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THE SURFACE AND SUBSURFACE WATER DISTRIBUTION UNDER CENTER PIVOT IRRIGATION SYSTEM

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ABSTRACT

The water uniformity for a center pivot system has been investigated. The surface and subsurface water uniformity was studied along the main system line and through system direction (system movement). Three sprinkler heights, (50, 100 and 125 cm) have been considered during the field experiments. The average volumetric soil moisture contents were measured at three soil depths, 20, 30 and 40 cm, to assess subsurface water uniformity. The measurements were carried out after 24, 48, and 72 hours after irrigation cycle. The results revealed that the subsurface water uniformity is higher than that the water surface uniformity. On the average, there was a noticeable decrease in the surface water uniformity measured along the main line (68.43 %) compared to that measured in the direction of system movement (80.5 %). On the other hand, there was small difference in the subsurface water uniformity measured in both directions (89.26 % along the system movement and 88.66 % along the system line). The results also was revealed that the subsurface water uniformity is less affected by the sprinkler heights compared to the surface water uniformity.

INTRODUCTION

The expectantly continuous growth of the world population increases the amount of water needed to produce more food and fiber. The agricultural sector is the most water consumer, particularly irrigation. To help conserve the irrigation water, efficient irrigation systems have been existed for decades. The sprinkler irrigation system is widely and universally spread. An efficient center pivot system is usually reflected by how the water is evenly distributed above the soil surface. This may not be an appropriate reflector of the actual water distribution in the root zone. Davis (1963) raised the importance of the water distribution inside the soil and stated that the evaluation of water distribution above the soil is not a good indicator of crop yield. For a solid

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sprinkle system, Hart (1972) assessed the evaluation of the water distribution above and below the soil surface. He noticed some differences between both methods of evaluation and emphasized on the consideration of water distribution below the soil surface when designing a sprinkle irrigation system. This study has a similar result to that reported by Ayars et al (1991). For cotton crop (IrriFrance center pivot made in France were used). These studies imply that the traditional measurement
of CU above the soil surface has to be reconsidered. Rao (2000) conducted a field experiment to study the influence of canopy on the coefficient uniformity and found that the CU below wheat canopy is higher than CU above the canopy.The increasing agricultural water use, the universal spread of the center pivot irrigation systems, and the continuously spatial and temporal changes of the field characteristics, along with other factors, encouraged the current study. The objectives of this study was carried out to determine the subsurface water uniformity and secondly the effect of sprinkler heights on surface and subsurface water distribution.

MATERIALS AND METHODS

Experiment site

The experiment was conducted at private farm – Alex. / cairo desert road. The field of experiment has an area about 16 faddans. The mechanical soil analysis revealed that the soil texture is sandy loam with 80 % sand, 7% silt, and 13 % clay. The chemical analysis of water source is shown in Table 1.

Table 1. Chemical analysis of irrigation water

				Cations (meq/l)				Anions (meq/l)		
	SP (%)	pH	EC (ds/m)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Hco_3^-	CL^-	So_4^{--}
Water	-	7.05	1.48	6.54	2.73	3.37	1.86	4.16	4.51	5.68

System characteristics

The arm length of the center pivot (Green Valley made in U.S.A.) irrigation system which used in the experiment was 145.3 m. with an inside diameter of 102 mm. The lengths of the first, second, and third towers were 42.5, 49.5, and 49.5 m. respectively. Although the system consisted of three towers, the last tower, which is away from the pivot, was considered for this study. Fixed spray type sprinklers were utilized with constant sprinklers spacing that was equal to 2.4 m.

The system was operated at a speed equal to 50 % of its maximum speed that is 3.9 m/min. The flow rate of the pivot was kept constant during the run of the experiment and equal to 22 l/s (79.2 m^3/h).

Determination of surface and subsurface water distribution

The determination of surface and subsurface water distribution was accomplished along the system main line (normal to the pivot) and along the system movement (parallel to the pivot). The surface water distribution was assessed by considering the amount of water collected in the cans, which are 15 cm height and 10 cm diameter.

For measurement along the main system line, two lines of cans were placed with an angle of 20 degree and distance equal to 3 m between each two successive cans. The distance from the pivot to the first can was 99 m. For measurement in the direction of system movement, two lines of cans were also used. The distances between the lines and the cans were 3 m and the distance from the pivot to the first line was 111m. The layout of the experiment is shown in Fig. 1.

For the subsurface water distribution assessment, the soil moisture contents were determined. The gravimetric method was utilized to measure the soil moisture contents at soil depths (20, 30 and 40 cm). " Given the difficulty of estimating water distribution underneath surface manner cans assembly was taking random samples of 10 samples / faddan under each depth mentioned experience "20, 30, 40 cm" at times the specified measurement "24, 48, 72 hours", and measure the moisture content of each sample".

The measurements were taken after 24, 48 and 72 hours. At the later, the irrigation started again. It should be noted that the mean of the measurements was considered for the determination of CU beneath the soil surface.

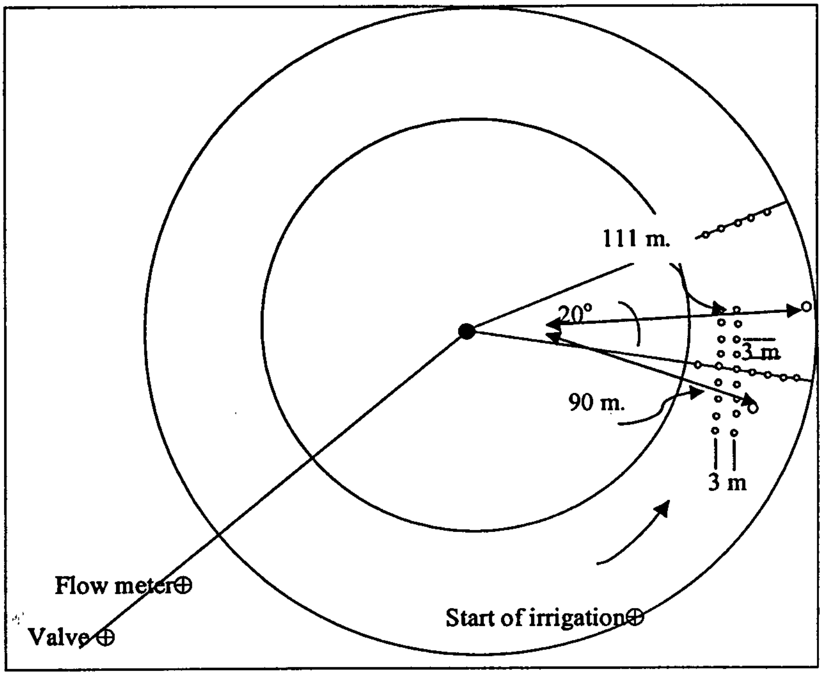

Fig. 1. Layout (Drawing Sketch) of the field experiment.

Computation of surface and subsurface water distribution

How water is evenly distributed over an irrigated filed is usually presented by uniformity terms such as coefficient of uniformity, CU. Several equations have been proposed to compute the coefficient of uniformity, CU. We calculated according to the modified Heermann and Hein's equation (ASAE Standards S436. (1994),):

$$CU_H = 100\left[1-\left(\frac{\sum_n S_n\left|D_n-\frac{\sum_n D_n S_n}{\sum_n S_n}\right|}{\sum_n D_n S_n}\right)\right] \quad (1)$$

That computed the surface soil CU along the main system line. The subsurface CU in both directions and the surface soil CU in the direction of system movement were calculated based on the Christiansen's equation,1942 (ASAE Standards S436. 1994,):

$$CU_C = 100\left(1 - \frac{\sum_{\eta} \left|D_s - \overline{D}\right|}{\sum_{\eta} D_s}\right) \qquad (2)$$

Where:

CU_H = Heermann and Hein's uniformity coefficient,
D_s = Collected depth (or soil water contents) at a distance S from the pivot,(cm^3)
S = Distance of the collector to the pivot, (m.)
s = Subscript denoting a point at S distance,
η = Number of catch containers,
CU_C = Christiansen's uniformity coefficient, and
$\overline{D}$ = Mean of collected depths (or soil water contents).

RESULTS AND DISCUSSION

Figure 2 shows the relationship between the above soil surface CU and the sprinkler height. The figure depicts that the CU, along the sprinkle main line and along the system movement, increases with the increase of the sprinkler height.

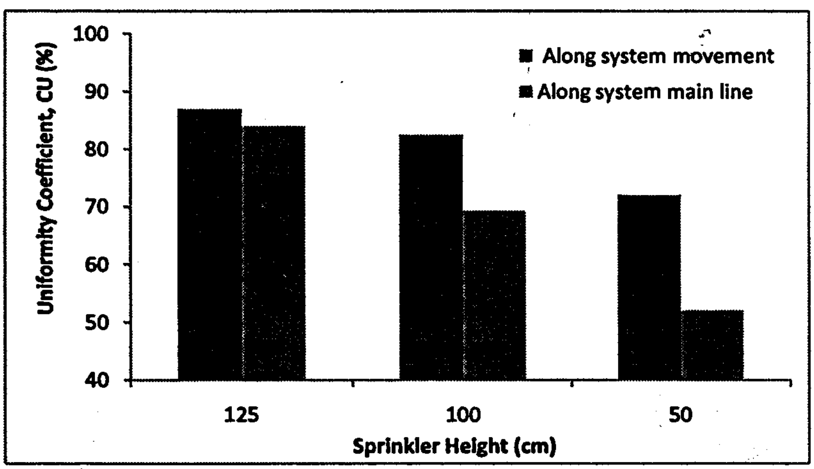

Fig. 2. Relationship between surface CU and sprinkler height

It could also be seen from the figure 2, that the variation of CU along the sprinkler main line is less than the variation of CU in the direction of the system movement. As shown in Table 2, the values of surface CU normal to the pivot were found to be 84.0, 69.3 and 52.0 % for sprinkler heights 125, 100 and 50 cm, respectively.

On the other hands, the values of the surface CU parallel to the pivot were 87.0, 82.5 and 72.0 % for sprinkler heights 125, 100 and 50 cm, respectively The average of both measuring normal and parallel 68.43% and 80.50% resp . This result agree with Hart (1972). Also the difference in values may be due to the effect of evaporation and system overlap.

Figure 3 shows the variation of the below water soil surface CU in both directions with the sprinkler heights. As can be seen from the figure, the CU gets better when the sprinkler heights increases. Unlike the surface CU, the subsurface CU values are almost identical for both directions.

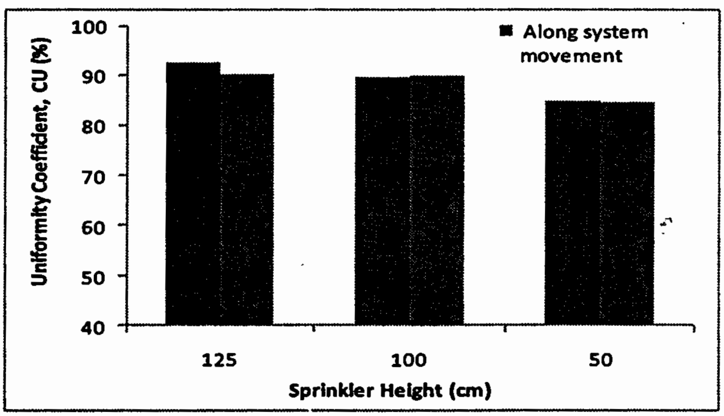

Fig. 3. Relationship between subsurface CU and sprinkler height

In other words, the values of CU along the sprinkler main line and in the direction of system movement are about the same. The insignificant variation of subsurface CU values is apparently attributed to the redistribution of water within the soil media.

This result supports and emphasizes the reconsideration of evaluating the sprinkler systems in general and the center pivot systems in particular.

Table 2 shows the average values of the subsurface CU normal to the pivot that were 90.5, 89.0 and 86.5 % for sprinkler heights 125, 100 and

50 cm, respectively. In addition, the average values of the subsurface CU parallel to the pivot were 91.8, 89.7 and 86.3 % for sprinkler heights 125, 100 and 50 cm, respectively. The average of both measuring normal and parallel for all sprinkler height's were 88.66% and 89.26% resp. This result agree with Davis (1963)., also the small difference lead to both center pivot low speed and mobility.

The subsurface evaluation of the center pivot, or even other irrigation systems, would be a difficult task to accomplish. Therefore, it is preferred to have a mathematical relationship between the subsurface CU and the surface CU.

Thus it was fortunate to possibly relate the subsurface CU to the surface CU. Since there were small differences between the values of the subsurface CU measured along the sprinkler main line and those measured along the system movement, the average values were considered as shown in Table 2.

Table 2. Values of surface and subsurface CU

Sprinkler height (cm)	Observed CU_{sur}(%)			Observed CU_{sub} (%)		
	Normal to pivot	Parallel to pivot	Average	Normal to pivot	Parallel to pivot	Average
125	84.00	87.00	85.50	90.50	91.80	91.15
100	69.30	82.50	75.90	89.00	89.70	89.35
50	52.00	72.00	62.00	86.50	86.30	86.40
Average	68.43	80.50	74.46	88.66	89.26	88.96

CONCLUSION

A field evaluation of center-pivot system uniformity was accomplished. The results indicated that the surface and subsurface CU are affected by the sprinkler heights with more significance to the surface CU. The results implied that CU increases with the increase of the sprinkler heights. The subsurface CU can be obtained from either surface CU, along the system main line or in the direction of system movement.

REFERENCES

[1]Ayars, J. E., Hutmacher, R. B., Schoneman, R. A. and Dettinger, D. R. (1991), "Influence of Cotton Canopy on Sprinkler Irrigation Uniformity." *Trans. ASAE*, 34, 890-896.

[2]Christiansen, J. E. (1942), "Irrigation by Sprinkling. California Agricultural Experiment Station". *Bulletin*, 670.

[3]Davis, J. R. (1963), "Efficiency Factors in Sprinkler System Design." Sprinkler Irreg. Assn. *Open Tech. Conf. Proc.* 13-50.

[4] Hart, W. E. (1972), "Subsurface Distribution of Non Uniformity Applied Surface Waters." *Trans. of the ASAE*, 15, No. 4, 656-661, 666.

[5] Rao, J. M. (2000), "Sprinkler Water Distribution as Affected by Winter Wheat Canopy." *Irrig. Sci.*, 20, 29-35.

[6] ASAE Standards S436. (1994),"Test Procedure for Determining the Uniformity of Water Distribution for Center Pivot, Corner Pivot, and Moving Lateral Irrigation Machines Equipped with Spray or Sprinkler Nozzles." *ASAE*, Joseph, MI 49085, 754-755.

الملخص العربي

إنتظامية توزيع المياه السطحية والتحت سطحية تحت نظام الري بالرش المحوري

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أجريت تجربة على نظام الري بالرش المحوري لبيان انتظامية توزيع المياه فوق وتحت سطح التربة، وذلك في اتجاه خط السير لجهاز الري بالرش المحوري وعلى طول خط الرش للجهاز، وبإعتبار ثلاث إرتفاعات للرشاشات (٥٠سم، ١٠٠ سم , ١٢٥ سم).

إستخدمت طريقة علب التجميع لبيان الانتظامية فوق سطح التربة، بينما استخدمت الطريقة الحجمية لتقييم الانتظامية تحت سطح التربة. وتم تقدير متوسط المحتوى المائي للتربة عند ثلاثة أعماق (٢٠، ٣٠، ٤٠ سم) وذلك بعد ٢٤، و ٤٨، و ٧٢ ساعة من الإنتهاء من الري.

أوضحت النتائج أن انتظامية توزيع المياه تحت سطح التربة أعلى من انتظاميتها فوق سطح التربة. (نظرا لصعوبة تقدير الانتظامية التحت السطحية بطريقة علب التجميع تم أخذ عينات عشوائية بواقع ١٠ عينات / فدان تحت كل عمق مذكور بالتجربة " ٢٠, ٣٠, ٤٠ سم " وفي الأزمنة المحددة للقياس " ٢٤, ٤٨, ٧٢ ساعة ", وقياس المحتوي الرطوبي لكل عينة).

وقد بينت النتائج أن هناك إنخفاضا ملحوظا في متوسط انتظامية المياه السطحية المقاسة على طول خط الرش (٦٨,٤٣ %) مقارنة بالانتظامية في اتجاه خط السير التي كانت تساوي (٨٠,٥ %).

في المقابل، وجد أن متوسط انتظامية إضافة المياه تحت سطح التربة كانت متقاربة في الاتجاهين، حيث كانت (٨٩%) في اتجاه خط السير، و (٨٨ %) على طول خط الرش.

كما بينت النتائج أن الانتظامية التحت سطحية اقل تأثرا بإرتفاع الرشاشات مقارنة بالانتظامية فوق سطح التربة.

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