve	(4×11.8)	0.8 : 1.6	9	0.5
6.5		(3×11.8)	1.2 : 2.2	9	0.7
7.0		(2×11.8)	1.8 : 2.4	9	0.8
7.0	Closed valve	(4×11.8)	1.2 : 2.0	9	0.8
7.5		(3×11.8)	1.6 : 2.8	9	0.9
8.0		(2×11.8)	2.2 : 2.8	9	1.0

The results in Fig. 7 show the effect of the **second design** sprinkler with open and closed valve on discharge in comparison with NPS by nozzle number of (9) at the same wetted radius. Discharge increased (under 6.0 m wetted radius) from 8.1 L/min by NPS to 18.0 L/min by MPS with internal nozzle dimensions (4×11.8) mm and open valve. Discharge increased (under 7.0 m wetted radius) from 9.6 L/min by NPS to 21.0 L/min by MPS with internal nozzle dimensions (4×11.8) mm and closed valve. Discharge increased (under 6.5 m wetted radius) from 9.0 L/min by NPS to 15.6 L/min by MPS with internal nozzle dimensions (3×11.8) mm and open valve. Discharge increased (under 7.5 m wetted radius) from 10.8 L/min by NPS to 20.4 L/min by MPS with internal nozzle dimensions (3×11.8) mm and closed valve. Discharge increased (under 7.0 m wetted radius) from 9.6 L/min by NPS to 13.8 L/min by MPS with internal nozzle dimensions (2×11.8) mm and open valve. Discharge increased (under 8.0 m wetted radius) from 11.4 L/min by NPS to 15.6 L/min by MPS with internal nozzle dimensions (2×11.8) mm and closed valve. In general, discharge recorded smaller values at the first design in comparison with the second design. Discharge recorded larger values when operated sprinkler with closed valve in comparison with operated sprinkler with open valve under all internal nozzles dimensions. Discharge increased by increasing the internal nozzle dimensions. MPS gave discharge greater than which obtained by NPS at the same wetted radius.

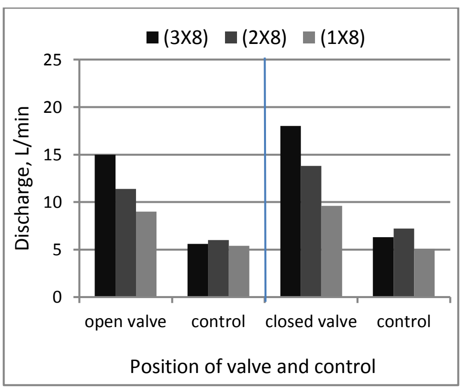

Fig. 6: Effect of the **first design** sprinkler on discharge

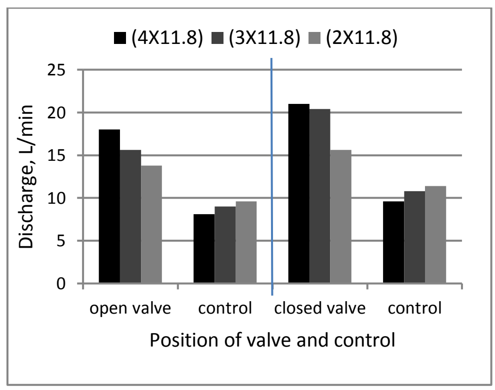

Fig. 7: Effect of the **second design** sprinkler on discharge

Effect of MPS on Christiansen's uniformity coefficient

Fig. 8 shows the effect of the **first design** sprinkler with open and closed valve on Christiansen 's uniformity coefficient (CU) in comparison with NPS by nozzle number of (6) at the same wetted radius. CU increased (under 7.5 m wetted radius) from 37.32% by NPS to 56.48% by MPS with internal nozzle dimensions (3×8) mm and open valve. CU decreased (under 8.5 m wetted radius) from 64.25% by NPS to 41.39% by MPS with internal nozzle dimensions (3×8) mm and closed valve. CU increased (under 8.0 m wetted radius) from 38.98% by NPS to 39.15% by MPS with internal nozzle dimensions (2×8) mm and open valve. CU decreased (under 8.8 m wetted radius) from 50.85% by NPS to 47.68% by MPS with internal nozzle dimensions (2×8) mm and closed valve. CU decreased (under 7.0 m wetted radius) from 39.10% by NPS to 35.77% by MPS with internal nozzle dimensions (1×8) mm and open valve. CU decreased (under 6.5 m wetted radius) from 42.22% by NPS to 29.45% by MPS with internal nozzle dimensions (1×8) mm and closed valve. The results in Fig. 9 show the effect of the **second design** sprinkler with open and closed valve on Christiansen 's uniformity coefficient (CU) in comparison with NPS by nozzle number of (9) at the same wetted radius. CU increased (under 6.0 m wetted radius) from 22.56% by NPS to 36.69% by MPS with internal nozzle dimensions (4×11.8) mm and open valve. CU increased (under 7.0 m wetted radius) from 25.07% by NPS to 43.54% by MPS with internal nozzle dimensions (4×11.8) mm and closed valve. CU increased (under 6.5 m wetted radius) from 20.71% by NPS to 41.49% by MPS with internal nozzle dimensions (3×11.8) mm and open valve. CU decreased (under 7.5 m wetted radius) from 50.72% by NPS to 43.32% by MPS with internal nozzle dimensions (3×11.8) mm and closed valve. CU increased (under 7.0 m wetted radius) from 25.07% by NPS to 44.03% by MPS with internal nozzle dimensions (2×11.8) mm and open valve. CU increased (under 8.0 m wetted radius) from 48.62% by NPS to 52.70% by MPS with internal nozzle dimensions (2×11.8) mm and closed valve. . In general, MPS using the first design gave CU smaller than which obtained by NPS at the same wetted radius. On the contrary, MPS using the second design gave CU greater than which obtained by NPS at the same wetted radius.

Effect of MPS on distribution uniformity

Fig. 10 illustrated that the effect of the **first design** sprinkler with open and closed valve on distribution uniformity (DU) in comparison with NPS by nozzle number of (6) at the same wetted radius. Distribution uniformity increased (under 7.5 m wetted radius) from 22.64% by NPS to 39.67% by MPS with internal nozzle dimensions (3×8) mm and open valve.

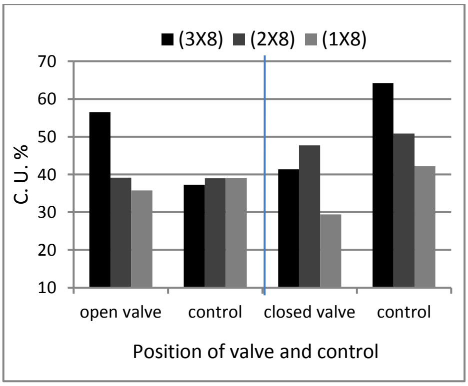

Fig. 9: Effect of the **second design** sprinkler on Christiansen's uniformity, CU

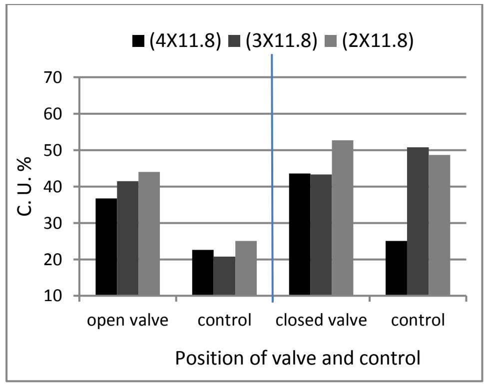

Fig. 8: Effect of the **first design** sprinkler on Christiansen's uniformity, CU

DU decreased (under 8.5 m wetted radius) from 54.24% by NPS to 32.67% by MPS with internal nozzle dimensions (3×8) mm and closed valve. DU decreased (under 8.0 m wetted radius) from 31.43% by NPS to 25.37% by MPS with internal nozzle dimensions (2×8) mm and open valve. DU decreased (under 8.8 m wetted radius) from 36.67% by NPS to 29.57% by MPS with internal nozzle dimensions (2×8) mm and closed valve. DU increased (under 7.0 m wetted radius) from 18.32% by NPS to 20.47% by MPS with internal nozzle dimensions (1×8) mm and open valve. DU decreased (under 6.5 m wetted radius) from 24.74% by NPS to 17.39% by MPS with internal nozzle dimensions (1×8) mm and closed valve. Fig. 11 shows the effect of the **second design** sprinkler with open and closed valve on Distribution uniformity (DU) in comparison with NPS by nozzle number of (9) at the same wetted radius. DU increased (under 6.0 m wetted radius) from 24.81% by NPS to 28.37% by MPS with internal nozzle dimensions (4×11.8) mm and open valve. DU decreased (under 7.0 m wetted radius) from 36.92% by NPS to 36.01% by MPS with internal nozzle dimensions (4×11.8) mm and closed valve. DU increased (under 6.5 m wetted radius) from 26.82% by NPS to 32.40% by MPS with internal nozzle dimension DU (3×11.8) mm and open valve. DU decreased (under 7.5 m wetted radius) from 44.44% by NPS to 28.26% by MPS with internal nozzle dimensions (3×11.8) mm and closed valve. DU decreased (under 7.0 m wetted radius) from 36.92% by NPS to 21.33% by MPS with internal nozzle dimensions (2×11.8) mm and open valve. DU decreased (under 8.0 m wetted radius) from 49.69% by NPS to 24.77% by MPS with internal nozzle dimensions (2×11.8) mm and closed valve. In general, MPS with the first and second design gave DU smaller than which obtained by NPS at the same wetted radius.

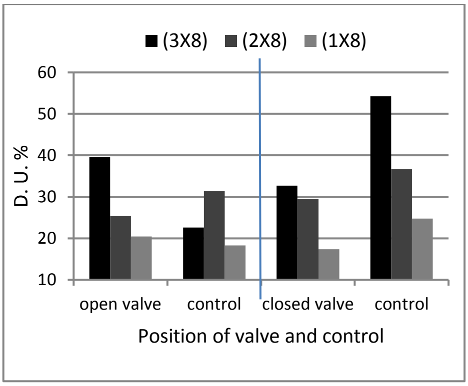

Fig. 10: Effect of the **first design** sprinkler on distribution uniformity, DU

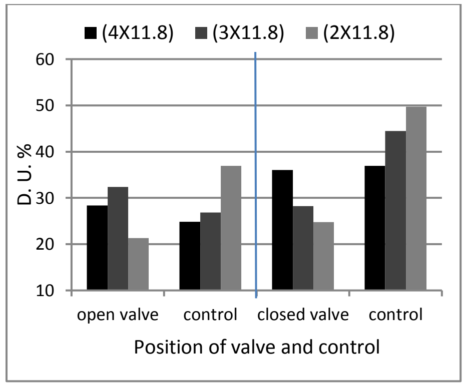

Fig. 11: Effect of the **first design** sprinkler on Distribution uniformity, DU

Effect of MPS on application efficiency of low quarter

Fig. 12 shows the effect of the **first design** sprinkler with open and closed valve on application efficiency of low quarter (AELQ) in comparison with NPS by nozzle number of (6) at the same wetted. AELQ increased (under 7.5 m wetted radius) from 15.26% by NPS to 33.19% by MPS with internal nozzle dimensions (3×8) mm and open valve. AELQ decreased (under 8.5 m wetted radius) from 53.10% by NPS to 39.51% by MPS with internal nozzle dimensions (3×8) mm and closed valve. AELQ decreased (under 8.0 m wetted radius) from 22.53% by NPS to 15.98% by MPS with internal nozzle dimensions (2×8) mm and open valve. AELQ increased (under 8.8 m wetted radius) from 22.53% by NPS to 23.35% by MPS with internal nozzle dimensions (2×8) mm and closed valve. AELQ increased (under 7.0 m wetted radius) from 13.83% by NPS to 14.84% by MPS with internal nozzle dimensions (1×8) mm and open valve. AELQ decreased (under 6.5 m wetted radius) from 12.64% by NPS to 12.39% by MPS with internal nozzle dimensions (1×8) mm and closed valve. Fig. 13 shows the effect of the **second design** sprinkler with open and closed valve on application efficiency of low quarter (AELQ) in comparison with NPS by nozzle number of (9) at the same wetted. AELQ increased (under 6.0 m wetted radius) from 13.72% by NPS to 16.86% by MPS with internal nozzle dimensions (4×11.8) mm and open valve. AELQ increased (under 7.0 m wetted radius) from 23.92% by NPS to 24.20% by MPS with internal nozzle dimensions (4×11.8) mm and closed valve. AELQ increased (under 6.5 m wetted radius) from 21.58% by NPS to 29.88% by MPS with internal nozzle dimensions (3×11.8) mm and open valve. AELQ decreased (under 7.5 m wetted radius) from 31.89% by NPS to 23.67% by MPS with internal nozzle dimensions (3×11.8) mm and closed valve. AELQ increased (under 7.0 m wetted radius) from 23.92% by NPS to 24.08% by MPS with internal nozzle dimensions (2×11.8) mm and open valve. AELQ increased (under 8.0 m wetted radius) from 32.54% by NPS to 34.17% by MPS with internal nozzle dimensions (2×11.8) mm and closed valve. In general, MPS with the first design gave AELQ smaller than which obtained by NPS at the same wetted radius. While, MPS with second design gave AELQ greater than which obtained by NPS at the same wetted radius.

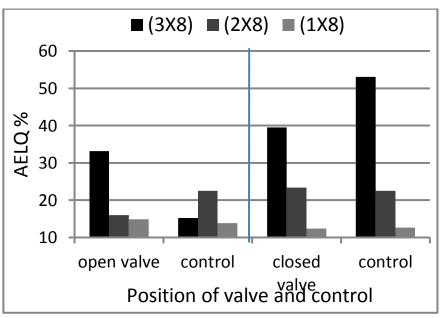

Fig. 12: Effect of the **first design** sprinkler on application efficiency, AELQ

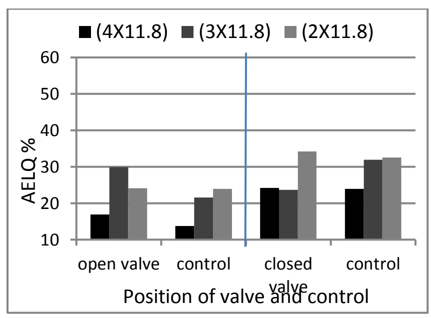

Fig.13: Effect of the **second design** sprinkler on application efficiency, AELQ

MPS and its effect on the coefficient of variation for square shape

Figs. from 14 to 19 indicate the wetted pattern of MPS with first design. Fig. 20 shows the effect of the **first design** sprinkler with open and closed valve on coefficient of variation for square shape ($C.V_S$). The maximum value of $C.V_S$. (39.7%) was obtained by treatment of internal nozzle dimensions (3×8) mm with open valve. While, the minimum value of $C.V_S$. (18.9%) was obtained at the treatment of internal nozzle dimensions (3×8) mm with closed valve.

Fig. 14: The wetted pattern of MPS with first design by the internal nozzle dimensions (3×8.1) mm and open valve

Fig. 15: The wetted pattern of MPS with first design by the internal nozzle dimensions (3×8.1) mm and closed valve

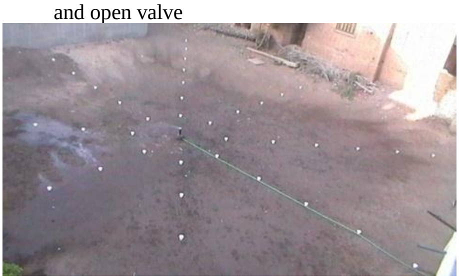

Fig. 16: The wetted pattern of MPS with first design by the internal nozzle dimensions (2×8.1) mm and open valve

Fig. 17: The wetted pattern of MPS with first design by the internal nozzle dimensions (2×8.1) mm and closed valve

Fig. 18: The wetted pattern of MPS with first design by the internal nozzle dimensions (1×8.1) mm and open valve

Fig. 19: The wetted pattern of MPS with first design by the internal nozzle dimensions (1×8.1) mm and closed valve

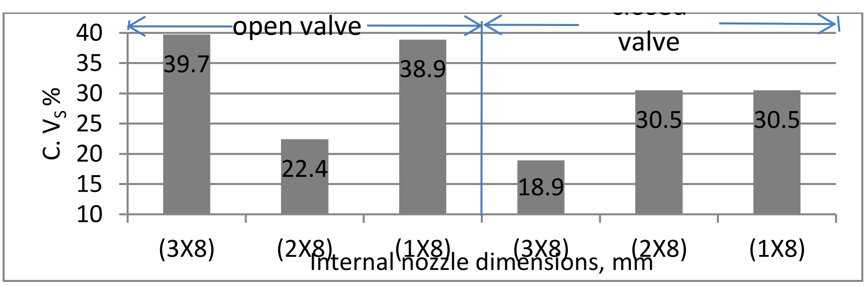

Fig. 20: Effect of the first design sprinkler with open and closed valve on the coefficient of variation for square shape, C.V$_S$

Fig. from 21 to 26 indicate the wetted pattern of MPS with second design. Fig. 27 shows the effect of the **second design** sprinkler with open and closed valve on coefficient of variation for square shape ($C.V_S$). The maximum value of $C.V_S$ (29.7%) was obtained at the treatment of internal nozzle dimensions (4×11.8) mm with open valve. While, the minimum value of $C.V_S$ (15.3%) was obtained at the treatment of internal nozzle dimensions (4×11.8) mm with closed valve.

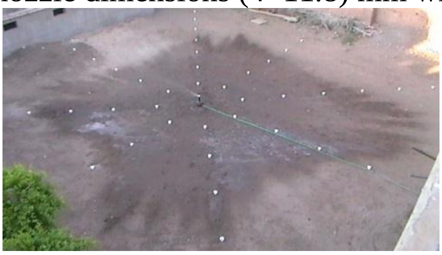

Fig. 21: The wetted pattern of MPS with second design by the internal nozzle dimensions (4×11.8) mm and open valve

Fig. 22: The wetted pattern of MPS with second design by the internal nozzle dimensions (4×11.8) mm and closed valve

Fig. 23: The wetted pattern of MPS with second design by the internal nozzle dimensions (3×11.8) mm and open valve

Fig. 24: The wetted pattern of MPS with second design by the internal nozzle dimensions (3×11.8) mm and closed valve

Fig. 25: The wetted pattern of MPS with second design by the internal nozzle dimensions (2×11.8) mm and open valve

Fig. 26: The wetted pattern of MPS with second design by the internal nozzle dimensions (2×11.8) mm and closed valve

In general, MPS with first and second design, the treatment by the second design with internal nozzle dimensions (4×11.8) mm using closed valve produced the smallest results of $C.V_S$.

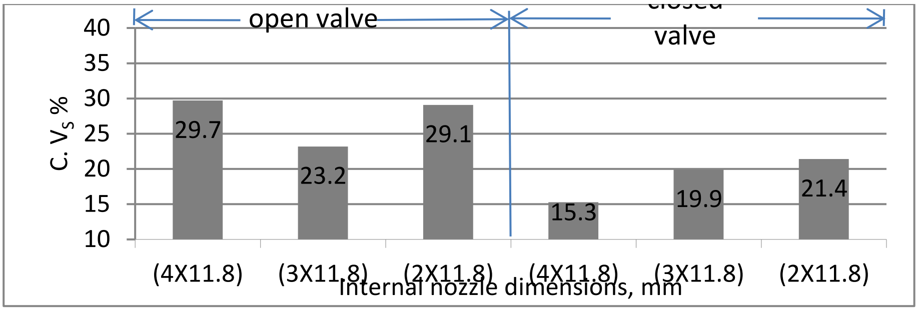

Fig. 27: Effect of the second design sprinkler with open and closed valve on the coefficient of variation for square shape, $C.V_S$

The distribution of water for the optimum treatment for MPS compared with NPS

The amount of water falling by MPS under the second design with (4×11.8) mm internal nozzle dimensions and closed valve (optimum treatment) increased by increasing the distance from the sprinkler until 4 m and then decreased by increasing the distance from the sprinkler. This is due to the low operating pressure. The highest value of the amount of water falling at the angles (0, 90, 180 and 270) and the lowest value of the amount of water falling at the angles (45, 135, 225 and 315), because the nozzle cross-section area is the highest value at zero angle and then decreased until it reaches the lowest value at the angle of 45° and then increased to reaches the highest value at the angle of 90. This is repeated until the angle was 360° degrees. While, the amount of water falling by NPS (with nozzles number (9) and 0.7 bar operating pressure) increased by increasing the distance from the sprinkler. This is due to the low operating pressure.

CONCLUSIONS

This can be obtained of wetted area with a square shaped when using the modified pop-up sprinkler (MPS) with the second design (4×11.8) mm internal nozzle dimensions and closed valve. However, there is a decrease in the uniformity of the water distribution. Therefore, it can be recommend that we have to conduct more researches and experiments to increase the uniformity of water distribution by increasing the operating pressure and carry out the corresponding overlapping at low rates such as 5, 10, 15 or 20%. Therefore, the MPS can be operated to obtain a wetted area with a square shape with acceptable water distribution ratios. Therefore, it can be reduced the number of sprinklers which used for the unit area, then the cost, the consumption water and the energy will be reduced.

REFERENCES

Amer, K. H; M. A. Aboamera; A. H. Gomaa and S. B. Deghedy (2012). Sprinkler irrigation system design and evaluation based on uniformity. Misr J. of Agric. Eng., 29 (2): 763-788.

Christiansen, J. E. (1942). Irrigation by sprinkler. California Agricultural Experiment Station. University of California. Berkeley, California, USA. Bulletin, 670.124 p.

El-Berry, A. M; M. H. Ramadan; M. A. El-Adl and H. M. Mahmoud (2009). Effect of nozzle shape and pressure on water distribution. Misr J. of Agric. Eng., 26 (1): 224-250.

Heermann, D. F; W. W. Wallender and G. M. Bos (1990). Irrigation efficiency and uniformity. (C. F. Hoffman, G. J., Howell, T. A., Solomon, K. H. (Eds.), Management of Farm Irrigation Systems. ASAE, St. Joseph, MI. 125-149).

Hegazi, M; K. H. Amer and H. M. Moghazy (2007). Sprinkler irrigation system layout based on water distribution pattern. Misr J. of Agric. Eng., 24 (2): 360-377.

Melvyn, K. (1983). Sprinkler irrigation, equipment and practice. Bastsford Academic and Educational, London. 120 pp.

Merriam, J. L. and J. Keller (1978). Farm irrigation system evaluation. A guide for management. Logan, Utah Agricultural and Irrigation Engineering Department, Utah State University, USA. 285 pp.

Sancheza, I; J. M. Facia and N Zapatab (2011). The effects of pressure, nozzle diameter and meteorological conditions on the performance of agricultural impact sprinklers. J. of Agricultural Water Management, (102): 13– 24.

الملخص العربي

تعديل الرشاش القفاز ليعطي مساحة إبتلال مربعة الشكل

م. عبد المنعم حشاد*، د. عادل محمد المتولي** ، أ. د. أسعد دربالة*** ،
أ. د. عصام الدين واصف**** و أ. د. طارق فوده***

عند تشغيل رشاشات المسطحات الخضراء من النوع القفاز داخل مساحة مربعة الشكل يتم دفع المياه في أتجاه نصف قطري. فيكون الإبتلال علي شكل دائرة مركزها هو موضع الرشاش و بناء علي ذلك يجب حدوث تداخل بين دوائر الإبتلال تجنباً لعدم ري ٢٢% من المساحة و التي تمثل أركان المربع. ولكي نتمكن من ري كامل مساحة المربع تم تنفيذ تجربة أولية بهدف دراسة تأثير تغير مساحة مقطع مخرج المياه للرشاش.-عند ثبات سرعة المضخة- علي نصف قطر الإبتلال. تم الإستفادة من النتائج المتحصل عليها من التجربة الأولية لتعديل أداء الرشاش بتصميم قطعتين تضاف للرشاش. ثم تم تنفيذ تجربة نهائية بنفس موقع التجربة الأولية وفي خلال نفس العام وذلك لتقيم أداء الرشاش القفاز بعد التعديل بالمقارنة بأداء الرشاش العادي وذلك عند نفس أنصاف أقطار الإبتلال المتحصل عليها من الرشاش المعدل. وكانت المعاملات تحت الدراسة هي التصميمن الخاصين بالجزء المثبت بجسم الرشاش (التصميم الاول ذو أبعاد الفوهات (٢×ع) مم حيث ع= (٨،١:١،٢) مم، التصميم الثاني ذو أبعاد الفوهات (٣×ع) مم حيث ع=(١١،٨:٤،١) مم. ووضع صمام التحكم (مفتوح ، مقفول). و أبعاد الفوهات الداخلية للجزء المركب علي الجزء الدوار للرشاش وهي {(٣×٨) ، (٢×٨) ، (١×٨)}مم للتصميم الأول و {(٤×١١،٨) و (٣×١١،٨) و (٢×١١،٨)}مم للتصميم الثاني. تم مقارنة أداء الرشاش ذو الإبتلال المربع الشكل بأداء الرشاش العادي عند تشغيل الرشاش منفرداً بدون تداخلات.
وكانت أهم النتائج المتحصل عليها هي :

١- أعطي الرشاش المعدل بالتصميم الاول قيم منخفضه لمعامل كرستيانس بالمقارنة بالرشاش العادي. و علي العكس وجد أن الرشاش المعدل بالتصميم الثاني أعطي قيم مرتفعة لمعامل كرستيانسن بالمقارنة بالرشاش القفاز العادي.
٢- أعطي الرشاش المعدل بالتصميم الأول و الثاني قيم أصغر لإنتظامية التوزيع من تلك المتحصل عليها من الرشاش القفاز العادي.
٣- أعطي الرشاش القفاز المعدل بالتصميم الأول قيم منخفضة لكفاءة إضافة المياه بالمقارنة بالرشاش القفاز العادي. أما عند تشغيل الرشاش القفاز المعدل بالتصميم الثاني وجد أنه أعطي قيم مرتفعة لكفاءة إضافة المياه عن الرشاش القفاز العادي.
٤- أعطي الرشاش القفاز المعدل بالتصميم الثاني وابعاد الفوهة الداخلية (٤×١١،٨) مم ومحبس تخفيف الضغط مغلق أقل قيمة لمعامل الإختلاف عن الشكل المربع و يقدر بـ ١٥,٣% أي أنه الرشاش الأفضل.

* طالب دراسات عليا. قسم الهندسة الزراعية. كلية الزراعة. جامعة طنطا.
** استاذ مساعد الهندسة الزراعية. قسم الهندسة الزراعية. كلية الزراعة. جامعة طنطا.
*** استاذ الهندسة الزراعية. قسم الهندسة الزراعية. كلية الزراعة. جامعة طنطا.
**** رئيس بحوث. معهد الهندسة الزراعية. مركز البحوث الزراعية. الدقي. جيزة.