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Improvement the Performance of the Center Pivot Irrigation System under Limited Water Supply to Irrigate Sugar Beet Crop in West West Mania, Egypt.

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ABSTRACT

This research aims to explore different strategies to operate the systems of center pivot when facing the problem of limited water supply or not receiving enough water to operate as designed to irrigate the total area. Four different scenarios were evaluated: Irrigated full circle (CP1) control, irrigated three-quarter circle (CP2), irrigated half circle (CP3), and irrigated full circle with removing one span (CP4). The results showed that the distribution uniformity (DU) was excellent for all scenarios, with values of 92.7, 92.8, 93, and 94 for CP1, CP2, CP3, and CP4 respectively. Also, the coefficients of uniformity (CU) values were 94.5, 93.8, 95.2, and 97.9 for CP1, CP2, CP3, and CP4 respectively. The irrigation water productivity was the highest in the CP4 treatment, which was 9.17 kg/m^3 but the lowest value in CP1, which was 6.56 kg/m^3, which was higher by 39.8% compared to CP1 treatments. The highest yield was obtained for CP4 treatment, which was 28 tons/fed, which was higher by 16.7% compared to CP1 treatments. The irrigation water applied was the highest in the CP1 treatment; it was 3660.5 m^3/fed but the lowest values in CP4, was: 3053.6 m^3/fed, the results indicate that the CP4 treatment utilized less water compared to the CP1 treatment, saving water by 16.6%. In conclusion, when of limited irrigation water, the best solution is to remove one of the axis towers from the center pivot which results in the highest yield and irrigation water productivity.

***Keywords*: Center pivot, distribution uniformity, irrigation water productivity, water applied, sugar beet.**

INTRODUCTION

Center pivot irrigation systems have seen a significant increase in usage in Egypt. The reasons for this growth include their ability to efficiently and uniformly apply water, high level of automation that reduces the need for manual labor, large area coverage, and their economic application of water and water-soluble nutrients across a wide range of soil, crop, and topographical conditions. Despite their advantages, center pivot systems may encounter issues with a decrease in water supply during the growing season, particularly in locations with varying water supply capacity in aquifers and wells. This problem is prevalent across the Great Plains and other areas. (Martin et al. 2019). McDougall (2015) found that the flow rate from irrigation wells often decreases during the irrigation season. He studied 28 wells and found that the discharge from 6 of them decreased by more than 30% during the season, with an average decline of 19% for all wells. According to AL-Ghobari (2010), the performance of center pivot should be evaluated on a regular basis, ideally two or three times per year. However, due to the diversity of climates, soil types, plant types, and system characteristics, it can be challenging to generalize the results of these evaluations to other regions. Studies have also been conducted on the uniformity of water distribution in center pivot systems, with Sui and Fisher (2015) finding a coefficient of uniformity (CU) of 86.5% for a constant water application rate and 84.3% for variable rates with the highest CU of 89.2%. Martin et al. (2019) found that uniformity of application can vary depending on inflow rate, with pressure regulators improving uniformity on sloping fields when inflow is at or above design inflow, but potentially reducing uniformity when inflow is well below design values. In cases where it is not possible to increase flow, re-nuzzling or adjusting the rotation speed of the pivot may be considered to enhance field uniformity on sloping or undulating fields. Sabah et al. (2011) suggest evaluating the center pivot system using three measurements: distribution and coefficient of uniformity (DU) and (CU), and application efficiency of low quarter (PELQ). CU ratings of 90%-95% are deemed excellent, 85%-90% are deemed good, 80%-85% require inspection and sprinkler package check, and below 80% require adjustments to the sprinkler package, changes to the default system, and full maintenance. DU is calculated by dividing the weighted average of the lowest 25% of catch cans by the weighted average of all catch cans, with values of 85% or greater deemed excellent, 80% deemed very good, 75% deemed good, 70% deemed fair, and 65% or less deemed poor and unacceptable. Harrison and Perry (2007) divided pivot coefficient uniformity (CU) values into four categories: excellent (CU values over 90%), good (CU values between 85% to 90%), fair (CU values between 80% to 85%), and poor (CU values less than 80%). This highlights the importance of maintaining a high uniformity coefficient in irrigation systems to achieve optimal water application. Hines and Neibling (2013) reported that irrigation with a pivot can be pose difficulties in arid areas, where daily evapotranspiration may be higher than the pivot's water application rate, particularly during the growing season which usually coincides with high

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summer temperatures. To overcome these challenges, can reduce the effects of drought stress by including pivot design and operation, soil types and crop water needs. This includes optimizing pivot design, selecting appropriate soil types, and properly operating and maintaining the pivot system, as well as considering crop water requirements and incorporating additional management practices to improve water-use efficiency. Derrel Martin, et al. (2017) reported that managing limited water resources requires careful consideration of the extent of area to be irrigated and the amount of water to be applied to the field. This decision involves evaluating the profitability of the dry land crop versus the irrigated crop, and requires the calculation of the net return from irrigation. This metric takes into account only the costs directly associated with irrigation and can be used to compare the financial viability of different irrigation strategies. If a cost does not change based on the irrigation depth or the area irrigated, then it will not impact the distribution of water. The total water available for the year must be divided and allocated to the area that will be irrigated. The irrigated area can be calculated using the equation:

$$A_{irri} = \frac{w_s}{d} \quad ......(1)$$

Where A_{irri}: the area irrigated, d: the depth of water applied and Ws: the available water supply in acre-inches. This equation can be used to determine the most profitable irrigation strategy, given a fixed amount of water.

Sugar, a strategic commodity in Egypt, is produced from both sugar cane and sugar beet crops (MALR, 2018). Sugar beet has become a strategic crop in Egypt, particularly due to the decline in cultivated areas of sugar cane and its high water usage of around 12,000-13,000 m^3 per hectare (CAPMAS, 2018). To address this, Egypt is focused on increasing sugar beet production and encouraging farmers to plant in new areas, particularly in northern Egypt. Currently, sugar beet represents about 75% of the total cultivated area for sugar production in Egypt (CAPMAS, 2018). According to Allen et al., (1998), (2011a), The sugar beet's crop-coefficient (Kc) different across various growth stages, with values spanning from 0.4-0.5 at the initial (25 to 30 days), 0.75-0.85 during development (35 to 60 days), 1.05-1.2 mid-season (50 to 70 days), 0.9-1.0 late-season (30 to 50 days) and 0.6-0.7 at harvest. Sugar beet's total water needs range from 550 to 750 mm per growing period, subject to climatic conditions and the growth period's duration. The timing of planting also affects crop development, with autumn-sown crops taking 140 days, spring-sown crops taking 90 days, and late spring/early summer-sown crops taking 60 days to reach maximum height.

This research aims to address the issue of center pivot irrigation systems not receiving enough water to operate as designed or to irrigate the total area. The study aims to explore different strategies to overcome the problem of limited water supply to the pivot. Scenarios applied in this research:

1-Using an End of Field Kit allows for the rotation of the pivot irrigation system at a specific angle, thus covering only a portion of the area.

2-Removing one tower to reduce the flow rate supplied to the pivot, making it more suitable for the area being irrigated.

MATERIALS AND METHODS

The Study area's description

The experiment was carried out on a farm, in West West of El-Menia Governorate. The hyper-arid climatic region is located at latitude 29°57\47\\ N, and longitude 28°23\34\\ E. field evaluations were carried out utilizing the Merriam and Keller (1978) and ASABE Standard, S436.1 (2007). The average lowest and highest air temperatures were 3.11°C and 41.0°C, respectively, with relative humidity fluctuating between 26 and 49 %, wind speeds ranged (1.5 to 6.3 m/s).(West West Metrological Station).

Soil type and its characteristics

The experimental site's soil is categorized as sandy soil. Tables (1 and 2) outline physical and chemical properties of the soil. Table (3) presents the irrigation water chemical characteristics, including pH, EC, and the concentrations of various soluble cations and anions, flowing through the experimental region.

Table 1. Physical properties of soil at the beginning season.

Soil Depth (Cm)	Particle size distribution Sand, %	Silt, %	Clay, %	Soil Texture	Bulk Density Mg/m^3	Field capacity, %	Wilting point, %	Available water, %
0-20	88.0	7.5	4.5		1.30	10.1	5.5	4.6
20-40	86.5	7.8	5.7	Sandy	1.35	10.5	4.3	6.2
40-60	85.5	8.3	6.2		1.35	11.0	4.4	6.6

Table 1. Soil chemical characteristics of the experimental site

Soil layer, Cm	pH	E.C, dS/m	Soluble anions, meq/l				Soluble cations, meq/l			
			CO_3^-	HCO_3^-	Cl^-	SO_4^-	Ca++	Mg^{++}	Na^+	K^+
0 –20	7.8	4.4	0	2.5	24.2	12.5	12.3	5.6	22.9	2.2
20-40	7.9	5.3	0	4.2	29.3	18.3	19.4	6.6	26.8	2.5
40-60	7.9	6.7	0	5.5	32.4	22.3	23.5	7.4	29.7	2.7

Table 3. Chemical Characteristics of Irrigation Water in the Study Region.

pH	EC, dS/m	Soluble cations, meq/L				Soluble anions, meq/L			
		Ca^{+2}	Mg^{+2}	Na^+	K^+	$CO3^{-2}$	HCO^{-3}	SO_4^{-2}	Cl^{-1}
7.5	3.7	4.36	2.81	7.6	0.13	0.0	1.32	5	8.58

Sugar beet cultivation and harvesting seasons

Two field experiments were conducted on sugar beet (Avantage) during the seasons of 2019/2020 and 2020/2021. The first experiment was planted on October 3st, 2019 and harvested on May 1st, 2020 with crop duration of 214 days. The second experiment was planted on October 15th, 2020 and harvested on May 17th, 2021 with crop duration of 215 days. The crop growth was divided into four stages: initial stage (25 days), crop development (64 days), mid-season (76 days) and late season stage (50 days). The recommended agricultural practices for growing sugar beet as per the Ministry of Agriculture and Land Reclamation (MOALR 2018) were followed throughout the experiments.

Integrated-agricultural water management

Integrated agricultural water management analysis was conducted to estimate the crop evapotranspiration and gross water requirements. Table (4) displays the average reference evapotranspiration (ET_0), crop evapotranspiration (ET_c) and gross water requirements (GWR) for the study area. Meteorological data were obtained daily from the West West Mania Meteorological Station, according to the Egyptian Ministry of Agriculture's data. The reference evapotranspiration (ET_0, mm/day) was computed utilizing the Penman-Monteith (PM) formula as described in the FAO protocol (Allen et al., 1998) for the purpose of irrigation scheduling. Crop evapotranspiration (ET_c) was calculated as:

$$ET_c = K_c \times ET_0 \quad .... (2)$$

Where:-

ET_c = Crop evapotranspiration (mm/day), Kc = Crop coefficient,
ET_0 = Reference evapotranspiration (mm/day).

Gross water requirements (GWR) were calculated as:

$$GWR = (ET_o * Kc) * LR * 4.2/Ea \quad .... (3)$$

Where:-

GWR = Gross water requirement for crop m^3/Fed./day,

Kc = Crop coefficient [dimensionless] as table (5),

ET_o = Reference evapotranspiration [mm/day].

LR = Leaching requirement (%) (Assumed 10% of the total applied water).

Ea = Efficiency of irrigation water system, % (Assumed 80%). 4.2 is a conversion factor applied to convert from millimetres per day to cubic meters per Feddan per day (Feddan = 4200 m^2). (Allen et al., 1998).

Table 4. Average reference evapotranspiration (mm), Crop coefficients and Crop evapotranspiration (mm) during (2019/2020) and (2020/2021) seasons.

Month	Days	ETo, mm	Kc	ETc, mm	Days	ETo, mm	Kc	ETc, mm
	Season 2019/2020				Season 2020/2021			
Oct.	25 3	6.44 4.73	0.5	3.22 5.47	16	6.00	0.5	3
Nov.	30	4.73	0.85	4.02	9 21	4.67		2.34 3.97
Dec	31	3.8		3.23	31	3.35	0.85	2.85
Jan.	31	2.6		2.6	10 21	3.19		2.71 3.19
Feb.	29	3.62	1.0	3.62	28	3.51	1.0	3.51
Mar.	16 15	5.2		5.2 3.64	26 5	4.8		4.80 3.36
Apr.	30	7.3	0.7	5.11	30	5.40	0.7	3.78
May.	1	8.2		5.74	17	8.00		5.60
Average, %		5.62		4.2		4.86		4.55

Table 5. The average crop coefficients (Kc) for sugar beet (Allen et al., 1998).

Item	Init.	Dev.	Mid.	Late.	Total.
Days	25	64	76	50	215
Kc	0.5	0.85	1.0	0.7	

Water Productivity (IWP, kg/m^3)

The water productivity (WP, kg/m^3) is the ratio between the yield obtained and the water utilized to generate that yield. This ratio assesses the effectiveness of water use in crop production and is frequently employed in lieu of the term "water use efficiency," as noted by Pereira et al. (2012) and Paredes et al. (2017).

$$WP = \frac{Ya}{TWU} \quad \text{-------------------- (4)}$$

Where:-

WP = Water Productivity, kg/m^3:

Ya = Total yield, Kg /fed., and

TWU = Total water consumed m^3/fed/season.

Equipment description and experimental treatments

The equipment used in the experiment included catch cans that were placed along lines extending radially from the pivot point of the center pivot irrigation system. The catch cans were positioned at a sufficient distance from the pipeline to allow for proper testing conditions. They were spaced 5 meters apart in two rows, with the first can located 12 meters from the pivot point, for a total of 80 and 65 cans as per the guidelines provided by Merriam and Keller (1978). At the commencement of the pivot system, water must not flow into the cans until the unit reaches its complete pressure and velocity. The catch cans, which were 10 cm in diameter and 15 cm tall, were utilized to gauge the quantity of water dispensed by the irrigation system. The center pivot irrigation system in use consisted of 7 and 6 towers, with a distance of 56.1 meters between towers. Pivot manufactured by Alkhorayef Industries Company, branded as WASTERN. The volume caught by each can was calculated by multiplying the depth of water by the represented area. The operating speed of the system was set at 100% and no end-gun sprinkler was installed. Nominated flow rate delivered from the pump was 190 m^3/hr while the actual one was measured as 160 m^3/hr. New sprinkler chart is created per each treatment and evaluated using catch cans way to confirm the actual application depth. The characteristics of the pivot irrigation system are presented in table (6) and the pivot irrigation system treatments are presented in table (7).

Table 6. The characteristics of center pivot irrigation system.

Length of	Number of spans	Discharge of system m^3/hr	Pivot Base Pressure (Bar)	Total number of sprinklers	Pivot End Pressure, (Bar)	Total irrigated Area/fed.	System length, m	Circle degree
56.1	7	190	1.96	177	1.0	125	410*	360
56.1	7	190	1.96	177	1.0	93.75	410*	270
56.1	7	190	1.96	177	1.0	62.5	410*	180
56.1	6	190	1.84	127	1.0	84.7	336.6	360

Application rate, 8.7 mm/day - * Total length system include the overhang of the center pivot (18 m).

Table 7. Performance parameters for center pivots and experimental irrigated treatments CP1, CP2, CP3 and CP4.

Treatments	Actual flow rate, m^3/h	Pivot Base Pressure (Bar)	Wetted area (fed.)	Time per rev. (hrs)	Number of spans	Average degrees Circle swept	Pivot End Pressure, (Bar)
CP1	160	1.78	125	10.5	7	Full Circle	1.0
CP2	160	1.78	93.75	7.9	7	Three-quarter circle	1.0
CP3	160	1.78	62.5	5.2	7	Half Circle	1.0
CP4	160	1.62	84.7	9	6	Full Circle	1.0

CP speed (m/min) 3.94 - The operating speed of the system was set at 100%.

Methodology and Equations to calculate the Uniformity Coefficient of Uniformity (CU)

The modified Heermann and Hein formula (ASAE 1996) was used to determine the coefficient of uniformity along the radial direction for the center pivot irrigation system. The formula is given by:

$$cu(\%) = \left[1 - \frac{\sum_{i=1}^{n} |D_i - \bar{D}_w| S_i}{\sum_{i=1} D_i S_i}\right] \times 100 \quad ....(5)$$

where cu = the coefficient of uniformity (%), N is the total number of the catch cans utilized in the data analysis, D_i is the depth of water collected in the i^{th} catch can (mm), S_i is the distance of the I th catch can from the point (m), and D_w is the weighted average depth (mm), calculated as:

$$\overline{D_w} = \frac{\sum_{i=1}^{n} D_i S_i}{\sum_{i=1}^{n} S_i} \quad .... (6)$$

Distribution Uniformity (DU)

The distribution uniformity can be evaluated using the catch can test, which determines the distribution uniformity (DU) coefficient. This coefficient considers the average of the lowest 25% of readings obtained from test cans and compares it to the overall average of all readings. The DU provides an indication of the degree of distribution problems, calculated as:

$$Du = \frac{D_S}{D_{ave.}} \times 100 \ldots\ldots(7)$$

Where:
D_u = distribution uniformity (%),
D_s = average depth caught in the lowest quarter of the catch cans, and
D_{ave}= average depth of water accumulated in all cans.

Lowquarter actual water application efficiency (AELQ)

The AELQ obtained in the field serves as an indicator of the system's performance. If the average depth of irrigation water infiltrated in the lowest quarter exceeds the soil moisture deficit (SMD), which represents the water storage capacity of the crop root zone, AELQ can be expressed as equation:

$$\mathbf{AELQ} = \frac{\mathbf{SMD}}{\mathbf{D_a}} \times \mathbf{100} \ldots\ldots\ldots\ldots (\mathbf{8})$$

Where: D_a= water depth applied by nozzles. (Merrlam and Keller 1978).

Cost of irrigation (LE/fed)

Cost of irrigation in the whole season for all treatments was calculated on the basis of energy consumption only (diesel price 6.5 L.E.).

RESULTS AND DISCUSSION

Performance of center pivot systems

Effects of covering part of the area on water distribution depths

The effects of covering different parts of the area on the distribution of water depths were analyzed by evaluating the relationship between the distance from the pivot point and the depth of irrigation water. The data was collected during the test, which took place under the conditions of an average wind speed of 1.5 m/s, an average temperature of 36°C, and an average humidity of 30%. The figures (1-4) depict the water application depths and the low quarter depths of water distribution for different treatments. Each figure shows the water distribution pattern for a specific system, with CP4 displaying the most uniform distribution. The results suggest that there is a correlation between the irrigated area and the performance of the center pivot systems, with CP1, CP2, and CP3 receiving less water than the average for CP4. The applied depth values (in mm) were 2.29, 2.36, 2.54, and 3.49 for CP1, CP2, CP3, and CP4, respectively.

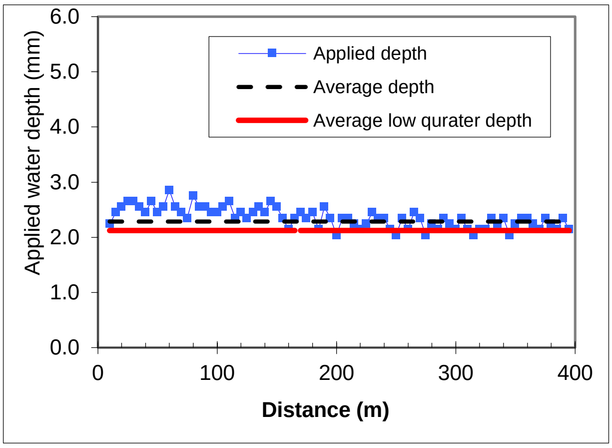

Fig. 1. Water distribution depth Patterns in treatment CP1 (7 Span, 360^0)

The average low quarter depth is an indicator of the efficiency of a water application system when managed optimally, while lower values may suggest issues with the system's design or management. This metric is determined by calculating the ratio of the lowest 25% weighted average depth measured in the catch cans to the average applied depth derived from factors such as flow rate, revolution time, and wetted area. The average low quarter depths for CP1, CP2, CP3, and CP4 are 2.12, 2.24, 2.42, and 3.27, respectively.

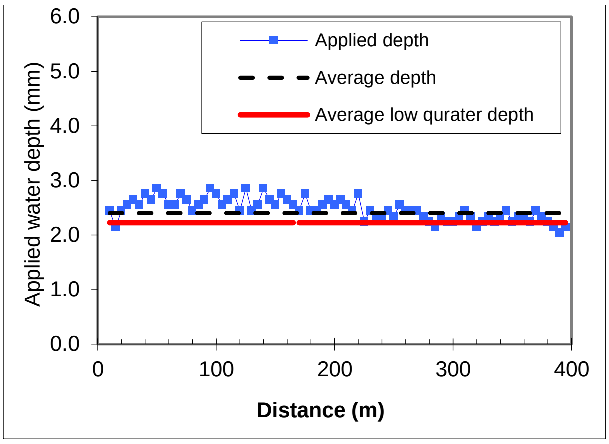

Fig. 2. Water distribution depth Patterns in treatment CP2 (7 Span, 270^0)

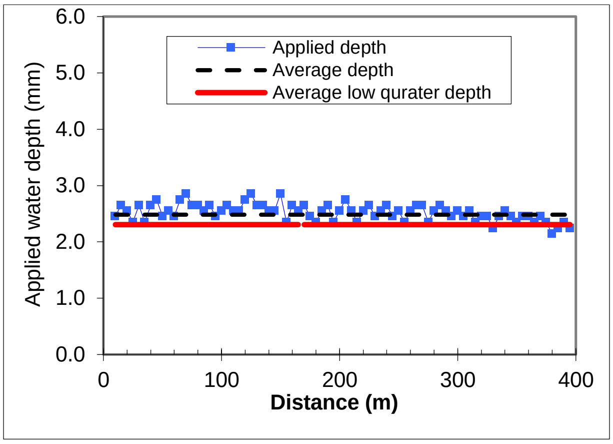

Fig. 3. Water distribution depth Patterns in treatment CP3 (7 Span, 180^0).

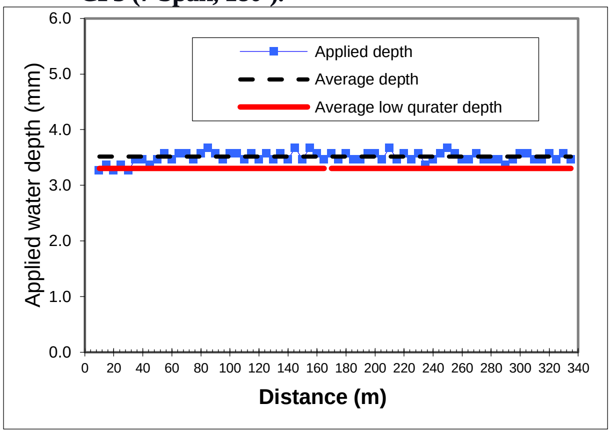

Fig. 4. Water distribution depth Patterns in treatment CP4 (6 Span, 360^0).

Effects of covering part of the area on DU and CU

Table (8) shows the variation of the distribution uniformity (DU). It is supposed to add 9.5 mm/day based on 191.7 m^3/hr but the catch can data reflected that the actual application rate is reduced to 7.3 mm/day. The effects of covering part of the area in CP1, CP2, CP3, and CP4 treatments on distribution uniformity (DU) are presented in table (8). The distribution uniformity is excellent which were 92.7, 92.8, 93, and 94 for CP1, CP2, CP3, and CP4 respectively. In addition, the mean DU values fall within the range of 92.7 to 94%. According to Merriam and Keller's classification (1978), the different classes of DU are as follows: excellent (DU ≥ 85), very good (75 ≤ DU < 85), good (70 ≤ DU < 75), fair (65 < DU < 70), and poor (DU ≤ 65). Table (8) showed that the Coefficient of Uniformity (CU) was in a range of 93.8 to 98.2%. CU values are 94.5, 93.8, 95.2, and 97.9 for CP1, CP2, CP3, and CP4 respectively. Moreover, the results indicated that the distribution uniformity and Coefficient of Uniformity increased as decreased covering part of the area or canceling one of the axis towers. The distribution uniformity and coefficient of uniformity are ranked as excellent, which may be attributed to the system being relatively new at the time of the study (only two years old).

Effects of covering part of the area on application efficiency

The center pivot system application efficiency was increased in CP4 compared with CP1, CP2 and CP3, table (8). The high application efficiency ranged from 97.9% at CP4. The low application efficiency ranged from 76.7% at CP1. The results indicate higher application efficiency was obtained from decreased covering part of the area and reducing the length of the center pivot by removing one of the axis towers.

Table 8. Variation of distribution uniformity (DU), Coefficient of Uniformity (CU) and application efficiency under different treatments applied to covering part of the area CP1, CP2, CP3 and CP4.

Treatments	DU (%)	CU (%)	Application Efficiency (%)	Irrigated area, fed.
CP1	92.7	94.5	76.7	125
CP2	92.8.0	93.8	80.6	91.8
CP3	93	95.2	83.2	62.5
CP4	94	98.2	97.9	85.3

Pivot irrigation system operating Costs

Table (9) presents the average operating Costs (L.E.) and area irrigated, (L.E/fed) under different treatments. The results indicate that reducing the length from 410 meters or narrowing the arc of irrigation from a full circle leads to an increase in the per-area cost of the center pivot system, beyond the standard investment cost per feddan costs ranged from 4032 to 5184 L.E/ fed. These results agree with Henggeler and Vories' (2009) observation that a standard center pivot is approximately 400 meters long and irrigates a complete circle. If economic evaluations of pivot irrigation rely on this standard setup, then variances from the typical length (shorter or longer) or the full 360-degree circle can result in substantial alterations to pivot economics. The prices are based on the year 2019 and the cost of diesel at 6.5 L.E. The numbers of irrigation days were 180.

Table 9. Average operating costs indicators for centre pivots, L.E and area Irrigated L.E/fed under different treatments applied to covering part of the area CP1, CP2, CP3 and CP4..

Item	CP1	CP2	CP3	CP4
Pivots operating cost, L.E	504000	453600	324000	361000
Irrigation area, fed.	125	93.75	62.5	84.7
Irrigated cost, L.E/ fed.	4032	4838.4	5184	4262.1

Prices in 2019 (diesel price 6.5 L.E.) – Number of irrigation days 180 .

Yield (ton/fed), water applied, (m^3/fed) and Water Productivity (WP, kg/m^3)

Sugar beet was designated as a strategic crop, especially as the cultivated area of sugar cane decreased due to its high irrigation water consumption of around 12000-13000 m^3/fed. In Egypt, sugar beet is considered one of the significant sugar crops. Averages yield, water applied, and water productivity as affected by covering part of the area, are shown in table (10). They were significantly affected by covering part of the area in different treatments. The CP4 treatment demonstrated the highest yield and water productivity, with values of 28 tons/fed and 9.17 kg/m^3, respectively. These values were 16.6% and 39.8% higher than those obtained with the CP1 treatment. The yield values for the CP1, CP2, CP3, and CP4 treatments were 24, 25, 27, and 28 tons/fed, respectively. The irrigation water applied for sugar beet under all treatments is summarized in table (10). The results showed that the highest amount of water was applied in the CP1 treatment, with a value of 3660.5 m^3/fed, while the lowest amount was applied in CP4, with a value of 3053.6 m^3/fed. Thus, CP4 used 16.6% less water than the CP1 treatment, resulting in water savings. The irrigation water productivity for sugar beet under all treatments is shown in table (10). The highest irrigation water productivity was observed in the CP4 treatment, with a value of 9.17 kg/m^3, while the lowest value was in CP1, with a value of 6.56 kg/m3. These results suggest that reducing the coverage area and/or removing one of the axis towers can increase yield, irrigation water productivity, and reduce irrigation water use.

Table 10. Average yield, total water applied and irrigation water productivity for sugar beet under different treatments applied to covering part of the area CP1, CP2, CP3 and CP4.

Item	CP1	CP2	CP3	CP4
Yield , ton/fed	24	25	27	28
Total water applied, m^3/fed	3660.5	3346.4	3126.4	3053.6
Irrigation water Productivity for sugar beet (WP, kg/m^3)	6.56	7.47	8.64	9.17

CONCLUSION

Results showed that there was a close relationship between the irrigated area and the performance of the center pivot irrigation system. The water distribution patterns in the four treatments indicated that the systems irrigating with CP4 had more uniform water distribution compared to CP1, CP2, and CP3. The results of DU and CU values ranged from 92.7 to 94% and 93.8 to 98.2% respectively, which were classified as excellent according to the Merriam and Keller (1978) classification. Additionally, the findings indicated the application efficiency, yield, irrigation water applied, and productivity increased as the covering part of the area decreased or one of the axis towers was removed. The operating costs per fed ranged from 4032 to 5184 L.E/ fed. The study concluded that reducing the length to 400 m or the arc irrigated from a full circle increases the per area cost of the center pivot beyond the normal investment cost. The study also found that irrigation water productivity was highest in CP4 treatment; it was 9.17 kg/m^3 which was higher by 39.8% as compared to CP1 treatments, respectively. The results of the study showed that reducing the coverage area or removing one of the axis towers increased yield and water productivity. The study concluded that if there is a limited supply of irrigation water, the best solution would be to remove one of the axis towers from the center pivot.

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تحسين آداء نظام الري المحوري تحت محدودية امدادات المياه لري بنجر السكر بمنطقة غرب غرب المنيا مصر

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الملخص

يهدف هذا البحث إلى تطبيق استراتيجيات مختلفة لتشغيل أنظمة الري المحوري عند حدوث نقص في إمدادات مياه الري أو عدم الحصول على كمية كافية من مياه الري لري المساحة الكلية حسب التصرف التصممي. تم إختيار أربعة سيناريوهات هي: ري دائرة كاملة (CP1)، ري ثلاثة أرباع الدائرة (CP2)، ري نصف دائرة (CP3)، و ري دائرة كاملة مع إزالة البرج الاخير(CP4). أظهرت النتائج أن انتظامية التوزيع (DU) كان ممتازًا لجميع المعاملات بقيم 92.7، 92.8، 93، 94 لكل من CP1، CP2، CP3، CP4 على التوالي. و كان معامل الانتظامية (CU) 94.5، 93.8، 95.2، 97.9 لكل من CP1، CP2، CP3، CP4 على التوالي. وكانت إنتاجية بنجر السكر للمعاملة CP4 بقيمة 28 طن/ فدان، حيث كانت أعلى بنسبة 16.6٪ مقارنة بالمعاملةCP1. وكانت كفاءة استخدام مياه الري للمعاملة CP4 9.17 كجم/م^3 حيث كانت أعلى بنسبة 39.8٪ مقارنة بالمعامة CP1.وكانت كمية المياه المضاف أعلى تحت المعاملة CP1؛ حيث كانت 3660.5 م^3/فدان. بينما أقل كمية مياه ري مضافة كانت للمعاملة CP4 حيث كانت 3053.6 م^3/فدان حيث وفرت المعاملة CP4 في كمية مياه ري بنسبة 16.6٪ مقارنة بالمعاملة CP4. واستخلص البحث انه اذا كان هناك إمدادات محدوده (نقص) لمياه الري بما يكفي طبقا للتصرف التصميمي، فإن أفضل حل هو إزالة البرج الاخير من جهاز الري المحوري مما يؤدي الي زيادة الإنتاجية وكفاءة استخدام المياه.

الكلمات الدالة: الري المحوري مع محدودية مياه الري – كفاءة استخدام المياه وكمية المياه المضافة- بنجر السكر.