PERFORMANCE OF ROTATING SPRAY PLATE SPRINKLERS

M. A. M. Ahmed [3], M. A. Awaad [2], M.Y. El-Ansary [1], Z. A. El-Haddad [1]

ABSTRACT

Understanding the distribution characteristics of an individual irrigation sprinkler or spray nozzle is necessary to improve the uniformity of any sprinkler system. Relevant factors affecting the improvement of the irrigation performance of sprinkler systems are the engineering factors (i.e. operating pressure, riser height of sprinkler / nozzle, sprinkler type, deflector plates, and nozzle diameter), and the climatic factors (i.e. wind speed, air humidity and air temperature). It is important to highlight that this study has been focused on center pivot sprinkler irrigation system as it is the widely used sprinkler irrigation system in new lands of Egypt (Toshka, Sinai and Nobaria). Therefore, five different types of spray nozzles, used on center pivot irrigation system, have been tested and evaluated. Several outdoor single-sprinklers and overlapped - sprinklers irrigation tests have been conducted for determining: water application rate, uniformity of water distribution, and application efficiency, under different engineering and climatic conditions.

Various sprinkler types - pressure -riser height combinations were used and the variation of application rate and weather conditions (i.e. air temperature, relative humidity, and wind speed) were measured during the test. A statistical approach has been used with these data to estimate water distribution uniformity coefficient CU, and water application efficiency AE, using a linear model. CU, and AE as sprinkler irrigation performance parameters, were estimated as functions of the sprinkler type, nozzle characteristics, riser height, operating pressure, and wind speed. Other climatic and engineering factors were not of significant effect on the CU or AE in this study. The model can be a useful tool to select the operational conditions (e.g. working pressure, riser height, nozzle type)

1, 2- Dept. of Agric. Eng; Fac. of Agric., Benha University.

3- Centr. Admin. of Agric. Extension., Ministry of Agriculture.

that can be suitable for certain environmental conditions (air temperature, relative humidity, etc.) to improve water distribution uniformity CU and water application efficiency AE.

INTRODUCTION

Sprinkler irrigation is one of the most effective methods of irrigation, especially for new reclaimed lands, as it allows the irrigation of many types of soils, crops, and varying topography with low labor input, (Li, 1997). Center-pivot sprinkler

system is increasing in popularity due to its low labor requirement and ability to irrigate large fields. Ah Koon (1994) attributed this adoption to three main reasons: first, there was a pressing need to replace the existing high pressure overhead system

which was becoming too costly to operate, in favor of systems like the centre pivot which require about half of the pressure (200 to 300 kPa) and hence less pumping costs than the high pressure sprinkler systems. Secondly, the system being mechanized, it is possible to irrigate large areas with reduced labour intervention; and thirdly, the investment cost of the system is by far inferior to the drip system which has been claimed to be one of the potential replacements for the sprinkler irrigation systems. Indeed, the cost of a centre pivot ranges, on average, from 1500 to 2500 LE /fed.* compared to 8000 to 10 000 LE /fed.*for the drip system. Also the operating cost of a centre pivot system can be as much as four times lower than that of a comparable conventional sprinkler system. The centre pivot has also other features that make it attractive to irrigation managers. It is easy to operate and does not require trained personnel. Water application can be easily adjusted to meet the soil and crop requirements. It also has greater management flexibility than other sprinkler systems. The system can be managed so as to apply the crop requirement either in small frequent doses or in one single application. Some models are computerised and therefore offer additional versatility. Selection of sprinkler head or spray nozzle plays an important role in the performance of modern irrigation machines (Sourell et al., 2003).Water distribution and application efficiency are important parameters to consider when evaluating the performance of an irrigation system. (Thompson et al.,1997).

Sourell et. al. (2003) mentioned that in all types of mobile irrigation machines, the characteristics of the spray plate sprinklers, overlapping spacing, and machine speed determines irrigation performance. The precipitation rate (mm h^{-1}) is a key factor in the evaluation of irrigation performance. (Keller and Bliesner, 1990; DeBoer et al., 1992). The aim of this study is to evaluate the possibility of improving the sprinkler irrigation performance (i.e. water distribution uniformity coefficient CU, and water application efficiency AE) through specifying the optimum operating factors that are suitable and advisable for the Egyptian conditions, concentrating on the following factors:

- Engineering factors, such as: Operating pressure, height of sprinkler head /or spray nozzle, nozzle type and configuration of deflector plates.
- Climatic factors such as: wind speed, air temperature and air humidity.

Such a study is thought to provide several recommendations for designers and irrigators to improve irrigation efficiency and to increase water distribution uniformity under field conditions.

MATERIALS AND METHODS

This study was conducted at the Agricultural Extension Farm of the ARE at Ismailia. In this study, three different types of spray nozzles widely used in center pivot and linear moving sprinkler irrigation were tested and evaluated.

*fed = 4200 m²

The climatic factors i.e. temperature, air humidity, and wind speed and direction at two meters height were registered using an automatic weather station, located 60 m away from the site of the concerned study.

Field test for evaluating irrigation performance.

The effects of the spray nozzle heights above the soil surface (1.0, 1.50, and 2.0 m), under different operating pressures (0.10, 0.15, 0.20 MPa) were studied on the application efficiency and uniformity of water distribution using three types of spray nozzles (i.e. rotator, spinner and wobbler) widely used for center pivot sprinkler irrigation equipment, under field conditions. Field tests were performed on the three spray nozzles between August 2006 and April 2007.

Two types of the nozzles were of Series 3000 RSPSs from the Nelson Irrigation Co. They were the R3000 (rotator) and the S3000 (spinner). The two types of nozzles are equipped with a deflector plate that rotates when hit by the water jet. The main difference between the two nozzles is that the R3000 (rotator) uses a slowly rotating plate, while S3000 (spinner) uses a rapidly spinning plate. One nozzle diameter, number 30 (6.00mm) dark brown was used for both types of spray nozzles, and two configuration types of deflector plates (6 and 8 grooves) were used. The third type of tested nozzle was Senninger i- Wob nozzle (as selected from Senninger Irrigation Inc., Orlando, Flo.) It has an oscillating-plate device with six grooves in which the jet passes through one or two grooves at a time and nozzle diameter of 6.40mm are shown in Fig.(1) .

R 3000 (rotator) S 3000 (spinner) i-wob (wobbler)

Fig.(1) Types of rotating spray plate sprinkler.

The spray nozzles evaluation equipment consisted of:

Support structure of an inverted U-shape frame designed to support a spray sprinkler at different heights. The structure was built with three wooden cylindrical bars of 110 mm diameter, 3.0 m high and 5 m wide. The frame was anchored to the soil with concrete blocks, Fig. (2).

Pumping unit: One centrifugal pump with 4kW electrical motor was used to supply the pressurized water to the spray sprinklers from under ground water well , the pump discharge was 15m^3/h at pressure head of 43m. Disc filter of 2 inch outlets diameter was used to avoid nozzle clogging. Main control valve and manometer were installed in the pumping unit. A 30m flexible hose PE (75mm diameter) conveyed water under pressure from the pump to the spray nozzles. Manometer and control valve were installed immediately upstream to regulate the water delivered to the spray nozzle under required pressure. Catch cans of 100 cm^2 surface area and 10 cm height were used to collect the applied water.Spray nozzle discharge was measured volumetrically under different operating pressures, i.e. 0.10, 0.15 and 0.20 MPa.

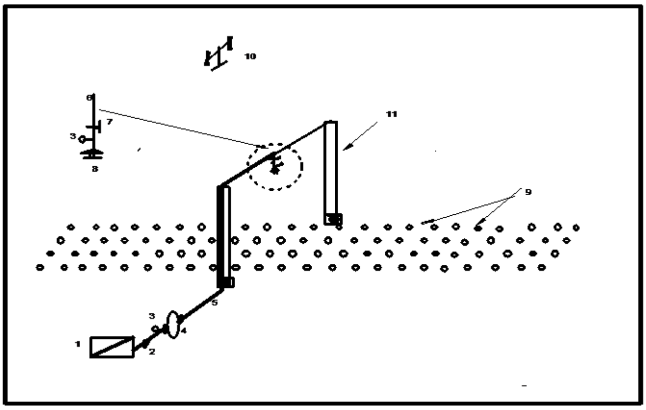


Fig.(2) Structure and components of experimental setup for evaluation of water distribution of single spray nozzles.

Determination of water application rate and distribution pattern:

To determine water distribution pattern of spray head, four rows of catch cans were placed perpendicular to the lateral and at a spacing of 1.0 m between rows, and 1.0 m apart within the row. Wind speed, relative humidity, and air temperature were recorded at beginning, mid, and end of the test. After 30 minutes sprinkling test, the water caught in catch can was collected and measured volumetrically with a calibrated tube, then the volume of water measured was divided by surface area of catch can ($100cm^2$) giving the water depth (mm). Usually four replicates with the same operating pressure and nozzle height were carried out under different climatic conditions. From each individual field test, including the nozzle/plate configuration, pressure, mounting height and, average wind speed, the pattern width (average of width from four can rows), the average water application rate, the peak rate, and the Christiansen uniformity coefficient (CU) were determined. The average water application rate was determined by using the following equation:

$$Ra = da / T, \quad (mm/h) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where

Ra: the average rate of water application (mm/h).
da: depth of water caught in catch-cans during the test period (mm)
T: total time of sprinkler operation (test period) (h).

The ratio of the peak rate to the average rate is defined as:

$$r = Rp / Ra, \qquad (1 < r < 2) \ldots\ldots\ldots\ldots (2)$$

Where: Rp is the peak rate (mm/h).

The uniformity (CU) values were calculated by integrating each row of collector data to obtain an average rate (relative application depth) for each row, and using these four values to calculate the "Christiansen uniformity" (ASAE standard S436.1-2001).The uniformity Coefficient (CU) was calculated by using the Christiansen formula (Christiansen,1942):

$$CU = \left[1- \frac{\Sigma|x- \bar{x}|}{n\bar{x}}\right] \times 100 \quad (3)$$

Where:

x = water depth collected by catch cans.

$\bar{x}$ = mean water depth collected in all catch cans.

n = total number of catch cans used in the evaluation.

Distribution uniformity of low quarter (DU_{Lq}):

$$DU_{Lq} = \frac{\text{Mean depth caught on the 1/4 of the field receiving the least amount X 100}}{\text{Mean depth caught on the entire field}}$$

Application Efficiency (Ea): (4)

$$Ea = \frac{\text{Mean water depth caught (mm) x sprinkler irrigated area (m}^2\text{)}}{\text{Average sprinkler or sprayer discharge (m}^3\text{/h) x 1000}} \text{ x } 100$$

(5)

Overlapping simulation of rotating spray nozzles:

The individual water distributions obtained for the RSPSs evaluations were mathematically overlapped to simulate the water application pattern produced by a section of a center-pivot. The method used to convert single –leg catch –cans data into grid catch- can data was introduced by Faci et al.(2001).

Microsoft office Excel 2003 was used to calculate the average application rate (mm/h) and the uniformity coefficient (CU) for the overlap of several spray nozzles on a pivot from single line data, by using these data. Therefore, the water application resulting from each individual spray nozzle was represented by a row vector whose elements are computed as the sum of the elements of the water application matrix in the same column. The next step is to overlap the vectors resulting from neighboring spray nozzle. The goal was to obtain a 12 m section of fully overlapped water application in the irrigation lateral. This section is characterized by 21 elements vector whose elements are calculated by addition of the water applied by each of the spray nozzles.

Three spray nozzles spacings were considered: 3.0, 4.0, and 6.0 m. A relevant limitation of the overlapping procedure was that the spacing must be a multiple of the data spacing in the water application matrix (1.0 m).

Fig. (3) illustrates the procedure used to overlap the water application between spray nozzles. The required number of spray nozzles varied with the spacing, ranging between 5 (for a spacing of 6.0 m), 8 (for a spacing of 4.0 m) and 10 (for a spacing of 3.0 m). The coefficient of uniformity CU (%),was calculated in the fully overlapped section of the lateral using the equation (3). This CU reproduces the uniformity of irrigation lateral traveling over a parallel line of 21 catch cans at 1.0 m spacing**.**

RESULTS AND DISCUSSION

Evaluation of water application rate and distribution pattern.

Figure (4) shows the water distribution patterns throughout the trajectory radius under different operating pressures for the three types of spray nozzles (S3000, R3000 and i-Wob) with deflector plates of 6-grooves. It could be seen that increasing operating pressure caused an increase in the application rate over most of the wetted area and produces a spread of the water distribution for all types of spray nozzles .This means that, increasing operating pressure from 0.10 to 0.20 MPa causes an increase in the wetted area and pattern width. For example, Fig.(4-a) with R3000 (6G) spray nozzle, and 1.50 m nozzle height, the average application rates were 7.22 and 8.35 mm/h, the wetted areas were 171.95 and 236.87 m² and pattern widths were 14.80 and 17.00 m respectively; Fig.(4-b) with S3000 (6G) spray nozzle, the average application rates were 9.17 and

11.30 mm/h, the wetted areas were 143.07 and 171.95 m² and pattern widths were 13.50 and 14.80 m respectively; Fig.(4-c) with i-Wob (6G) spray nozzle, the average application rates were 10.48 and 12.35 mm/h, the wetted areas were 122.66 and 165.05 m² and pattern widths were 12.50 and 14.50 m respectively.

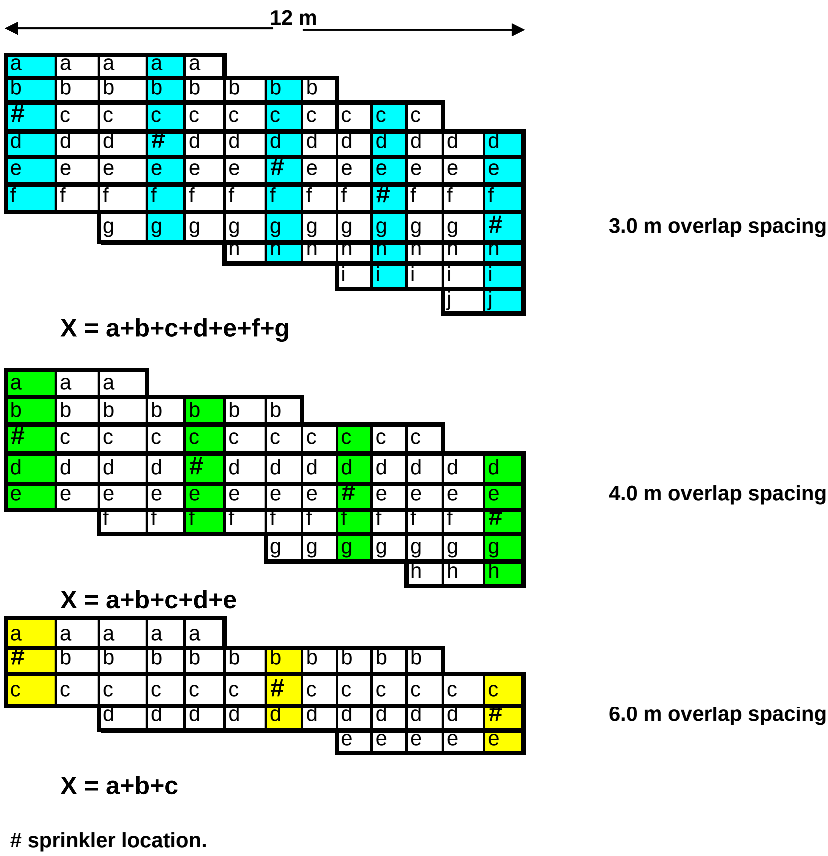
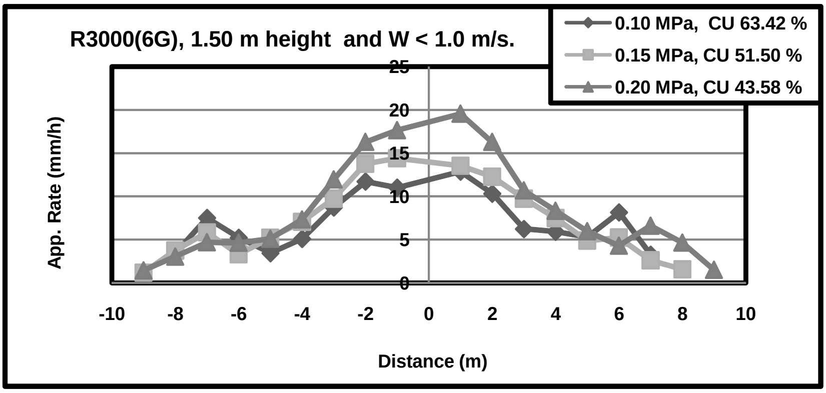
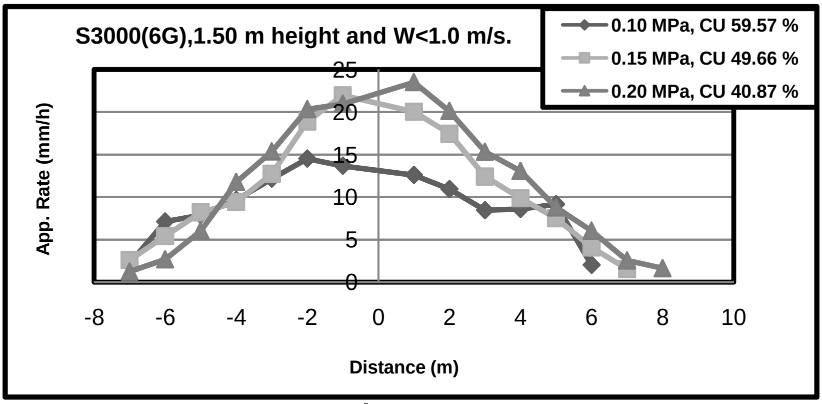


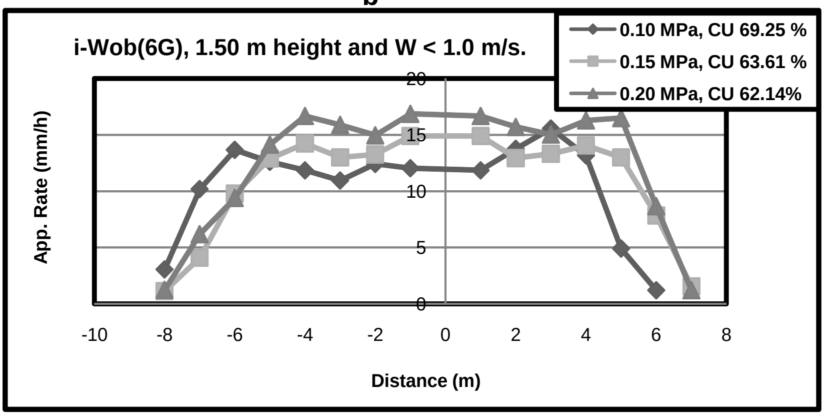
Fig.(3) Scheme of mathematical procedure used for simulation of overlapping of spray nozzles at different spacings.



a



b



c

Fig. (4) Effect of operating pressure on water distribution pattern for the three tested spray nozzles (S3000, R3000 and i-Wob) of 6 grooves deflector plates.

Fig.(4) shows that increasing operating pressure from 0.10(MPa) to 0.20 (MPa) always decreased the coefficient of uniformity(CU) values, under the different used nozzle heights and wind speeds for all spray nozzle types.

For example Fig.(4-a) reveals that under wind speed (W)< 1.0 m/s at 0.10 (MPa) and 0.20 (MPa) operating pressures and 1.50 m nozzle height the CU values for R3000 (6G) spray nozzle were 63.42 and 43.58 %. Fig.(4-b) the CU values for S3000(6G) spray nozzle were 59.57 and 40.87 %. Fig.(4-c) the CU values for i-Wob(6G) spray nozzle were 69.25 and 62.14 %.

Figure (5) shows that increasing nozzle height caused an increase in the wetted area , pattern width but decrease the application rate, for the three types of spray nozzles (S3000, R3000 and i-Wob) with deflector plates of 6-grooves.

Increasing nozzle height from (1.0 to 2.0 m) caused an increase in the wetted area and pattern width.

For example, Fig.(5-a) for R3000 (6G) spray nozzle, increasing nozzle height from (1.0 to 2.0 m), for 0.15 MPa operating pressure at wind speed W < 1.0 m/s, the average application rates were 8.23 and 6.75 mm/h, the wetted areas were 188.60 and 240.41 m^2 and pattern width were 15.50 and 17.50 m, respectively; Fig.(5-b) for S3000 (6G) spray nozzle, the average application rates were 10.93 and 9.98 mm/h, the wetted areas were 143.07 and 171.95 m^2 and pattern widthes were 13.10 and14.80 m, respectively and Fig.(5-c) for i-Wob (6G) spray nozzle, the average application rates were 11.98 and 9.85 mm/h, the wetted areas were 143.07 and 176.63 m^2 and pattern widthes were 13.50 and15.00 m, respectively.

Fig(5) shows that increasing nozzle height from 1.0 m to 2.0 m at (W)< 1.0 m/s under the different used operating pressures (MPa), always decreased the CU values for R3000(6G), S3000(6G) spray nozzles, but increased the CU values for i-Wob(6G) spray nozzles.

Fig.(5-a) shows that increasing nozzle height from 1.0 m to 2.0 m, at wind speed (W)< 1.0 m/s and 0.15 (MPa) operating pressure, the CU values for R3000(6G) spray nozzle were (52.45 and 47.37 %). Fig.(5-b) the CU values for S3000(6G) spray nozzle were (56.15 and 47.52%).Fig.(5-c) the CU values for I-wob(6G) spray nozzles were(61.57 and 67.29 %) respectively.

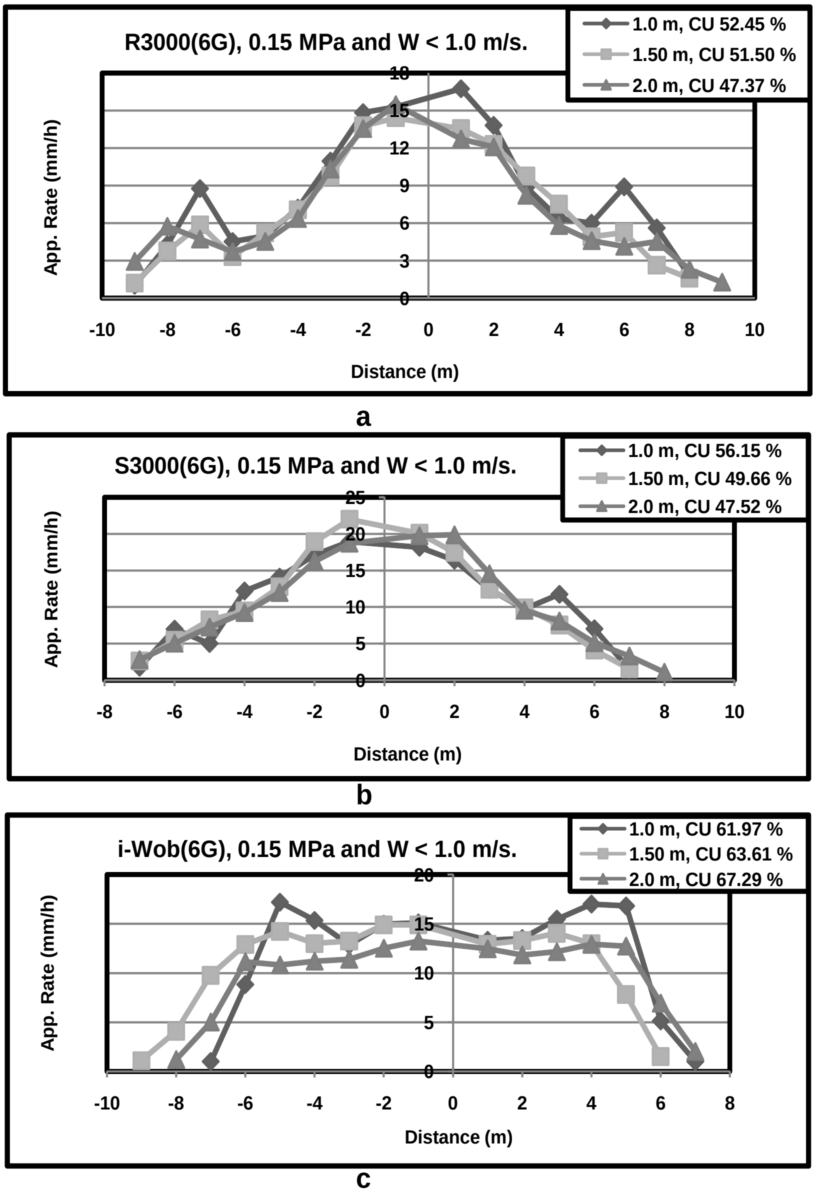


Fig. (5) Effect of nozzle height on water distribution pattern for the three tested spray nozzles (S3000, R3000 and i-Wob) of 6 grooves deflector plates.

Effect of configuration of deflector plate on water distribution pattern.

Data illustrated in Fig. (6) reveal increasing in application rate and decreasing pattern width and increasing water application near the spray nozzle for six grooves comparing with eight grooves.

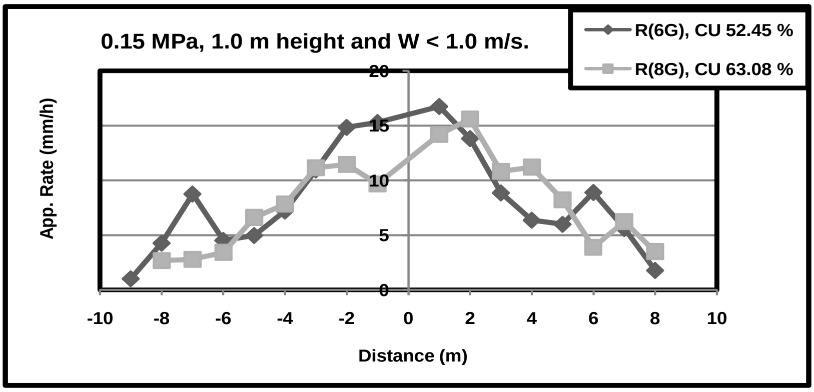
Application rate pattern depends on the number of grooves, trajectory angle and speed of plate motion.

Fig. (6) shows that water distribution patterns recorded for two different configuration of a rotating deflector plates (6 and 8G) under field conditions. The nozzles were of the same diameter and operated at the same pressure and height from the ground. The plateau found for the six grooves rotator was narrower, and therefore the application pattern was triangular, but for eight grooves the application pattern was trapezoidal. It also could be seen that application rates were higher and pattern width was lower near the spray nozzle for six grooves comparing with eight grooves.

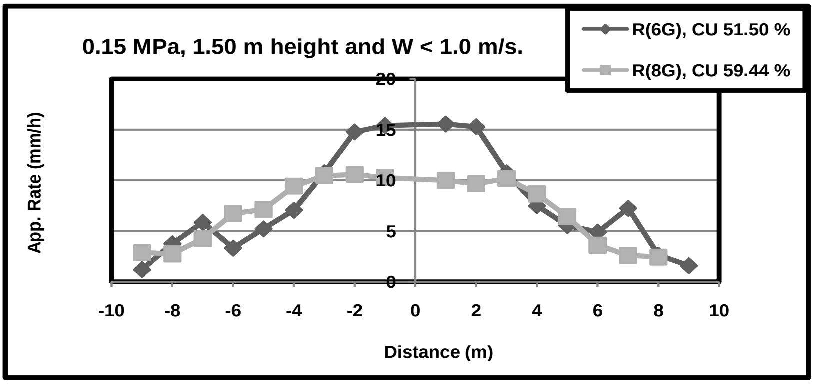
For example, Fig.(6-a) for R3000(6G)and R3000(8G) spray nozzles at wind speed W < 1.0 m/s and 1.0 , 1.50 and 2.0 m nozzle heights, for 0.15 (MPa) operating pressure, the average application rates were 8.23 and 7.46 mm/h;7.29 and 6.95 mm/h; 6.75 and 6.07 mm/h respectively, and the pattern widths were 15.50 and 15.70 m ;16.50 and 17.10 m; 17.50 and 18.50 m, respectively, and the CU values were 52.45 and 63.08 % ; 51.50 and 59.44 % ; 47.37 and 61.17 % respectively.

Regarding, the effect of speed of motion plate on water distribution pattern for the three types of spray nozzles under different conditions, we notice from Fig. (7) for R3000(6G), S3000(6G) and i-Wob (6G) spray nozzles, that the application rate pattern for a fast rotating-plate (spinner) S3000(6G), provided a more uniform application rate pattern of elliptical shape with the highest application rate near the spray nozzle.

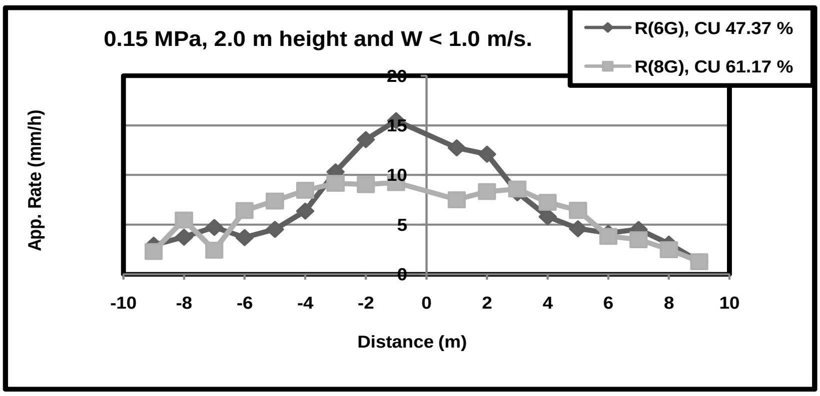
Regarding the slowly rotating-plate R3000 (6G) (Rotator), the plate provided a more uniform application rate, with increases in the wetted area of the spray nozzle and reduction in the application rate near the spray nozzle. For wobbling-plate type spray nozzle having 6 grooves, the application rate pattern was very uniform except near the sprinkler, for donut-shaped pattern.



a

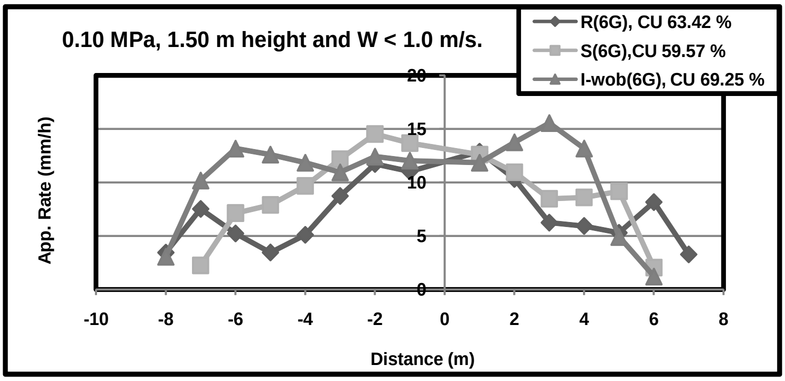


b

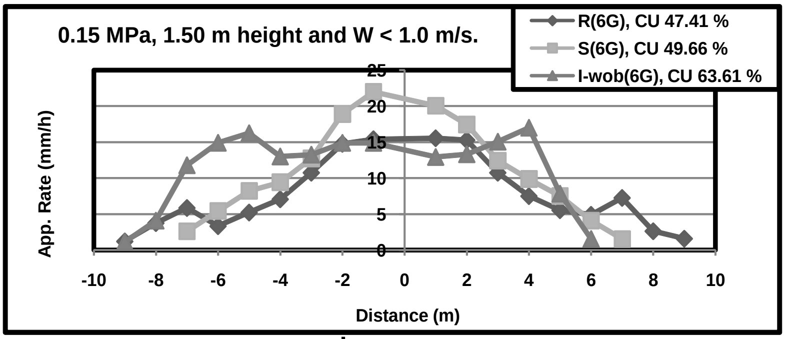


c

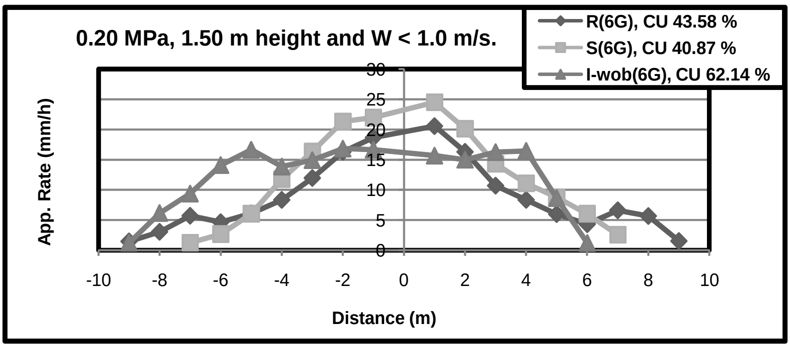
Fig. (6) Effect of configuration of deflector plates on water distribution pattern for R 3000 (6G) and R 3000 (8G) rotating spray nozzles ,under different nozzle heights,0.15 MPa operating pressure and (W) < 1.0 m/s.



a



b



c

Fig.(7) The effect of speed of motion plate on water distribution pattern for three types of rotating nozzles, 1.50 m height, under different operating pressures(MPa) and W < 1.0 m/s.

For example ,Fig.(7-a), 1.50 m nozzle height and W < 1.0 m/s for R3000(6G), S3000(6G) and i-Wob (6G) spray nozzles, for (0.10 MPa) the water application rates were 7.22, 9.17 and 10.48 mm/h and the pattern widthes were 14.80 and 13.50 m and 12.50 m, and the CU values were 63.42 , 59.57 and 69.25 % respectively .

Fig.(7-b) for (0.15 MPa)the water application rates were 7.29, 10.88 and 10.72 mm/h, and the pattern widthes were 16.50, 14.00 and 14.30 m and the CU values were 47.41 , 49.66 and 63.61 % respectively . Fig.(7-c) for (0.20 MPa) the water application rates were 8.35, 11.30 and 12.35 mm/h ,and the pattern widthes were 17.00 , 14.80 and 14.50 m and the CU values were 43.58 , 40.87 and 62.14 % respectively.

Effect of wind speed on water distribution pattern.

Considering the effect of wind speed on the application rate patterns for the three types of investigated spray nozzles i.e. R3000(8G), S3000(8G) and i-Wob(6G),from Fig.(8) it is obvious that, increasing wind speed from (W <1.0 m/s to W 2-3m/s), decreased wetted area and the coefficient of uniformity(CU) and increased average application rate for the two types of rotating spray nozzles but increased the CU value for the third type.

For example, Fig.(8-a) the performance of R3000(8G), under 0.15 MPa operating pressure and 1.50 m nozzle height caused a decrease in the wetted area from 229.54 to 128.61m² and the CU values were 59.44 and 51.29 % and on the other hand increase in the average application rate from 6.95 to 7.41 mm/h respectively. Fig.(8-b) for S3000(8G), the corresponding decrease occurred in the wetted area was from 160.52 to 113.04 m² and the CU values were 59.19 and 47.86 % whereas the increase in average application rate from 10.05 to 10.57 mm/h. Fig.(8-c) for I-wob (6G),shown that the wetted area decreased from 160.52 to 120.70 m² whereas the increase in average application rate from 10.72 to 12.14 mm/h and the CU values were 63.61 and 68.57 %.

From Fig.(9),we notice that, increasing wind speed (W) to be > 2.0 m/s produced a displacement of water application ,decreased the coefficient of uniformity (CU) and average application rate in the direction of (upwind side) and increased them in the direction of (downwind side).

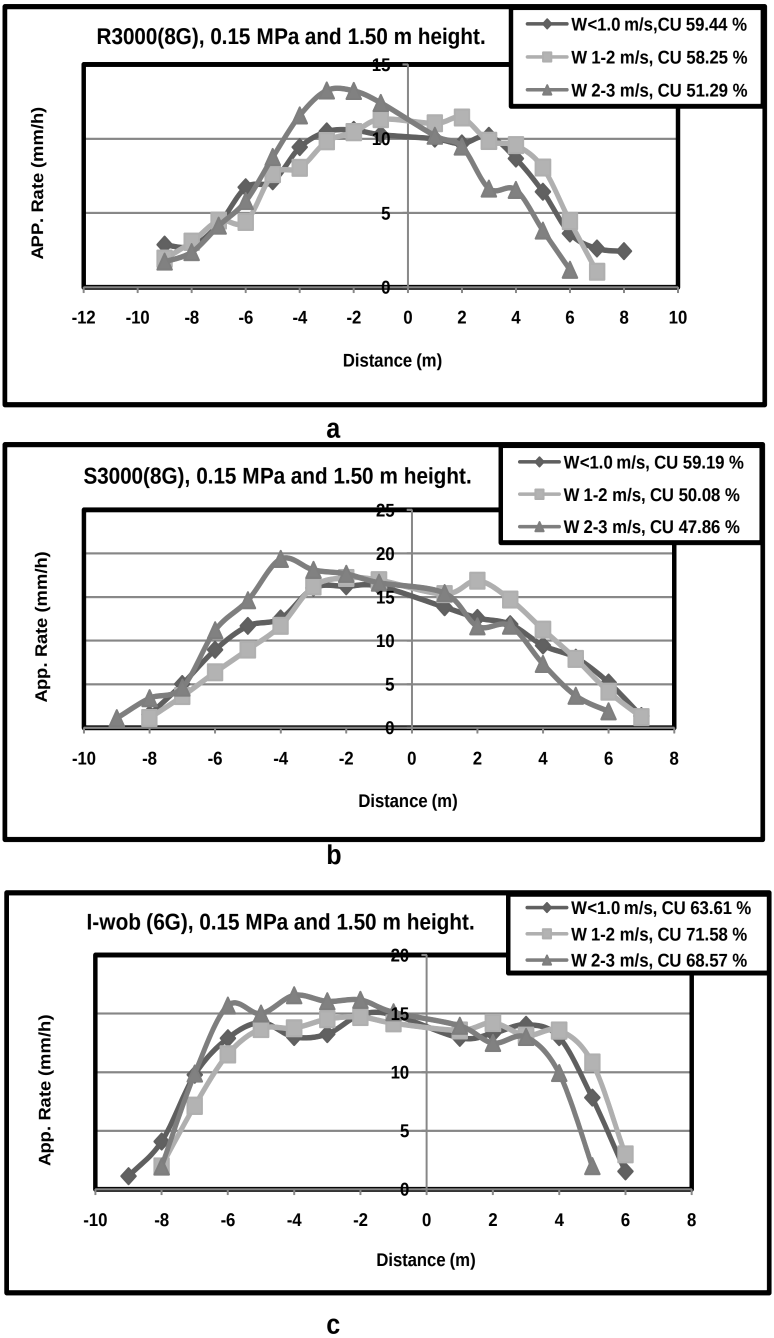
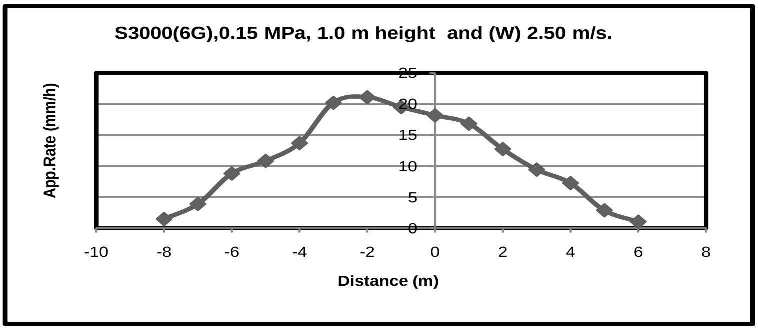
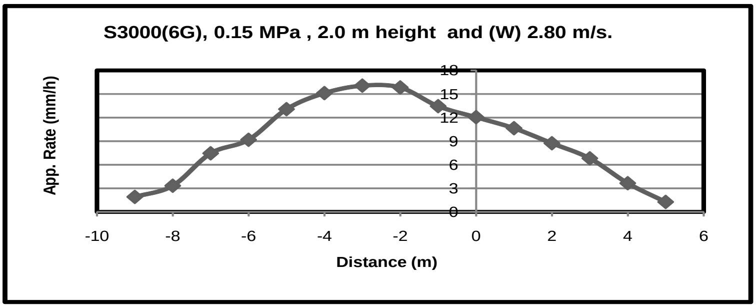


Fig.(8) Effect of wind speed(m/s) on water distribution pattern for three types of rotating spray nozzles, 0.15 MPa operating pressure and 1.50 m height.

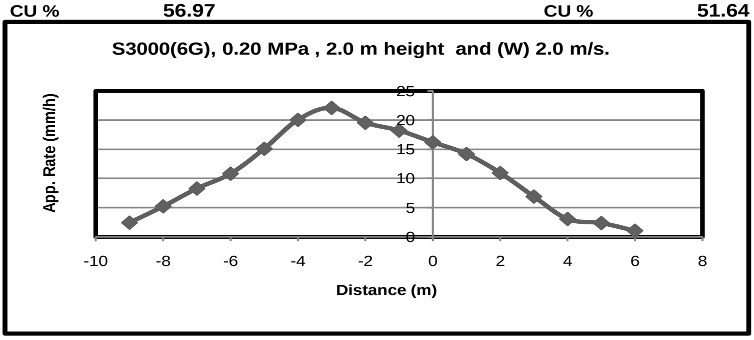
For example, from Fig.(9-a) which illustrates a S3000(6G) spray nozzle, at wind speed 2.50 m/s, 0.15 MPa for 1.0 m nozzle height, it can be found that in the upwind side



Down wind side		(a)	Up wind side	
Iav.(mm/h)	12.43		Iav.(mm/h)	8.36
CU %	50.24		CU %	44.48



Down wind side		(b)	Up wind side	
Iav.(mm/h)	10.50		Iav.(mm/h)	6.22
CU %	56.97		CU %	51.64



Down wind side		(c)	Up wind side	
Iav.(mm/h)	13.53		Iav.(mm/h)	6.42
CU %	55.04		CU %	33.51

Fig.(9) The effect of wind speed (upwind and downwind side) on water distribution pattern for S3000(6 G) spray nozzle 1.0 m and 2.0 m nozzle heights, 0.15 and 0.20 MPa operating pressures and W 2-3 m/s.

the average application rate was 8.36 mm/h, and the CU value was 44.48 % and downwind side, the average application rate was 12.43 mm/h, and the CU value was 50.24 %. But for wind speed 2.80 m/s, 0.15 MPa for 2.0 m nozzle height, it could be seen from Fig.(9-b) that in the upwind side the average application rate was 6.22 mm/h and the CU value was 51.64 % and for downwind side, the average application rate was 10.50 mm/h, and the CU value was 56.97 %. For the wind speed 2.13 m/s, 0.20 MPa for 2.0 m nozzle height, Fig.(9-c) reveals that in the upwind side, the average application rate was 6.42 mm/h, and the CU value was 33.51 %, whereas in the downwind side, the average application rate was 13.53 mm/h, and the CU value was 55.04 %.

Effect of overlap spacing on water application rate and uniformity.

The water distribution pattern, which was obtained from the single rotating spray nozzle tests, was overlapped for three overlap spacings at 3.0, 4.0 and 6.0 m intervals.

This describes the portion of the pivot that has similar sized nozzles and spacing.

Figs. (10 and 11) show that increasing the overlap spacing from 3.0 to 6.0 m decreased the CU values, and the average application rate (mm/h) under the different operating conditions.

For example i-Wob spray nozzle Figs.(10 and 11) reveal that, at wind speed (W) $<$ 1.0 m/s ,0.10 (MPa) operating pressure and 1.0 m nozzle height for 3.0 m overlap spacing, the average value of CU was 99.52 % and the average application rate was 49.57mm/h, but for 6.0 m overlap spacing, the CU value was 90.44% and the average application rate was 23.29 mm/h.

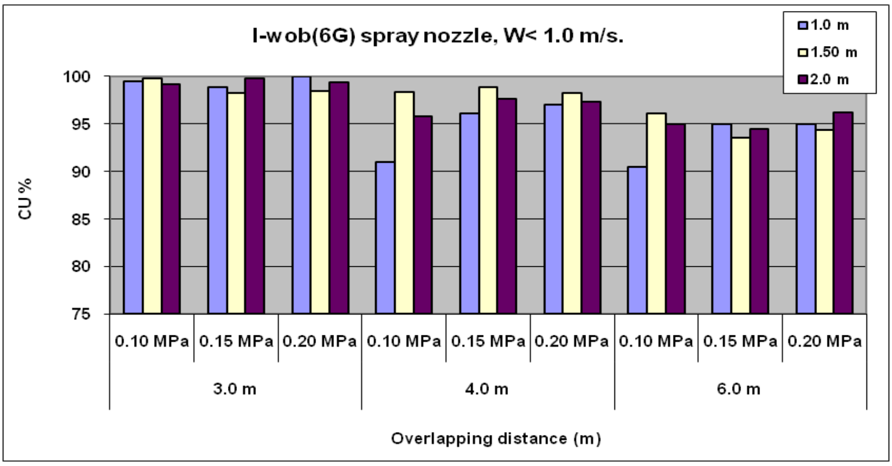


Fig. (10) Average CU (%) for I-wob (6 G) spray nozzle under different conditions of operating pressure (MPa), nozzle height(m), overlapping distance (m) and wind speed < 1 m/s.

For 2.0 m nozzle height at 3.0 m overlap spacing, the average value of CU was 99.13 % and the average application rate was 39.43mm/h, but for 6.0 m overlap spacing, the CU value was 94.96 % and the average application rate was19.26 mm/h.

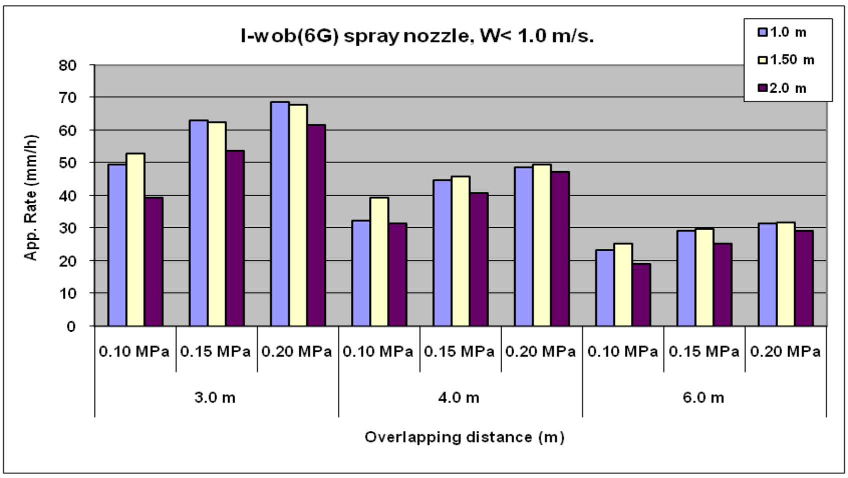


Fig.(11)Average application rate (mm/h) for I-wob (6 G) spray nozzle under different conditions of operating pressures (MPa), nozzle heights (m), overlapping distances (m), at wind speed <1m/s.

Multiple regression analysis for rotating spray nozzles was carried out to derive a relationship between technical and meteorological factors affecting irrigation uniformity. The most important factors were operating pressure P (MPa), overlap spacing S (m*m) and nozzle height h (m) (technical factors) and wind speed W (m/s)
(meteorological factor) on coefficient of uniformity CU (%) (Improvement index).
The resulting models were as follows:

$$CU = 27.77\ P + 0.245\ W + 91.32 \qquad R^2 = 0.87$$

$$CU = 3.64\ h + 0.245\ W + 90.03 \qquad R^2 = 0.93$$

$$CU = 27.77\ P + 0.245\ W - 1.46\ S + 97.6 \qquad R^2 = 0.83$$

$$CU = 3.64\ h + 0.245\ W - 1.46\ S + 96.34 \qquad R^2 = 0.87$$

The results of the regression analysis indicate that, under the experimental conditions the CU value increased with increasing operating pressure and nozzle height, but decreased with increasing overlap spacing. The models also showed that, wind speed ranged from 1-2 m/s,had very little effect on the CU value.

REFERENCES

AH KOON D.1994. L'Irrigation avec le système pivot.*PROSI Magazine* (308):22- 27.

ASAE-Standards, 50 ed. S436.1 June, 2001. Test procedure for determining the uniformity of water distribution of central pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles. St.Joseph, Mich. ASAE: 906-912.

Christiansen, J.E. 1942. ″Irrigation by sprinkling.″ Bull. No.670,
Uni.of Cal. Coll. of Agr. Exp. Station, Berkeley, 110-116.

DeBoer. D.W., Beck. D.L. and Bender. A.R. 1992. A field evaluation of low, medium and high pressure sprinklers. Trans. ASAE 35(4): 1185-1189.

Faci, J. M., Salvador, R., Playan, E., and Sourell, H. 2001. " Comparison of fixed and rotating spray plate sprinklers." J. Irrig. Drain. Engin.., 127(4), 224- 233.

Keller, J. and Bliesner, R. D. 1990. Sprinkler and Trickle Irrigation,AVI Book. New York. : Van Nostrand Reinhold. (1702).

Kincaid, D.C. 2005. Application Rates from Center Pivot Irrigation Current Sprinkler Types. Applied Engineering in Agriculture, ASAE Vol. 21(4): 605-610.

Li, J. 1997." Effect of pressure and nozzle shape on the characteristics of sprinkler droplet spectra". J. Agric. Eng. Res. 66; 15-21.

Nelson, 2003. Nelson Irrigation Corporation, Interactive Brochore,Water Application Solution. Walla Walla, WA USA. www.nelsonirrigation.com.

Sourell, H. Faci, J. M. and Playan, E. 2003. Performance of rotating spray plate sprinklers in indoor experiment. Irrigation and Drainage Eng. 129(5): 376-380.

Tarjuelo, J.M., Montero, J. Carrion, P. Honrubia, F.T. and Calvo. M.A. 1999b. Irrigation uniformity with medium size sprinklers. Part 11. Influence of wind and other factors on water distribution. Trans. ASAE 42(3): 677-689.

Thompson A.L; Martin D.L; Norman J.M; Tolk J.A; Howell T.A; Gilley J.R; Schneider A.D. 1997. Testing of a water loss distribution model for moving sprinkler systems. Transactions of the ASAE, 40(1): 81-88.

الملخص العربى

تقييم أداء الرشاشات ذات الرأس الدوارة

م.مرزوق عبدالله محمد د.منتصر عبدالله عواد ا.د محمد يوسف الأنصارى

ا.د زكريا عبدالرحمن الحداد

تم اختبار ثلاثة انواع من الرشاشات ذات المسطح الدوار والتى تستخدم فى نظم الرى بالرش المتحرك تحت ثلاثة ضغوط مختلفة هى ٠,١٠ ، ٠,١٥ و ٠,٢٠ ميجابسكال وتحت ثلاثة ارتفاعات مختلفة هى ١م ، ١,٥م و ٢م تحت الظروف الحقلية، لدراسة خصائص الآداء لتلك الرشاشات والتى تشمل: معدل اضافة المياه وشكل توزيع المياة وكفاءة التوزيع.

وقد تم ادخال البيانات الناتجة من الاختبارات الفردية للرشاش فى برنامج اكسيل ٢٠٠٣ فى عمل مسافات تداخل بين الرشاشات وهى ٣م ، ٤م و ٦ م ومنها تم حساب معدل الاضافة وكفاءة التوزيع. ويمكن لنتائج هذه الدراسة ان تساعد مصممى نظم الرى على اختيار رشاشات الرى المناسبة لتحقيق اعلى كفاءة ممكنة.

وقد اتضح ان كفاءة التوزيع تزيد بزيادة الضغط وشدة الرياح تحت ظروف التجربة، ومع التداخل الكافى، وتقل عموماَ مع زيادة المسافات.