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Improving The Performance of Center-Pivot Irrigation System

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Abstract :

The main objective of this research is to elucidate the performance of moved center pivot sprinklers irrigation systems under different conditions, and examine the hydraulic uniformity coefficient according to (Heermann and Hein 2007) under different system layouts. The uniformity of water application under a field center pivot (used as experimental system) is determined by setting out 102 catch containers along a line extending radially from the point 312m away from the center of the pivot. To support the result that measured form the filed, software program named (EPANET2) was used as a computerized approach to confirm the field result through the comparing between the field and the software program outputs. The filed results indicated that the overall average seasonal value of the uniformity coefficient for the field center-pivot was 73% which indicates a good uniformity coefficient. The comparison between the field results with the EPANET2 software outputs indicates a good agreements (Not exceed 5% average error). Therefore, the software used as a tool to predict the behavior of the sprinkler system under different layouts was adopted. Changing the water supply from one edge of the system to the middle point of the main pipe leads to increase the average uniformity coefficient 4.8% as compared with the traditional system, while the average percentage of improving uniformity coefficient when change the movement system from the circular motion to the rotational motion is about 5.3 %.

Key words : 1) Center-Pivot Irrigation System (C.P.) , 2) Uniformity Coefficient (CU),
3) EPANET2 Software Program.

تحسين أداء منظومات الري المركزية

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الخلاصة

إن الغرض الأساسي من هذا البحث هو بيان تحسين أداء منظومات الري المركزية المتحركة تحت ظروف مختلفة، واختبار معامل الانتظامية الهيدروليكي بالاعتماد على بحث (هارمن و هين 2007) باستخدام طرق ربط مختلفة. تم حساب انتظامية توزيع المياه للمنظومات المركزية الحقلية بنصب 102 علبة على خط يمتد نصف قطريا من نقطة تبعد 312 متر عن المركز إلى محور المنظومة. ولدعم النتائج التي تم الحصول عليها من الحقل ، استخدم برنامج يدعى (EPANET2) لتأكيد النتائج الحقلية من خلال إجراء مقارنة بين نتائج الحقل ومخرجات البرنامج. النتائج الحقلية بينت إن معدل معامل انتظامية التوزيع الشامل للموسم الزراعي يصل إلى 73 % والذي يعتبر معامل انتظامية جيد. وبعد مقارنة نتائج الحقل و مخرجات البرنامج تبين إن هناك تطابق جيد (لا يتجاوز معدل الخطأ 5 %). لذلك، تم اعتماد البرنامج كأداة للتنبؤ بسلوك المنظومة لطرق ربط مختلفة. إن تغير تجهيز المياه في المنظومة من احد الإطراف إلى نقطة في منتصف الأنبوب الرئيسي الناقل للمياه يؤدي إلى زيادة في معدل معامل انتظامية التوزيع يصل إلى 4.8 % وذلك إذا تم مقارنته مع الربط التقليدي، في حين نسبة معدل التحسين في معامل الانتظامية عن تغير حركة المنظومة من دائرية إلى دورانيه هو 5.3 %.

الكلمات الدالة: منظومات الري المركزية ، معامل الانتظامية ، برنامج EPANET2 .

Nomenclature

CU_H = Heermann and Hein uniformity coefficient.

i = is a number assigned to identify a particular collector beginning with i =1 for the collector located nearest the pivot point and ending with i = n for the most remote collector from the pivot point.

n = number of collectors used in the data analysis.

V_i = the volume (or depth) of water collected in the i^{th} collector.

V_p = the weighted average of the volume (or depth) of water caught.

S_i = the distance of the i^{th} collector from the pivot point.

Introduction

Iraq is a country known historically to be the cradle of ancient civilization, which has risen in the area based upon a well-planned agriculture and ample production. Ruins of these civilizations remaining up to this day reveal the understanding and implementation of irrigation for agricultural production.

Surface irrigation of agricultural crops has been practiced for many decades ago. However, irrigation using pressurized systems has only been around since the early 1900s and the very first center-pivot machine was developed only in the late 1940s. By the mid-1970s, center-pivot and lateral move machines were rapidly starting to dominate the new and expanding irrigation areas in the USA and Middle East. Center-pivot was first introduced into Australia in the 1960s. However, center-pivot irrigation of cotton has been undertaken in the USA sine the late 1960's and Australia sine the early 1970s (Foley J.P. 2001)[3].

Center-pivot system is one of the most important systems newly enter to our country. Thus, proper evaluation and improvement of this system in Iraq is very important to identify major problems and to suggest possible measures to insure better performance. Center-pivot system has been quite well perfected, which it is mechanically reliable, simple to operate and economically water distribution. A sprinkler water distribution pattern in the center-pivot depends on the system design parameters such as: the operating pressure, nozzle diameter, and environmental variables such as: wind speed and direction (Keller J. 1990)[4].

Most of farmers as a result of experiment lack and avoid using the system manual, reduces the efficiency of the system and decrease the uniformity (Alamirew T. 2012)[1].

In this study an alternatives ways will be discuss to improve the uniformity coefficient, and one of these alternatives is by changing the layout, and because of the difficulty to change the layout system in the field due to the cost issue, EPANET2 program has been adopted and used to exam the improving by changing the water supply from the pivot point to the middle main pipe, to improve the hydraulic pressure in the system.

Experimental Work

To compare the result that measured from the EPANET2 software program, we need to evaluate one field center-pivot system, which is located at Hilla city 90 km south-east of Baghdad (44^0 47' 24.19" E & 32^0 31' 30" N). which. All the practices of irrigation like, time of application, applied discharges, frequency of irrigation, and agricultural practices decided upon by the farmers or the operators in order to evaluate actual performance of the center-pivot systems. The uniformity of water application under a center pivot is determined by setting out 102 catch containers, the container size is 11cm diameter and 9cm height located at one line extending radially from the point 312m away from the center of the pivot at 3m spacing between each container **Figure.(1).**

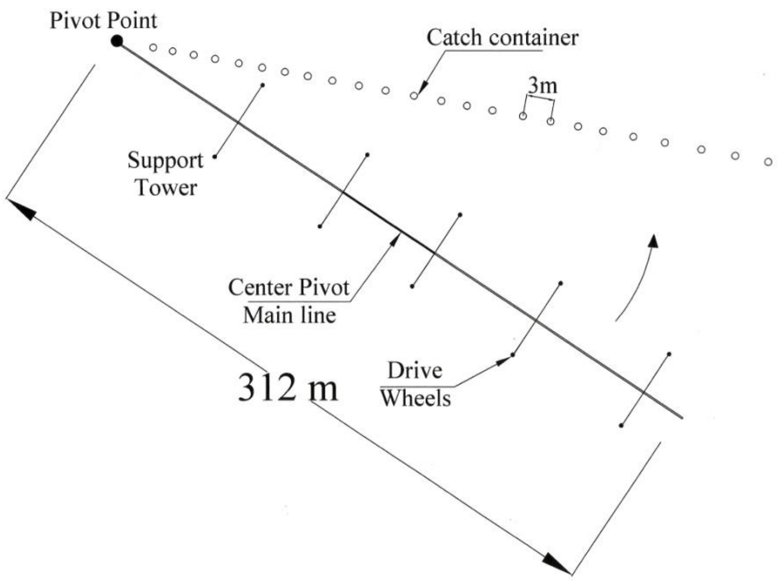


Fig .(1) the catch containers setting wit the field center pivot irrigation system

The most important parameter is the center pivot coefficient of uniformity, CU. This coefficient defines how uniform water is being distributed over the area being irrigated and can be calculated by using the modified formula of Heermann and Hein (2007)[5]:

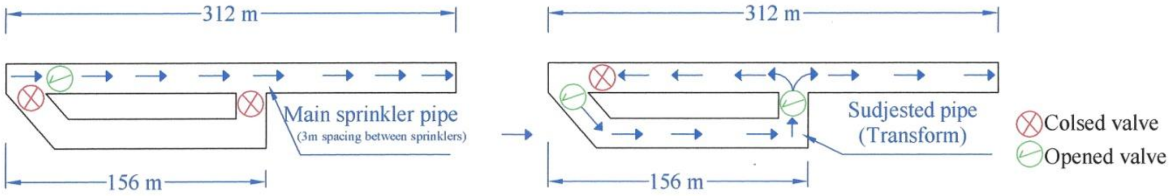
$$CU_H = 100 * \left[1 - \frac{\sum_{i=1}^{n} S_i \left| V_i - V_p \right|}{\sum_{i=1}^{n} V_i S_i} \right] \quad \dots \quad \dots\dots\dots\dots\dots\dots \text{(1)}$$

Where:

$$V_p = \frac{\sum_{i=1}^{n} V_i S_i}{\sum_{i=1}^{n} S_i} \quad \dots \quad \dots\dots\dots\dots\dots\dots \text{(2)}$$

The Theoretical Approach

To support the field system evaluation, the EPANET2 software program was used to evaluate and improve the uniformity coefficient by change the water supply connection from the center to the middle of the main pipe line. This connection will lead to decrease the pressure looses through the main pipe system since it decrease the distance to the end point of the main pipe**. (Figure. 2)** show the water direction for both cases.



(a) Traditional center water supply **(b) Proposed middle water supply**

Fig .(2) System layouts.

Results and Discussion

After the center –pivot data measured and gathered, it was found that the values of uniformity coefficient were good for most irrigation set numbers throughout the season. The overall average seasonal value of the uniformity coefficient for the field system was 73% which indicates a poor field uniformity coefficient (ASABE 2007)[2]. The results of evaluation the field center-pivot irrigation systems are shown in **Table**.(1).

Table (1) Evaluation Results for The Field Center Pivot Irrigation System

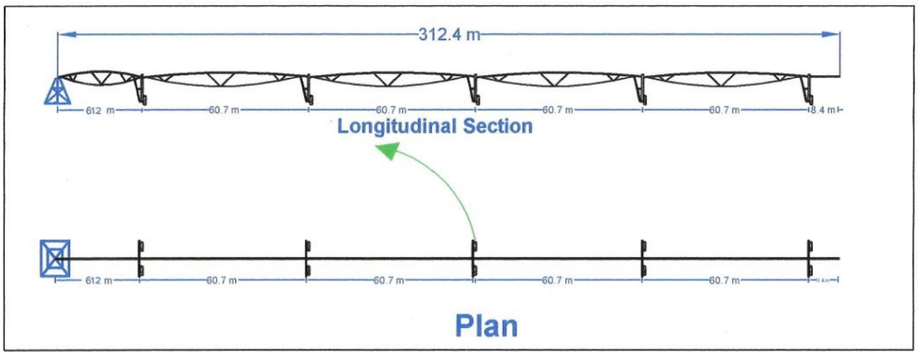
Evaluation parameter	Field system
Spray losses	39%
Runoff losses	0%
Deep percolation losses	38%
Distribution uniformity	72%
Uniformity coefficient	73%
Irrigation efficiency	33%
Crop production or	1.8 ton/ha
	2.1 kg/m^2

The average value of uniformity coefficient for the proposed system by using EPANET2 software was increased by 4.8 % as compared with the traditional system. **Table.(2)** shows the comparison between the two cases at different water pressure condition.

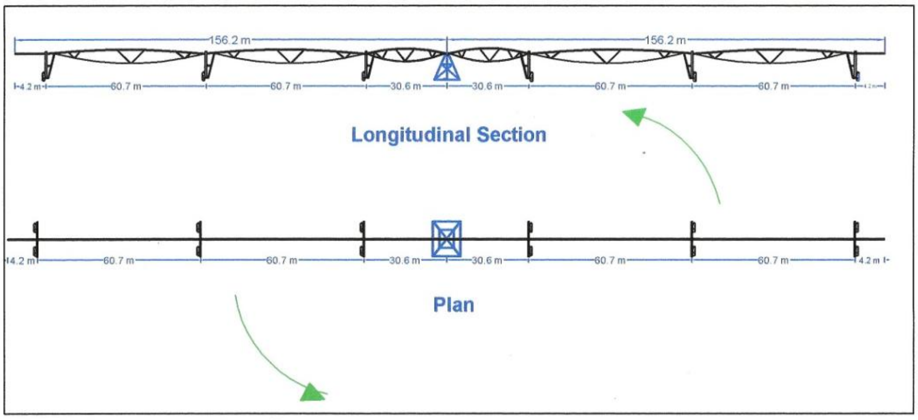
Table .(2) The Variation of Uniformity Coefficient in The EPANET2 Software Program at Different Pressure Conditions

Pressure (kpa)	Coefficient of Uniformity (%)		The Improving (%)
	Center Water Supply	Middle Water Supply	
100	90.2	96.3	6.1
120	90.33	96.35	6.02
150	90.47	96.32	5.85
170	90.71	96.25	5.54
200	92.41	97.7	5.29
220	93.44	98	4.56
The average improvement = 4.8%			

Another alternatives could be done by changing the traditional system (circular motion) to the rotational motion, which will allow to use the same system of irrigation without additions and at the same time suppose to reduce the losses to half. **Figure (3)** shows the comparison between the two motions.



(a) Circular Motion



(b) Rotational Motion

Fig .(3) Circular and rotational system layouts.

The average percentage of improving uniformity coefficient for the change the of movement system from the circular motion to the rotational motion is about 5.3 %. **Table (3)** shows the variation of uniformity coefficient in the EPANET2 program when changing the movement system.

Table .(3) The Variation of Uniformity Coefficient for the Rotational Water Supply as Compared With the Traditional System.

Pressure (kpa)	Coefficient of Uniformity (%) Circular Water Supply (traditional)	Coefficient of Uniformity (%) Rotational Water Supply (proposed)	The Improving (%)
100	90.2	96.34	6.14
120	90.33	96.6	6.27
150	90.47	97.34	6.87
170	90.71	97.68	6.97
200	92.41	98.04	5.63
220	93.44	98.23	4.79
The average improvement = 5.3 %			

Through comparison between the data that measured from the field and the result obtained from the Program, it was found that there are almost matches between them, and an improvement in the operation system was obtained. It is obvious through the raise that is occurred in the pressure as shown in **Figure.(4).**

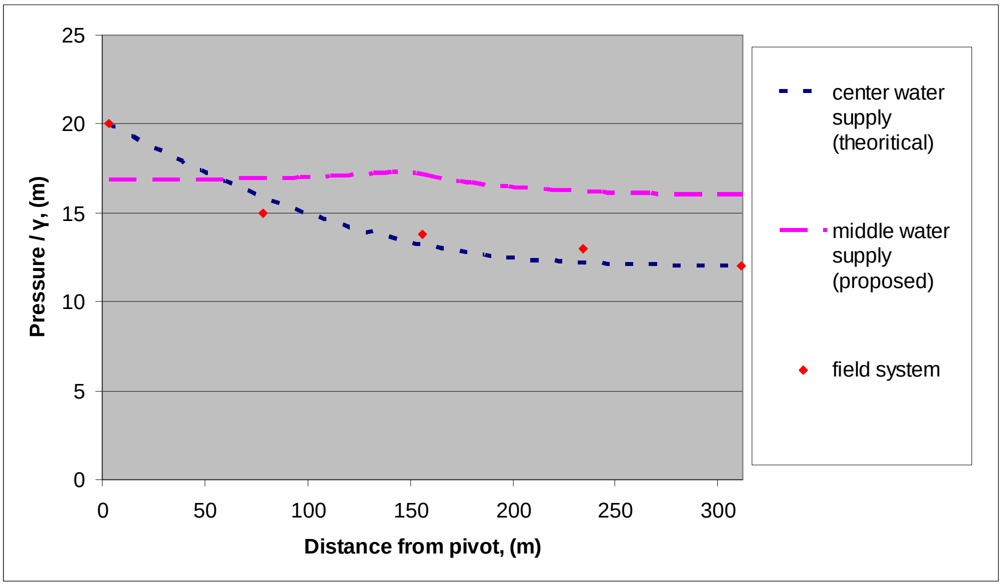


Fig. (4) Pressure Distribution Curve Using Traditional and Proposed System Layouts.

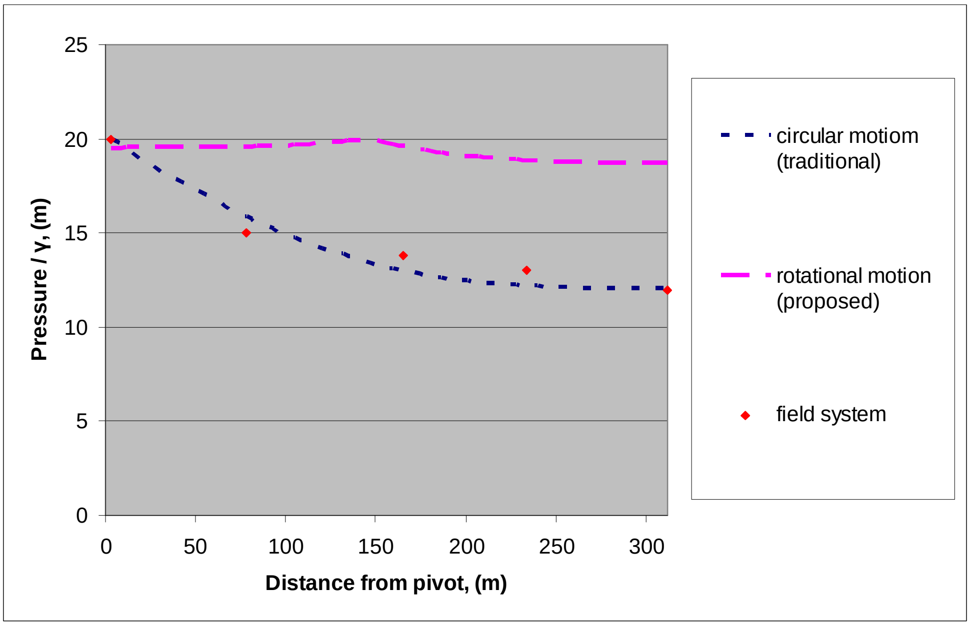


Fig .(5) Pressure Distribution Curve Using Traditional Circular and Proposed Rotational Motion.

Conclusions

The following conclusions can be drawn:

1- The overall average seasonal value of the uniformity coefficient for the field system was 73% which indicates a poor field uniformity coefficient.

2- The coefficient of uniformity could be increased by changing the water feed point. The average improvement percentage in CU values was 4.8 %.

3- It is possible to change the circular motion of the center-pivot to the rotational motion **Figure.(3)**, this will allow to use the same system of irrigation without additions and at the same time reduce the losses to half.

4- The average percentage of improving uniformity coefficient when change the movement system from the circular motion to the rotational motion is about 5.3 %.

References

1. **Alamirew T., "Evaluation coefficient of uniformity for center pivot sprinkler irrigation ", trans. Global Journal of Biology, Agriculture and Health Sciences (G.J. B.A.H.S) Vol.1 (1) PP. 17-21 (2012).**

2. **ASABE, "Test Procedure for Determining the Uniformity of Water Distribution of Center Pivot and Lateral Move Irrigation Machines Equipped with Spray or**

Sprinkler Nozzles ", Trans. ANIS/ASAE S436.1 revision approved Oct. (1997); reaffirmed Jan. (2007).

3. **Foley J.P, "Center Pivot and Lateral Move Machines In The Australian Cotton Industry ", Trans. National Centre for Engineering in Agriculture (NCEA), University of Southern Queensland, Toowoomba. Vol. (1) (2001).**
4. **Keller J. "Sprinkle and trickle irrigation ", An AVI Book. Published by Van Nostrand Reinhold. New York PP. 307-388 (1990).**
5. **Heermann, D, and Hein P, "Performance Characteristics and Self-propelled Center-Pivot Sprinkler Irrigation Systems", Trans. of the ASAE, Vol.13, No.6, PP.790-794, (2007).**